Communication under high task load.

Rainer Dietrich, Humboldt-Universität zu Berlin

.... ladies and gentlemen,

Language is the most efficient method of human communication. People acquire a language in the first years of their lives and practise it for hours and years on end every day, and thus become highly trained experts in language use. Verbal communication is fast , doesn’t require technical equipment, is adaptable to different kinds of channels, media and situational conditions, and can be done while doing other things at the same time Language processing is sturdy and secure; there is, on average, one error per thousand executions of a production procedure.

With this background, one can hardly imagine that language and communication range among the prime causes of accidents and disasters in high risk environments. The results of an ASRS Study (NASA's Aviation Safety Reporting System) found that about a third of the accidents in air traffic were connected to complications in communication. (See Etem & Patten (1998)).

(Slide: Tenerife accident)

Ambiguity was arguably involved in the most severe accident in commercial aviation, the collision of two airplanes at a Tenerife (Norte Los Rodeos) Airport in March 1977. [Klick] This incident centers around the question of whether the phrase *we are now at takeoff* is to be interpreted as ‘we are now at the takeoff point’ or as a kind of progressive tense, ‘we are now in the process of taking off’.

There are other such word ambiguities or structural ambiguities in aviation language. [Klick] Cushing (1994) mentions the verb *hold*, which in aviation parlance means ‘stop what you are doing right now’, but in ordinary English can also mean, ‘continue what you are doing right now’.

The effect of linguistic misunderstandings on plane crashes is documented in the linguistic investigations of cockpit-voice-recorder data such as used by MacPherson (1998) and Cushing (1994).

Beyond ambiguity of language, the way language is used is a known source of misunderstandings in stressful situations. False interpretations, filling out incomplete statements in ways not intended by the speaker, and holding back important information for reasons of politeness, to name just a few, have been documented repeatedly in actions like fire fighter operations and desaster relief missions.

- [Klick] An object is on fire in the 'Kaiserstraße', but the fire-fighters drive to the 'Königsstraße'.
- [Klick] A woman calls up the police, saying 'My husband does not live anymore', but is understood as 'My husband does not love me anymore'.
- In a training drill of rescue workers the following (written) report arrived at the Technical Operation Headquarters:

Due to a damaged rudder, a liquid butane ship [on the Rhein, R.D.] has hit a tank ship full of vinyl chloride on the front broad side above the water line and rammed a hole in it. Vinyl chloride is leaking out. Acute danger of fire and explosion due to outflow of gas cloud.

The staff member responsible for the mission in the operation head quarters read ***chlorine gas*** instead of ***vinyl chloride*** in the report and measures taken were against chlorine gas. The repercussions of such a mix-up could have been deadly. (Ungerer 2004: 84-88)

[Rainer – vielleicht wäre hier noch ein Beispiel von Mitigation angebracht, z.B. von dem Birgen-Air-Unfall, wo der erste Offizier sich nicht klar und verständlich ausdrückt]

Problems of communication of this sort made governments, agencies, business and academia intensify their efforts to find ways to reduce the risk of communication.

[Klick] One approach is **standardisation** of the linguistic means to circumvent the ambiguity trap.
Another one is **adjusting the communicative strategies** of teams under high workload to the situation based threat and danger.

We will discuss both endeavours in light of the findings of five years of empirical research.

Standardisation

[Klick] Air traffic is probably the domain with the most elaborate repertoire of standardised linguistic means of communication world-wide. The International Civil Aviation Organisation (ICAO), a special agency of the United Nations, is authorised by international contracts to settle and administrate regulations about the wording and the structure of verbal information interchange in civil aviation. The ICAO standard phraseology regulates words to be used, many structural patterns and procedural features of verbal interaction within and outside of the cockpit.

Here is a sample from Garuda Indonesia Airways flight GA 152 arriving from Jakarta Indonesia on September 26, 1997; Phase: Initial approach to Medan (Indonesia) Airport:

MEDAN: GIA 152, maintain 3000ft for a while. Maintain heading Medan VOR. Traffic now still taxi Runway 23. [ATC; COMMAND]

GIA 152: Maintain 3000. [Cockpit; CONFIRM by READ BACK]

MEDAN: Merpati 152, you turn left heading 240 vectoring for intercept ILS Runway 05 from right side. Traffic now rolling. [ATC; COMMAND]

MEDAN: GIA 152 do you read? [ATC; QUESTION; ‚read' ~ hear, receive]

GIA 152: GIA 152, say again? [Cockpit; REQUEST]

MEDAN: Turn left heading a ...... 240, 235. Now vectoring for intercept ILS Runway 05.

