Coherence in operating room team and cockpit communication: A psycholinguistic contribution to applied linguistics

Patrick Grommes and Rainer Dietrich
Humboldt-Universität zu Berlin, Germany

Introduction. The major endeavor of linguistic research from the beginning of the twentieth century to the late 1950s concentrated on the description of structural properties of languages and theory of grammar. When there was some need for linguistic expertise in nonlinguistic fields as, for instance, in foreign language teaching, machine translation, or the use of language in the courtroom, the theory of language prevalent at the time or suitable parts of it were transferred to the extralinguistic problem and were applied. Famous examples of this strategy of applied linguistics include the contrastive approach to foreign language teaching, which was basically a couple of inferences drawn from the structural description of language and the behavioral theory of learning. In a similar manner the communicative method of foreign language teaching adopted speech act theoretical principles and machine translation implemented formalisms of the transformational grammar (for an overview of, for example, the development of second language acquisition research and its application, see Cook 1993: 8–24).

The experts in the related extralinguistic fields recognized soon that mere reformulation of linguistic-external phenomena in terms of linguistic models did not help very much to solve their problems.[1] Foreign language learners did not make all the interference errors predicted by applied linguistics handbooks; neither did they acquire fluent and idiomatic conversational English by using speech act theory based practice books in English as a foreign language courses.

However, in the last two decades of the twentieth century linguistics has changed. Language today is thought of as being central to the human cognitive faculty instead of merely as a structured system of signs. One of its most recent offsprings, experimental psycholinguistics, is becoming more and more creative in helping to understand the human language faculty as an applied cognitive capacity. As a consequence of its internal development, the perspective of applying linguistics to language use in everyday as well as in professional settings is also changing and becoming more problem-related compared to its more self-centered view in the past century.

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The development of revised applied linguistics is not completely new. Again, foreign language teaching was at the front edge. It was as early as in the seventies of the last century that psycholinguists began to study second language acquisition by adult learners as a complex cognitive process and no longer took it as the mere development of a language system in contrast to the one that already existed somewhere in the learner's mind. The time course of acquisition was carefully reconstructed and principles of the structural development, the factors that make the learner move from one stage of interlanguage to the subsequent one, have been revealed. A major result of this scrutinized analysis was the hypothesis of a cognitive program, something like a built-in syllabus for language learning. It is, of course, still described by means of grammatical categories, but it is not simply grammar. As a consequence, the model of foreign language teaching is being reconsidered. Teaching is no longer seen as a process of input into and programming of the learner's mind, but as a bundle of measures to give support to the learner's autonomous activity of intake along the guidelines of her or his cognitive program of acquisition.[2]

A similar shift of perspective takes place in more remote areas of language processing. The issues treated in the papers of this volume show a move toward a sort of engineering perspective of applied linguistics. The basic principles of applied linguistics as engineering are:

- Other-relatedness: Try to understand the phenomena from the field of application at hand from the perspective of this field's experts, not based on terms of linguistic concepts.
- Communication as a key concept: Analyze language in use within the broader framework of communication processes, not just as an application of grammatical structures.
- The tool perspective: Use linguistic and, especially, psycholinguistic models as tools for problem resolution in the field of application, not as theories that already form the solution to the problem.
- Symbiotic growth: Let the problem resolution through the use of linguistic tools in a certain professional field have retroactive effects on linguistic and psycholinguistic theories.

In this paper we will present a typical example illustrating this applied linguistics approach of psycholinguistic engineering. The question is whether structures and dynamics in two different types of professional teams—cockpit crews and surgical teams—are similar or not. If so, successful methods for the training of cockpit crews could be transferred to, and made useful for, the training of operating room (OR) teams, too. Otherwise medicine would have to develop its own methods for professional training—a time- and money-consuming procedure.

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Background.[3] Performing a surgical operation and flying an airplane are activities that require the exchange of information by verbal communication. The situations in which OR teams and cockpit crews work can easily become threatening, and pilots—as well as surgeons, anesthesiologists, and other OR personnel—are trained to work under conditions of time pressure, threat, and danger. Thus, they should be prepared to master interaction under these conditions.

Nevertheless, human error or human failures are keywords in the search for causes of incidents and accidents not only in these fields. Thus, research in human factors is increasingly becoming an issue of public concern and aviation is clearly the most popular example. In this field we already find not only scientific results but also some examples of theory put into practice, as shown by the widespread integration of the so-called Crew Resource Management (CRM) program used in the training of cockpit crews since the 1980s. On the linguistic level, one may reduce CRM to two basic maxims: "Be sure to communicate all relevant information to all team members involved in the current task," and "Get the team members involved in problem resolution." There are several studies that prove CRM to be effective, showing fewer errors and incidents in CRM-trained crews than in non-CRM crews (for a description of CRM, see Helmreich and Foushee 1993; Kanki and Palmer 1993).

At a glance there appear to be similarities in the formal properties of verbal interaction in communication within the cockpit and the OR. In high workload situations in both fields, for example, utterances become shorter and more elliptic, and fewer side structure utterances introducing background information occur. This observation has led to research considering the transfer of CRM training techniques into the OR environment (see Howard et al. 1992; Helmreich and Schaefer 1994; Helmreich 2000). An in-depth look at the communication in the two fields, however, shows striking differences on the functional level of discourse. Whereas reduction in the form of the utterances tends to lead to a reduction in communicative efficiency within the cockpit environment, this does not seem to hold true for the OR environment. Here, formally reduced utterances seem to perfectly fulfill their communicative purposes.

To demonstrate this, consider the following examples. The first one is a transcript of the last minutes of the cockpit voice recorder recordings of the B757 Birgen Air flight scheduled from Puerto Plata to Berlin (see FSF 1999: 4; Appendix 4).[4] About five minutes after take-off the aircraft crashed into the sea. The pilots had been misled about their actual speed by defective instruments. The cockpit crew is unable to decide on a strategy to counter the consequences, while the aircraft begins to descend rapidly. The transcript shows that the captain (CA) finally recognizes the defect and orders to increase speed: "thrust levers." The copilot (CO), however, sticks to his former perception of the situation and claims the contrary action: "retard." The captain repeats his command more intensely: "don't pull back," and the copilot finally agrees: "okay open open." Nevertheless, as the subsequent turns show, the captain does not recognize the copilot's approval.