GIA 152: Roger, heading 235. GIA 152. [Cockpit; EXPLICIT CONFIRM + READ BACK]

GIA 152: GIA 152 heading 235. Confirm we cleared from a ..... mountainous area? [Cockpit: REQUEST]

MEDAN: Affirm sir! Continue turn left on heading

[Klick] The Operating theatre is perhaps among the linguistically least standardised domains of high risk workplaces. Basically, there are only some two hundred technical terms, acronyms and elliptical forms of utterances.

Situation: Operation. Participants: Operating surgeon (COP), Assistant (AST); Actual task: The opening of the thorax from the position of the sixth rib

(1) cop a) das hier is die sechste rippe. (*this here is the sixth rib*)
b) und danach gehste rein mit dem (...) ICR Thorax. (*and then go in with the ...*)

(2) ast also (.) hier (.) drauf; (*then (.) here(.) on that*,)

(3) cop na auf der hier (*well, on this here*)

(4) ast o.k. und das hier rein? (*okay, and then in this here*?)

(5) cop da rein.(*in there*)

(6) ast gut. (.) bitte elektrisch- (*good (.) please electrical-[electrical coagulation to cut through the tissue and, at the same time, to close the vessels*])

(7) cop pass auf (.) und jetzt machste[=so=d]ass de n bisschen- (*watch out (.) and now*

you do it so that you. . .a little. .)

(8) ast [=ja=a=] (*yes*)

(9) cop am oberrand mehr oder- (*more on the upper edge, or-*)

.....

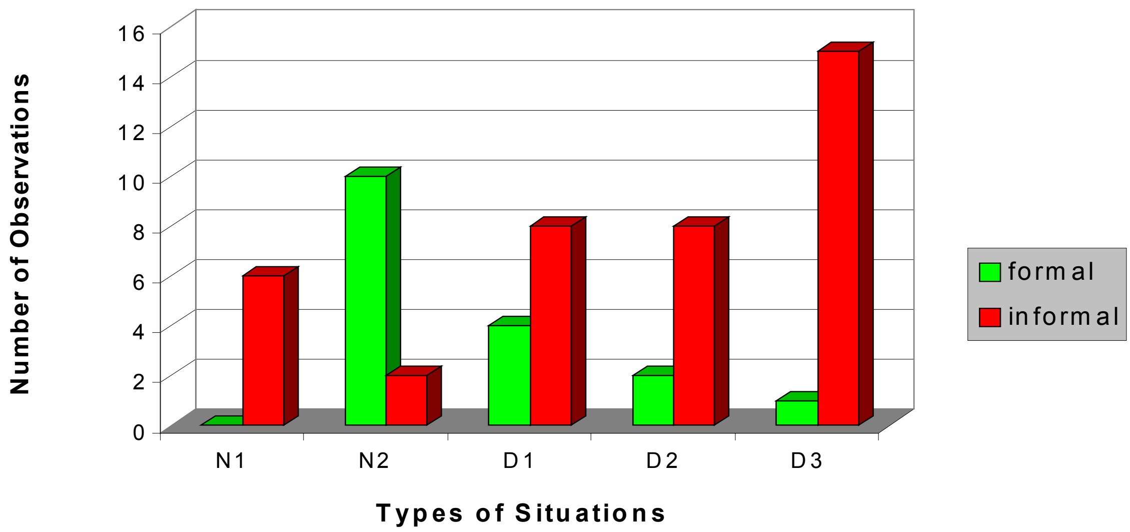
There is no standardised format of how to address the interlocutor,no regulations determining the turn taking procedures, no rule of confirming the previous message etc.

Given these differences in regulations, corresponding differences in the relative amount of misunderstandings in aviation and the OR could be expected to result.

We tested this prediction on the bases of two types of data, transcripts of authentic and simulator flights on the aviation side and transcripts of authentic operations. The authentic data are CVR-transcripts of segments of 14 authentic flights. The simulator data consisted of one set of flights collected in 1987 by the NASA-Ames Research Group, and another set designed in the project and carried out by Lufthansa City Line. The good thing about similator data is that the same problem scenario can be presented to different crews, and the crews can be evaluated as to how well they did comparatively.

Each utterance of the authentic data was coded for the category **Register .** All utterances were analysed as belonging to one of two classes [formal] or [informal].

Relevant indicators were the way in which crew members address each other: "Sir" correlates with [formal], first name with [informal]. Another clue is whether they stick to the standardised aviation language or whether they use sloppy formulations. The use of taboo and swear words is also typical for [informal] language use.



What is remarkable about this diagram is the surprisingly high number of instances of informal language use that can be observed in almost all situation types, except from N2. In N2, the dominant value is [*formal*]. The crews have to run many checklists, and the observed distribution of values shows that in the majority of cases the crew members stick to the fixed phraseology prescribed by the checklists. In all the other situation types, the dominant value is [*informal*].

One important factor that contributed to these results is the cultural background of the crews. Most of the transcripts in our data set stem from American crews. For them, a rather informal language use is generally accepted, and the choice of the informal register outside the checklist communication is consistent with the social norms.

This situation is completely different for crews from the Far East and from Moslem cultures. They strictly stick to formal language use, even in situations as dangerous as D3. The hierarchical structures are so deeply rooted in their cultures that it is difficult to give up the formal register, and a failure to choose the register according to the social conventions would equal a loss of face. A very telling sequence took place during the Japan Airlines flight 123 in 1985: The captain asked the co-pilot to stop using the formal register.

CPT: Nose down. Lower nose.
F/O Yes, sir.
CPT: Lower nose.
F/O: Yes, sir.
CPT: Lower nose.
F/O: Yes, sir.
CPT: Stop saying that. Do it with both hands, with both hands.
F/O: Yes, sir.

For the complete transcript see MacPherson (1998: 64-68)

These data however, don't tell us anything about the interrelation of the use of standardised language and the flight crew's performance.

This was evaluated by the *linguistic factors group* of the GIHRE project on the basis of the above mentioned simulator data. The overall finding concerning standardisation was:

- Somewhat surprisingly, the use of standard wording by the captain was clearly negatively related to performance. A possible reason is that standard wording, despite its benefits, can be used to mask communication deficiencies.

(Krifka, Martens & Schwarz (in print), p. 84)

This runs against what a number of researchers found in analyses of aviation accidents. Interestingly, most of these data stem from communications between cockpit and air-traffic controllers, that is, cockpit-interactions with external interlocutors. A study of 71 Runway-incursion Occurrences world-wide found:

The relevant findings in the present context are:

"Crew communication – such as improper readback, mishearing and/or improper phraseology – was a factor in 31 percent occurrences."
In addition it is shown that these results parallel the findings from analyses of Approach-and-landing Accidents, especially civil flights into terrain (CIFT-events) (Kwata 2002; Flight safety foundation News March 21, 2002):

The author, accordingly, recommends the use of standard phraseology and communication procedures such as readbacks and control of readbacks.

How could this contradiction be accounted for? Can the findings of the GIHRE study really be compared with the Kwata-Data, for instance? That is at least questionable. The Kwata-Analysis focuses on the cockpit-external communication while the GIHRE-study dealt mostly with crew-internal interactions. It might, hence, be the case that violations of and deviations from the standard communication procedures increase the risk of misunderstanding and affect the safety of the operations in non-face to face-settings while the same type of behaviour does not cause problems in face to face-communication.

This assumption is supported by parallel evidence in the medical domain. Team internal communication is weakly standardised or not at all. Still, we could not observe incoherence or misunderstanding caused by lack of standardised wording while errors did occur in 'team-external' communication over shift, for instance. Additional evidence in favour of this explanation can be seen in the fact, that in spite of not sticking to standard phraseology good crews (in the NASA simulator study) answered more questions than poor performing crews.

What can be concluded from this picture in general is the recommendation:

Use standard patterns of interaction especially in team external communication. Repeat, confirm the information addressed to you or at least let the sender know that you could not 'read' his or her message due to workload or other intervening factors.

This brings up the measures to improve strategies of communication in fighting misunderstandings which may cause incidents and accidents in high risk environments.