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(1)

CO	okay, five thousand feet
CA	thrust levers, thrust thrust thrust thrust
CO	retard
CA	thrust, don't pull back, don't pull back, don't pull back, don't pull back
CO	okay open open
CA	don't pull back, please don't pull back
CO	open sir, open
CA	( )
RC[5]	sir pull up
CA	what's happening
CO	oh what's happening

Our second example is a piece of dialogue between the operating surgeon and his assistant during an abdominal tumor resection. The problem here is that they will soon have to cut several vessels that supply the tumor with blood, but the exact position and extension of the vessels are hard to define.

(2)

001 S	*kannst du mir die cava weghalten?=*
	would you keep the caval vein out of my way?
002 A	*=ja.sofort.*
	yes. immediately
005 S	*<<leiser> hm jets isse weg; hm?>*
	<<softly> hm it is away now; hm?>
006	*(oder meinste) da fehlt noch n stück.*
	(or do you think) there is a piece missing.

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007 A *(zustimmendes murmeln)*

(affirmative murmur)

008 S *da kommt noch n mAst; he?*

there is another mast; right?

009 *oder is das (neuro)?*

or is this (neuro)?

010 A *das kann sein.*

that could be.

011 A *das geht dich vielleicht gar nichts mehr an; ne.*

maybe that is no concern of yours, right.

012 S *meinste?*

you think so?

013 A *(das vielleicht vorher der punkt).*

(maybe that has been the point previously).

Of course, the situation here differs in many respects from that in the cockpit. Although there is a certain time pressure, it is not as stringent as in the cockpit, since it is not a case of immediate emergency and naturally the threat is to the patient and not to the doctors, whereas in the cockpit the pilots are very much involved themselves. Nevertheless, decisions must be taken quickly and consequences can be serious.

What we find here then are a little more elaborate utterances than in the sequence above, but still they look quite reduced and they are hardly interpretable by any outsiders be they laymen or professionals. The action requested in line 001 seems to be fulfilled in a not completely satisfactory way, so the surgeon (S) starts a discussion of this topic in line 005. The striking observation here is that the turn-sequence seems to lack local coherence, since there are hardly any linguistic connectives.[6] The use of the deictic "da" serves to express exophoric reference to objects in the field of operation, rather than anaphoric reference to previously mentioned information units. Even the second occurrence of the

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demonstrative "das" in line 011 serves exophoric reference. Nevertheless, the utterances seem to be coherent and obviously S and his assistant (A) reach their communicative goal better than in the example above. Thus, in this case, the source for coherence has to be searched on another level other than the strict surface level of the utterances. The guiding question for the following analysis then is to find out which tools are provided by linguistic and related theories to describe the maintenance of coherence in cases like this.

Database. The data for the analyses are taken from cockpit voice recorder transcripts of authentic air traffic incidents available on the Flight Safety Foundation website and the website of the National Transportation Safety Board and from a series of about thirty real-life surgical operations recorded on videotape and digital audio mini-disc in a general hospital in Münster and a cancer hospital in Berlin. The video camera was installed in one corner of the operating room and focused in a way that enabled the filming of the head movements not only of the surgical team, but also of most persons approaching the operating table as well. The microphone was placed above the barrier that separates the anesthesiological area from the surgical area. The complete surgical team was in the range of the microphone, whereas the anesthetists were only audible if they addressed the surgeons directly and came closer to the barrier. The audio recordings in the cockpit are taken from the individual headsets of the pilots, a cockpit area microphone, and radio transmissions, for example, from air traffic control.

Analysis of the Operating Room Data.

Coherence in general. Utterances can be understood as overt linguistic expressions of underlying propositional structures that are based on the conceptualization of a situation. Situations are perceived as being comprised of categories such as events, processes, or states, persons and objects as agents or patients, as well as spatial, modal, or temporal relations (see Levelt 1989: 74). These categories can be conceived as conceptual domains, which are referred to by certain elements of an utterance. Thus we can speak of the referential filling (RF) of a domain. RF itself is guided by the current communicative task that is a consequence of actual or desired changes of a situation. According to recent psycholinguistic models, this task can be seen as the mental representation of an abstract question that the speaker is setting out to answer—the "quaestio" from ancient rhetorics (see Stutterheim and Klein 1989; Stutterheim 1997).

The type and content of the quaestio could be shown to have a systematic influence on the content and the structure of the produced discourse. A quaestio may, for example, require permanent references to a person as the main character of a story or to objects that have to be built together, for example, in instructions. In this case RF establishes static coherence similar to Givón's "coherence as continuity" maintained by "elements that can recur across text" (Givón 1995:

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61). Additionally, referential fillings that follow a certain "principle of linearization" (Levelt 1981), for example, in the chronological or spatial ordering of events as in the "imaginary tour" (Linde and Labov 1975), lead to referential movement (RM) and thus maintain dynamic coherence.

We can then distinguish the following types of referential filling and referential movement:

- Introducing a new referent for the first time and without any connection to referents mentioned.
- Maintaining reference for two or more utterances, for example, by the same NP or by a pro-form.
- Restoring a reference established two or more utterances earlier.
- Shifting reference by introducing a new reference that is connected to a given one.
- Limiting reference by choosing a specific reference out of a set of given ones.
- Extending reference as the opposite to limitation.
- Summing up maintained or restored references in a single expression (see Stutterheim 1997: 63–64).

On the basis of these assumptions we will now try a first analysis of the data. Table 1 sketches the flow of information in the sequence introduced above in terms of referential filling and movement.

The turn-sequence is opened by a question. References in nearly all conceptual domains are new, except those to persons S and A. The summarizing utterance in 002 by A might have been a closing turn, but in line 005 S signals further need for information. Here, the reference to the caval vein in the patient-domain in line 001 is restored in the agent-domain. This reference is then kept stable through maintenance or restoring until the closing of the sequence. Thus it is a typical example of static coherence by referential filling.

As the table shows, the domain of situations displays a special picture of referential movement. Each utterance introduces a new situation, which means that a permanent change of the state of affairs has to be communicated. The patient-domain reveals a similar impression, as it serves mainly to introduce new references.

Of more interest are the spatial and the temporal domains. In the spatial domain, a reference to the starting point of the requested action is introduced, then restored as the action has to be continued, and finally shifted by deictic means to a neighboring point. Spatial relations are semantically constructed following the path of the vein and by the use of spots identified in relation to it. In the temporal domain, unless reference is mentioned explicitly as in lines 002 and 013,

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Table 1. Emerging of static and dynamic coherence on a psycholinguistic basis

	Ag	Sit	Pat	Space Pos	Source	Time	Mod
001	A res	event new	spObj,P new,res		from x new		poss new
002		event sum				t_{0+n} new	fact ires
005	spObj res 001	state new			from res 001	t_0 res	imaint
006	limit 005	state new		deikt shift005 5		imaint	
007		(sum)					
008	spObj maint 006	event new		deikt maint			
009	maint	state new	spObj new				
010		state sum					poss new
011	spObj res 009	state new					poss maint
012		maint/sum m					poss maint
013	res 011	state new				$t<t_0$ new	poss maint

Note: The first line describes the referential filling, the second line describes the referential movement. Implicitly maintained references are only spelled out once.

Source: The table is based on the transcript of an excerpt from recording II/02/99/B.

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reference is implicitly shifted with the time of utterance of one utterance to that of the next one. In these cases, we then can speak of dynamic coherence.

It can now be recognized clearly how the psycholinguistic mechanics of referential movement contribute to the emergence of mutually comprehensible and, thus, coherent sequences of conversation. There is a frame-setting kind of linking as in the agent-domain, and a dynamic linking as in the spatial and temporal domains. But this is, of course, an informal interpretation of one piece of discourse in retrospect! It does not give an answer to the question as to how the interlocutors identify the references in the reduced structures online and which processes allow for the referential linkage.

Common ground. Identifying the references may be possible because the interlocutors exploit their shared knowledge about what they see in the given situation. An analytical instrument for the systematic reconstruction of this sharing of information is offered by the "common ground" framework of the social psychology of communicative interaction (see Clark 1996). In this model communication is understood as a joint activity of the interlocutors that aims at the extension of the knowledge they have in common.

The members of an OR team in action share an especially large proportion of knowledge within the given domain of attention. There is, in the first place, their general professional knowledge. Second, there is the information they take in from the shared narrow focus of their senses directed to the limited visible field of operation. What one then can expect is an automatic adaptation to the demanding situation by a facilitation of utterance processing at the lower levels of parsing and referential understanding and, at the same time, the ongoing of complex processing on the level of macro and micro planning of coherent discourse. Under the assumption of generally limited resources of the cognitive capacity of the human computational system, the decrease of efforts on the lower levels allows for the managing of increased efforts on the levels of general problem solving and of the simultaneous planning of coherent communicative interaction. This raises the question as to what is meant by "planning of coherent communicative interaction."

Linking turns by quaestio. Up to now we have presupposed that the quaestio-approach can be applied to dyadic communication, although it has originally been designed for more or less monological settings.[7] We will now try to spell out how this approach might be transferred to the study of dyadic communication since we believe that interlocutors manage the linking of their contributions by means of coordinating each others' quaestiones.

We assume that nearly every production of an utterance is preceded by the—implicit—formulation of a quaestio, even if it results only in a brief phrase. The interlocutors then perceive each other's utterances as answers to quaes-

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tiones. Therefore, they must signal in each turn, except the opening turn, that they understand the underlying quaestio as well as the corresponding answer. If one interlocutor has no new information to add to an ongoing conversation, then the approval of a first speaker's quaestio would lead to the closing of a sequence. Alternatively, a second speaker could first approve a given quaestio and then create a new quaestio derived from the overt or implicit answer to the original one. She or he then answers this quaestio within the current turn, thus shifting the first quaestio and pushing the communication forward to the common goal, the solving of the problem at hand. These shifts continue until the interlocutors agree that the goal has been achieved. In the first case we speak of quaestio-maintenance, in the second case of quaestio-shift. Schematically, the two options look like this:

QUAESTIO-MAINTENANCE

S1: "[quaestio] answer"

S2: "[quaestio maintained] approval of answer"
Result: turn-sequence is closed.

QUAESTIO-SHIFT

S1: "[quaestio] answer"

S2: "(approval of answer S1) [quaestio shifted] answer/additional information"

S1: "(approval of answer S2) [quaestio shifted] answer/additional information" continues until ending the sequence by quaestio-maintenance:

S1/2: "[quaestio maintained] approval of answer S1/2"
Result: development of a coherent sequence of discourse on the basis of related quaestiones.[8]

The examples in Table 2 show how these patterns work.

CONDITION: QUAESTIO-MAINTENANCE, HIGH LEVEL OF COMMON GROUND. In line 112, N is skeptical about the size of an instrument. Her quaestio might be: "Inform the team about your doubts." The surgeon shifts this quaestio to: "How to assess her doubts?" His answer is that the desired action can well be performed with this instrument. The quaestio-shift comes along with a referential movement in the situation-domain. A's repetition of the final phrase approves this answer and thus maintains the surgeon's quaestio, and maintenance is also the type of RM we find in this case. In the next utterance in line 115, A shifts the quaestio one more time

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Table 2. Discourse organization by quaestio-maintenance

	quaestio	**ag**	**sit**
112 N =und der s n bisschen groß, he?		SpObj	state
and that one's a little too big, eh?	new	limit096	new
113 S (geht doch) [gut so			state
(works out) fine that way	shift		new
114 A [gut so.			
fine that way	maint		maint
115 (-) mach ich zu, ne?=		A	state
I'll close then, ok?	shift	res	shift
116 S =ja=a.			
yes		maint	sum

Note: Participants are the same as above plus a theater nurse (N). The excerpt is from the same recording as Table 1. For a longer stretch see Appendix 1.

to: "How do we proceed?" Again this shift parallels a shift in the situation-domain. S finally maintains the quaestio and closes the sequence by summing up in terms of referential movement. These almost redundant structures and their underlying processes show how agreement about the level of shared information is reached, a function of closing sequences that has also been described in Coates (1995).

CONDITION: QUAESTIO-SHIFT, HIGH LEVEL OF COMMON GROUND. In lines 051–054, S produces a sequence of utterances to answer his quaestio: "How to define the boundaries of the tumor?" A signals acceptance of this quaestio by his affirmative murmur and in that he ties the references in the agent-domain and the spatial domain to those in lines 051/052. The referential shift that takes place in the spatial domain also points to the quaestio-shift that A performs in his utterances. His quaestio is: "How would I limit the tumor?" and his answer introduces the new object "liver" and shifts the spatial relation from a positional one to a directional one: "reaches out into the liver." In line 058, S shifts the quaestio in a similar manner along with a similar referential shift: "beyond the liver." Unfortunately, this sequence just fades out, but some seconds later both

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Table 3. Sequence continuation by quaestio-shift

line/s	ag	sit	pat	space		
quaes				pos	path	goal
051/S	S	state		deictic		
	res	new		new		
052/S	SpObj	state			dei/ext	
new	res	new			shift 051	
053/S	S	state				
shift	ires	new	maint			
054/S	Obj	state		in front		
shift	new	new		shift 052		
055/A						
		sum				
057/A		state	spObj			dir
shift	res 052	new	new			shift 054
058/S	S/A	state	spObj	beyond		
shift	res	new	ext	shift 056		

Note: Participants and recording code are the same as in Table 1.

seem to be content about the effects of their actions (see Appendix 2).[9] Nevertheless, Table 3 shows the step-by-step completion of the shared knowledge base.

(3) 051 S *ich kann halt hier oben nicht sagen*
I just cannot say up here
052 *wie weit das da geht; ne,*
how far it expands

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053	*das <stoß ans mikro> nich tasten.*
	that <microphone hit> not touch
054	*[erst dieses weiche zeugs is. ne?*
	there is first this soft stuff, right?
055 A	*[(<zustimmend>)*
	(<approvingly>)
057 A	*m=hm. das geht da-(.) in die leber hinaus; ne,*
	mhm. it reaches there out to the liver
058 S	*über die leber(hemis) sind wer ja schon weg*
	we are beyond the liver(hemis) already

A first summary. So far we have seen that the dynamics of discourse are determined by the speaker's decision to move forward the discourse by shifting a given quaestio within his or her response to an utterance or not to move it on. From a psycholinguistic point of view, then, coherence in conversation is basically the cooperative linking of each other's utterances by means of quaestio-shift and/or maintenance. The quaestio, then, sets constraints to processes of filling and moving references in the propositional structure of subsequent utterances. Thus, we find a secondary source of coherence on the propositional level by exophoric references. These observations match with Givón's statement that "coherence is fundamentally not a property of the produced text. Rather, that text is a by-product of the mental processes of discourse production and comprehension, which are the real loci of coherence" (Givón 1995: 60; italics by Givón).

Furthermore, the entire processing would not function so well within real time and even by means of highly elliptic forms of utterances without a reliable amount of shared knowledge. In cases where a sufficient common ground first has to be established, more efforts have to be made. This is illustrated by the example in Table 4.

Here A, a junior surgeon, has to open up the thorax for the purposes of a lung resection. He is supposed to identify the rib at which he wants to cut into the thorax. As he sets out to count the ribs, he is interrupted by S because he started counting with the first rib, which is practically impossible to touch. In the following S is not very cooperative with respect to A's quaestiones. She frequently restores her quaestio, indicated by the marker "back," because she wants to be sure that the imbalance between A's and her knowledge bases becomes leveled. Under the conditions of this type of discourse, there are, obviously, more elaborate utterances and more background is introduced. As a consequence there occur substantially longer sequences with twenty and more units compared to a maximum of ten to fifteen units in the other type of situation. This sequence also seems to be less

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Table 4. Building up common ground from a lower level

line			Quaestio
097	A	eins. zwei. drei. vier. fünf. das müsste die hier sei[one two three four five this should be the one	new
098	S	[und sie ham die erste rippe getastet? and you did touch the first rib?	shift
(...)			
103	A	=dann sind wer ein weniger-= then it is one less	shift
104	S	=ihr seid super.= you (pl) are great	back
105	A	=eins. [zwei. drei. vier. dann müssen wer hier rein. one two three four then we have to cut in here	shift
106	S	[die erste rippe kAnn man nicht tasten- you can't touch the first rib	back
(...)			
118	S	das is hier die sechste rippe. this one is the sixth rib	shift
(...)			
120	A	also (.) hier (.) drauf. then at this one	shift
121	S	na auf dEr hier- no at this one	shift
122	A	okay. und dann hier rein? okay and then in there	shift
123	S	da rein. in there	main

Note: Participants here are a senior surgeon (S) and her assistant (A). The excerpt is taken from recording II/05/99. For the full sequence see Appendix 3.

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coherent although there are no breaks on the reference level, which again points to the importance of quaestio-coordination for coherence in discourse. Nevertheless, lines 120–123 show that the sequence is ended successfully.

Summing up. The condition of low workload, as in the previous example, allows the participants in OR discourse to deal with discrepancies of their knowledge bases via more elaborate verbalization. This appears, however, to be sometimes less cooperative, maybe also due to the personal style of the interactants. In phases of higher workload, as in the first examples, there seems to be a stronger urge for cooperation. The participants in dialogue stick closer to the common ground and tune in to each other's utterances more effectively. The balance between verbally expressed versus situationally given information is shifted in the direction of the latter one.

Coherence in cockpit communication. With these observations in mind we will now come back to the question of whether the conditions of high workload communication in the cockpit are similar to those in the OR, and, if so, whether the same mechanisms consequently apply.

The brief excerpt from the Birgen Air flight cockpit voice recorder (CVR) suffices to demonstrate a clear lack of coherence. The copilot reacts with contradictory statements to the captain's commands. He keeps on repeating the commands although the copilot agrees finally. The copilot's suggestion to pull up the airplane, then, receives no response; instead, the captain asks a completely new question. The two crew members, both experienced pilots, are unable to produce a coherent piece of discourse. How could this happen?

We will try to find out more about this on the basis of a more extended and also typical piece of data, the CVR recordings of the last nine minutes of the Atlantic South East flight from Atlanta to Gulfport (see NTSB 1996; for a more extensive excerpt, see Appendix 5). Twenty minutes after take off, one of the four blades of the left propeller separated and destroyed the rest of the propeller and the engine. The airplane turned left and began to descend. The cockpit crew had three problems to solve in this emergency: Task Number 1 was flying the airplane; Number 2 was getting control over the technical consequences of the damage (i.e., avoiding a fire, activating auxiliary power units, etc.); and Number 3 was the adaptation of the flight plan to the new flight conditions (i.e., landing as soon as possible at an airport different than the scheduled airport).

Each member of the crew has his or her own well-defined domain of responsibility and focus of attention, separate from those of the comembers. The pilot has to fly the airplane, a highly demanding psycho-motor activity. The copilot has to find out as much as possible about the incident and to counter its consequences. Both pilot and copilot have to decide on a new flight plan. The great challenge to the crew members' cognitive capacity is that they have to communicate with each other in order to accomplish their individual tasks. The special handicap is that they have no

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visual access to the rapidly changing situational conditions within their comembers' domains of action. No severe problems arise, of course, as long as there is no time pressure. All relevant information can be given verbally, and the common ground for understanding messages, quests, and commands can be established. As soon as time pressure increases, there is no longer time for extended turns and discourse. In addition, the capacity for language processing is constrained by the augmented problem-solving activity.

Consider now the following extracts from the transcript. The captain reacts to the incident by (a) continuing to pilot the plane, (b) giving commands for technical measures to counter sources for additional trouble:

1243:38 Capt: We got left engine out. Left power lever. Flight idle.

The turn comprises two utterances. The first introduces background information to the copilot, which the pilot cannot assume to be shared. The second is a command with the aim to avoid more trouble. They continue:

1243:48 Co: Yeah.

1243:49 Capt: Feather. Yeah we're feathered. Left condition lever, fuel shut-off.

The airplane continues descending and rolling left. Flying the plane becomes more difficult and the captain asks the copilot for help, without giving him necessary background information. The copilot interprets this utterance in relation to the previous turn and simply approves. Then the captain realizes that he was not understood and repeats the request:

1243:59 Capt: I need some help here.

1243:59 Co: OK.

1244:03 Capt: I need some help on this.

The copilot is still not in possession of the relevant knowledge about the captain's situation. So he asks him for confirmation about the state of the propeller that is, in turn, given by the captain:

1244:07 Capt: It's feathered.

1244:09 Co: OK.

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This ends the sequence from the copilot's point of view but not from the captain's perspective. He still needs help and repeats his request for assistance, but this time successfully by providing additional information and thereby extending the common ground:

1244:20 Capt: I can't hold this thing. Help me hold it.

1244:24 Co: OK.

The following pieces of discourse reveal the same mechanism: If the speaker's turn is related to his own domain of attention not shared by the addressee, it is not understood without additional background information augmenting the common ground. As the situation becomes more threatening and both crew members are occupied by their own business, there is no more time left for long turns. The communication finally breaks down, first in the domain of getting control of the incident's consequences. The end of communication in this domain is this: The captain asks the copilot to go through the checklist for measures in case of single engine failure. The copilot, occupied with managing the flight route by radiocommunication with ground control, disclaims the new initiative:

1251:17 Capt: Sing/single/single engine checklist please.

1251:28 Co: Where the # is it?

After that he no longer searches for the list. The crew concentrates on navigation. The captain asks the copilot to tell ground control that the plane is below the clouds and can be landed according to visual flight rules (VFR). It follows a sequence of cockpit-ground communication; at the end of which the crew is no longer able to manage this additional channel of communication because the captain can no longer hold the airplane. The request to change radio frequency remains unanswered. Shortly after the breakdown in communication on navigation, communication in the domain flying the plane terminates because time is running out. The plane crashes half a minute after the last call from ground control.

1251:33 Capt: We are below the clouds. Tell'm.

1251:36 Co: 'K. We're uh VFR at this time. Give us a vector to the airport.

1251:39 GC: Turn left. Fly heading zero four zero . . .

1251:47 Co: Zero four zero. AC five twenty nine

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1252:20 Capt: Help me/ Help me hold it . . .

1252:56 GC: AC five twenty nine. Change frequency one one eight point seven if able.

Conclusion. Communication under stress has been analyzed on the basis of two sets of data from OR and cockpit settings, respectively. The overt linguistic data show rather similar formal features: short utterances, ellipses, little background information. However, the similarity of the phenomena cannot be explained by one and the same underlying mechanism. A functional analysis of the OR data reveals that the communicative interaction remains successful under conditions of high workload and multiple tasking. The data are analyzed with respect to these parameters of communication: the psycholinguistic mechanism of producing coherent discourse in interaction and the social-psychological parameter of shared knowledge and common ground. It was found that quaestio-maintenance and quaestio-shift determine the dynamics of verbal interaction and that the proportion of common ground shared by the interlocutors determines the amount of linguistic effort necessary for successful communication.

The results of the analysis of the cockpit communication confirm these findings. The distribution of labor among the crew members excludes, however, the possibility of visually establishing sufficient shared knowledge. An emergency situation does not offer the time conditions for verbally bridging the gaps of shared knowledge. The mechanism is blocked and communication breaks down.

The results of the two sample analyses attest some validity to the proposed program for applied linguistics:

- Other-relatedness: The reconstruction of the professional discourse urges the linguist to study carefully the conditions and processes of OR work and of handling an airplane. Psycholinguistic engineering is, therefore, essentially interdisciplinary and based on cooperation with nonlinguistic experts.
- Communication as key concept: Linguistic theory alone is not enough to study language in use. The phenomena need to be understood from different points of view: linguistic, psycholinguistic, sociolinguistic, and sociopsychological. The integration of these perspectives is possible only under the broader concept of communication.
- The tool perspective: None of the models that supplied the theoretical background of the analysis could simply be applied to the data. The speech production model does not suffice for the description of dialogical discourse and does not explain the dynamics of interactive discourse. The socio-linguistic model does not explain the quaestio-movements lying behind discourse dynamics. And the model of common

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ground and shared knowledge does not explain the balance between low and high language processing procedures and conditions of low and high workload, respectively. The three models did, however, work as analytical tools and by this means yielded a more complete understanding of the data.

- Symbiotic growth: The results of the study can be made relevant both for the extra-linguistic domains and for linguistic reasoning about the concept of coherence in dyadic discourse.

The results of the OR part of the analysis can help to decide whether or not additional CRM training could be necessary and helpful for managing communication in phases of high workload. The analysis shows that the utterances look rather cryptic from a formal point of view. It was, however, also shown that communication is not affected as long as the team members can compensate the reduction of verbal communication by visually establishing the common ground needed for coordinated activities. CRM training in aviation can be improved by teaching the crew cooperative discourse behavior under conditions where common ground is lacking. The results do, however, also show the limits of communication and trainability. If no compensation can be gained through the visual channel and the speakers are not able to accelerate their verbal information exchange, alternatives might have to be considered on the side of the technical equipment.

If so, then the benefit for the sciences is obvious. The analysis yielded insight in the interplay of psycholinguistic, socio-linguistic, and socio-psychological parameters of coherent dyadic communication. The blueprint of an integrated model of quaestio-movement, discourse dynamics, and common ground came into sight.

NOTES

1. Note, however, that skepticism against applied linguistics as a simple transfer of linguistic theory to language learning methods arose even in the 1970s (see Mackey 1973).
2. The benefits and boundaries of recent SLA research and its application to second language learning and teaching are discussed, for example, in Cook (1996; 204–208) and Ellis (1994: chapters 1 and 15).
3. This study is part of the international, interdisciplinary research project "Group Interaction in High Risk Environments," funded by the Gottlieb-Daimler-and-Karl-Benz-Foundation, Ladenburg, Germany. The project involves linguists, psychologists, medical doctors, and airline pilots. Its primary goal is to better understand how team interaction is influenced by changing workload and to transfer research results into practice, for example, into improved guidelines for airline pilot training.
4. The presentation of the CVR transcripts here and below has been modified for the reader's convenience. The original presentation is provided in the appendix.

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5. RC – relief captain.
6. Nevertheless, there is coherence and to show this is one of the purposes of this paper. But coherence, here, is not primarily based on cohesion markers that warrant intersentential connectivity on a formal linguistic level. A similar point of view is taken by Sanders, Spooren, and Noordman (1992: 2–3): "In a coherence approach, cohesive elements like connectives in the discourse are viewed as important though not necessary features of discourse."
7. There have been only a few attempts to study more dialogical settings by this model. However, they concentrate on the influence of an intervening hearer [*sic*] on the speaker's planning of utterances (see Speck 1995; Stutterheim and Kohlmann 1998).
8. S – speaker; [ ] – is not expressed overtly; ( ) – can be expressed overtly; "..." – complete turn.
9. The difficulties of S and A in coming to terms here may be understandable if one keeps in mind in coming that in this case they are trying to resect an abdominal tumor weighing approximately 4.5 kilograms and that was having a considerable effect on the anatomy.

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APPENDIX 1. EXCERPT FROM OR RECORDING II/02/99/B

103 S *kannst du einen setzen?*
could you set one?

104 A *was willst du jetzt?*
what do you want now?

105 *n overhold?*
an overhold?

106 S *ja- (achter) noch;*
yes- one more of (size eight)

107 A *nimmst erst (am besten) n kleine, ne?*
you take first (at best) a small one, right?

108 N *na kommen sie-*
come on

109 S *hm- ich komm jetzt schlecht noch hier raus; weißte,*
hm- I get out here only by difficulty; you know,

110 A *hm=hm*
hm=hm

111 S *kannst du das vielleicht=*
maybe you could=

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112 N *=und der s n bisschen groß, he?*
and that one is a little too big, eh?

113 S *(geht doch) [gut so*
(works out) fine that way

114 A *[gut so*
fine that way

115 *(-) mach ich zu, ne?=*
I'll close then, okay?=

116 S *=ja=a*
yes

APPENDIX 2. EXCERPT FROM OR RECORDING II/02/99/B

058 S *über die leber(hemis) sind wer ja schon weg.*
we are beyond the liver(hemis) already

059 *[wir sind ja schon- (clip.)*
we are already- (clip.)

060 A *[(ich bin ja der ansicht-)*
I am of the opinion-

061 (7 sec) (…)

062 S *das doch gut.*
that's fine

063 A *schön.*
fine

APPENDIX 3. EXCERPT FROM OR RECORDING II/05/99

097 A *eins. zwei. drei. vier. fünf. das müsste die hier sei[*
one two three four five this should be the one

098 S *[und sie ham die erste rippe getastet?*
and you did touch the first rib

099 *sie sind der erste held unter der sonne;*
you are a really smart guy

100 *der das schafft-=*
to do that

101 A *=neulich mit (name). na dann bin ich= -*
the other day with (name). well then we'll have to cut in here

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102 S *=echt?=*
really?

103 A *=dann sind wer ein weniger-=*
then it is one less

104 S *=ihr seid super.=*
you (pl) are great

105 A *=eins. [zwei. drei. vier. dann müssen wer hier rein.*
one two three four then we'll have to cut in here

106 S *[die erste rippe kAnn man nicht tasten-*
you can't touch the first rib

107 *jedenfalls all die thoraxchirurgen*
at least all the thorax surgeons

108 *die ich kennengelernt hab*
I got to know

109 *[die mindestens tausend-*
who did at least a thousand-

110 A *[konnten das nicht-*
could not do that

111 S *die ham das nicht gekonnt.*
they could not do that

112 A *hat der mir ( ) (vorgezählt).*
he counted that for me

113 S *die obere die kannse nich*
the highest you can't

114 *[die obere die zählste nich.*
you do not count the highest

115 A *[das die zwei-*
that's the sec-

116 S *das s die zweite.*
that's the second

117 *dann kommt die dritte vierte fünfte-*
then there is the third fourth fifth

118 *das is hier die sechste rippe.*
this one is the sixth rib

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119 *und danach gehste rein mit dem (( ) ICR thorax)*
and beyond that you go in with the (ICR thorax)

120 A *also (-) hier (-) drauf.*
then. at this one

121 S *na auf dEr hier-*
no at this one

122 A *okay. und dann hier rein?*
okay. and then in here?

123 S *da rein.*
in there

124 A *gut. (.) bitte elektrisch-*
okay. the electric please

APPENDIX 4. COCKPIT VOICE RECORDER TRANSCRIPT (EXCERPT), BIRGEN AIR FLIGHT ALW-301, FEB. 6, 1996

Flight Safety Foundation editorial note: The following transcript is as it appears in the Junta Investigadora de Accidentes Aéreos of the Director General of Civil Aeronautics of the Dominican Republic accident report, except for minor column rearrangement and addition of notes (...). Times are local.

Time	Source	Content
(...)		
2346:48	HOT-2	Altitude hold
2346:51	HOT-2	Okay, five thousand feet
2346:52	HOT-1	Thrust levers, thrust, thrust, thrust, thrust
2346:54	HOT-2	Retard
2346:54	HOT-1	Thrust, don't pull back, don't pull back, don't pull back, don't pull back
2346:56	HOT-2	Okay, open, open
2346:57	HOT-1	Don't pull back, please don't pull back
2346:59	HOT-2	Open sir, open
2347:01	HOT-2	****
2347:02	CAM-3	Sir, pull up
2347:03	HOT-1	What's happening?

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2347:05	HOT-2		Oh, what's happening?
(...)			
	CAM-3	=	Relief captain
	HOT-1	=	Captain
	HOT-2	=	First officer
****		=	unintelligible"

(Flight Safety Foundation 1999, 6–7)

APPENDIX 5. COCKPIT VOICE RECORDER TRANSCRIPT (MODIFIED EXCERPTS), ATLANTIC SOUTHEAST AIRLINES, INC., FLIGHT 529, EMBRAER EMB 120RT, AUGUST 21, 1995

HOT	=	Crew member "hot" microphone voice or sound source
HOT-M	=	Aircraft mechanical voice heard on all channels
RDO	=	Radio transmission from accident aircraft
CAM	=	Cockpit-area microphone
INT	=	Transmission over aircraft interphone system
CTR	=	Radio transmission from Atlanta ARTCC
ATLA	=	Radio transmission from Atlanta approach control
-B	=	Sounds heard through both pilots' "hot" microphone systems
-1	=	Voice identified as captain
-2	=	Voice identified as first officer
-3	=	Voice identified as flight attendant
-?	=	Voice unidentified
*	=	Unintelligible word
#	=	Expletive
( )	=	Questionable insertion
[ ]	=	Editorial insertion
. . .	=	Pause

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Local time	Source	Content
1243:38	CAM-1:	we got a left engine out. left power lever. flight idle.
1243:45	CAM:	[shaking sound starts and continues for thirty-three seconds.]
1243:46	CAM-1:	left condition lever. left condition lever.
1243:48	CAM-2:	yeah.
1243:49	CAM-1:	feather.
1243:51	HOT-B	[series of rapid beeps for one second similar to engine fire warning]
1243:54	CAM-1:	yeah we're feathered. left condition lever, fuel shut-off.
1243:59	CAM-1:	I need some help here.
1244:02	CAM:	[mechanical voice messages for engine control and oil cease. chimes and autopilot warning continue.]
1244:03	CAM-2:	OK.
1244:03	CAM-1:	I need some help on this.
1244:05	CAM-?:	(you said it's) feathered?
1244:06	CAM-1:	uh,
1244:07	CAM-2:	it did feather.
1244:07	CAM-1:	it's feathered.
1244:09	CAM-2:	OK.
1244:09	CAM:	[master warning chimes and voice warning continue.]
1244:10	CAM-1:	what the hell's going on with this thing.
1244:13	CAM-2:	I don't know ... got this detector inop.
1244:16	CAM-1:	OK ***.
1244:18	CAM-?:	OK, let's put our headsets on.
1244:20	CAM-1:	I can't hold this thing.
1244:23	CAM-1:	help me hold it.
1244:24	HOT-2:	OK.

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1244:26	CAM-1:	all right comin' on headset.
1244:26	RDO-2:	Atlanta center. AC five twenty-nine, declaring an emergency. we've had an engine failure. we're out of fourteen two at this time.
1244:31	CTR:	AC five twenty-nine, roger, left turn direct Atlanta.
1244:33	HOT-1:	# damn.
1244:34	RDO-2:	left turn direct Atlanta, AC five twenty-nine.
1244:36	HOT-?:	[sound of heavy breathing]
1244:41	HOT-?:	** back **.
1244:57	HOT-?:	[sound of squeal]
1245:01	CAM:	[tone similar to master caution cancel button being activated. All warnings cease.]
1245:03	HOT-1:	all right turn your speaker off. oh, we got it. its.
1245:07	HOT-1:	I pulled the power back.
1245:10	CTR:	AC five twenty-nine, say altitude descending to.
1245:12	RDO-2:	we're out of eleven six at this time. AC five twenty-nine.
1245:17	HOT-1:	all right, it's, it's getting more controllable here... the engine ... let's watch our speed.
1245:32	HOT-1:	all right, we're trimmed completely here.
1245:38	HOT-2:	I'll tell Robin what's goin' on.
1245:39	HOT-1:	yeh.
1245:44	HOT-B	[sound of two chimes similar to cabin call button being activated]
(...)		
1245:58	CTR:	AC five twenty-nine, say altitude leaving.
1246:01	RDO-2:	AC five twenty-nine's out of ten point three at this time.
1246:03	CTR:	AC five twenty-nine roger, can you level off or do you need to keep descending?
1246:09	HOT-1:	we ca.. we're gonna need to keep con.. descending. we need a airport quick.

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1246:13	RDO-2:	OK, we uh, we're going to need to keep descending. we need an airport quick and uh, roll the trucks and every thing for us.
1246:20	CTR:	AC five twenty-nine, West Georgia, the regional airport is at your ... ten o'clock position and about ten miles.
1246:28	RDO-2:	understand ten o'clock and ten miles. AC five twenty-nine.
1246:30	CTR:	's correct.
(...)		
1248:40	HOT-1:	how long, how far West Georgia Reg ... what kind of a runway they got.
1248:44	RDO-2:	what kind of runway's West Georgia Regional got?
1248:54	HOT-1:	go ahead and finish the checklist.
1248:58	CTR:	West Georgia Regional is uh, five say one six and three four and it's five thousand feet ...
1249:01	HOT-2:	OK, APU started. OK, prop sync, off. prop sync's comin' off.
1249:03	HOT-1:	OK.
1249:04	HOT-2:	fuel pumps failed engine. you want uh, max on this?
1249:07	HOT-1:	go ahead, please.
1249:08	HOT-2:	OK.
1249:09	CAM:	[sound similar to propeller increasing in RPM]
1249:09	CTR:	... and it is asphalt sir.
1249:11	HOT-2:	hydraulic pump, failed engine? as required. put it to the on position?
1249:15	HOT-1:	correct.
1249:17	HOT-2:	'K. engine bleed failed engine is closed and the pack is off.
1249:19	HOT-1:	'K.
1249:26	HOT-2:	'K, cross-bleed open.
1249:29	HOT-1:	'K.

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1249:32	HOT-2:	electrical load, below four thousand amps.
1249:38	HOT-1:	it is. put the ice ba.. (well you) don't need to do that just leave that alone.
1249:45	HOT-1:	all right, single-engine checklist please.
1249:48	CTR:	AC five twenty-nine, I've lost your transponder. Say altitude.
1249:52	RDO-2:	we're out of four point five at this time.
1249:54	CTR:	AC five twenty-nine, I've got you now and the airport's at your, say say your heading now sir.
1249:59	RDO-2:	right now we're heading uh, zero eight zero.
(...)		
1251:05	HOT-1:	we can get in on a visual. just give us vectors.
1251:07	RDO-2:	one one one point seven. ... just give us vectors. we'll go the visual.
1251:17	HOT-1:	sing, single, single-engine checklist, please.
1251:28	HOT-2:	where the # is it?
1251:29	ATLA:	AC five twenty-nine, say altitude leaving.
1251:31	RDO-2:	we're out of nineteen hundred at this time.
1251:33	HOT-1:	we're below the clouds. tell 'm...
1251:35	ATLA:	you're out of nineteen hundred now?
1251:36	RDO-2:	'K we're uh, VFR at this time. give us a vector to the airport.
1251:39	ATLA:	AC five twenty-nine. turn left uh, fly heading zero four zero. bear, the uh, airport's at your about ten o'clock and six miles sir. radar contact lost at this time.
1251:47	RDO-2:	zero four zero, AC five twenty-nine.
1252:07	HOT-M:	five hundred.
1252:10	HOT-M:	too low gear. [starts and repeats.]
1252:11	ATLA:	AC five twenty-nine, if able, change to my frequency, one one eight point seven. the airport uh, in the vicinity of your ten o'clock at twelve o'clock and about four miles or so.

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1252:20	HOT-1:	help me, help me hold it, help me hold, help me hold it.
1252:56	ATLA:	AC five twenty-nine, change frequency, one one eight point seven if able.
1252:32	HOT-B:	too low gear. [Warning stops.]

(...)
(NTSB 1996, 84-109)

APPENDIX 6. ABBREVIATIONS/SYMBOLS USED IN THE OR TRANSCRIPTS AND TABLES

Ag –	Agent	ext –	extending reference
imaint –	implicitly mainta etc.	limit –	limiting reference
maint –	maintaining reference	Mod –	Modality
nec –	necessity	new –	first mention of a reference
Pat –	Patient	Pos –	Position
poss –	possibility	res –	restoring reference
shift –	shifting reference	Sit –	Situation
spObj –	specified object	sum –	summing up references
t_0 –	time of utterance		
? –	rising intonation	, –	slightly rising intonation
– –	constant intonation	; –	slightly falling intonation
. –	deeply falling intonation		
= –	latching of turns; within a sound: two syllables		
cAps –	emphasis	[ ] –	overlap
( ) –	inaudible, or, if filled, presumed words		
(-) –	pause <1sec	(x sec) –	pause of x seconds
< > –	comments and their reach		

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