Strategies of communication

Communication is maintaining and updating the common ground between the participants of communication. While looking simplly from the outside, this is, as a matter of fact, an extremely complex thing. Successful communication means, first, that the information state and the focus of attention of the other participants has to be gauged correctly, and that the content of what is to be communicated has to be planned accordingly. Then the utterance has to be planned, , the message is built up as a mental representation, the lexical units are activated and put together in a well formed syntactic string, the phonetic shape is derived from that string and the articulation programs are initiated and put to work in one's lungs, mouth and lips, the acoustic waves reaching the external part of the ear of the addressee, being analysed acoustically, transformed into cortical activations etc. until – eventually, and hopefully, – the message is understood by the person or persons to whom it was directed.

Communication and workload

One important factor that has to be accounted for is that communication may be affected by additional cognitive task load.
One can hardly be better acquainted with the issue than by looking at an experiment run by Dario Salvucci two years ago at the Drexel University, Philadelphia.
[The following can be shortened considerably, for the interest of time]
Subjects had to drive a car (in a simulator) and, simultaneously, perform a language processing task (Daneman & Carpenter 1980). etc. The task involves two current activities, namely judging sentence sensibility

'The boy brushed his teeth' (Correct respone: YES) versus 'The train bought a newspaper' (Correct response: NO)

and memorising and rehearsing final words and then report the memorised list: 'teeth', 'newspaper',

When combined with driving, the task puts a substantial cognitive load on drivers as they attempt to integrate the task. Under the dual task condition, the drivers' capacity to follow a lead vehicle displayed on the computer screen of the simulator was severely affected. Brake reaction times increased significantly as did the amount of lateral deviation from the centre of the lane. At the same time, the distance between the driver's vehicle and the lead vehicle, shrank significantly.

2.1 The problem

In real life, this would not cause a severe problem. Drivers can simply give up communicating or slow down or even interrupt the ride. Members of a professional team engaged in a task like flying an airplane can, however, not simply interrupt the flight at any time. They have a problem. Team work in such cases means that each of the members is assigned one ore more partial tasks and the handling of them depends more or less on the time course and the outcome of the work of the co-team-members. This requires continuous co-ordination within the team. This is accomplished by verbal and non-verbal information interchange. On the other side communicating is costly in terms of time and cognitive energy and the question is, whether people would not be better advised to stop talking and pay full attention to the their primary task.

The question, is: What should team-members do to minimise the risk of failure under the pressure of unexpected high task load?

- Tune down their communication activities and concentrate on their primary task
- or try to go on with communication and, thereby, risk severe detriment to the performance in their primary task? [Klick]

2.2 What the data say

Let us first look at an anecdotal piece of evidence:

The situation: An Airbus 320 arriving from Frankfurt/Main at the Warschau-Airport mid September 1993.

The landing is affected by heavy windshear over the runway causing problems for the touch down. The Airbus' right gear touched down 770m from the Runway 11 threshold. The left gear touched down 9 seconds later, some 1500 m behind the threshold. Only when the left gear touched the runway, automatic systems depending on shockabsorber compression unlocked use of ground spoilers and engine thrust. The wheel brakes began to operate after about another 4 seconds. Seeing the approaching end of the runway and the concrete embankment behind it, the pilot steered the aircraft off the runway to the right. The aircraft left the runway at a speed of 72 kts and rolled 90m before it hit the embankment.

Here is the transcript of the pilots' communication while the airplane is approaching the end of the runway and the massive concrete wall (ACO is the voice of the automatic altitude control): [Klick]

15.33:15	ACO	Four hundred.
15.33:20	ACO	Three hundred.
15.33:26	ACO	Two hundred.
	Tower	<Radio communication with an other airplane in Polish>
15.33:29	PNF	Von rechts kommt jetzt - . (Here comes [the windshear] from the right ---
15.33:31	PF	Jetzt kommt die windshear. (Here comes the windshear.)
15.33:33	ACO	One hundred.

15.33:36	PNF	Dreht, dreht (turning, turning)
15.33:37	ACO	Fifty.
15.33:39	ACO	Thirty.
15.33:40	ACO	Retard, retard.
15.33:45		<Clack>
15.33:49	PF	Brems mal mit. (Help me with the brakes!)
15.33:52	PF	Full braking.
15.33:56	PNF	Reverse auf? (Reverse up?)
15.33:57	PF	Ja´s voll. (Yes, full reverse thrust.)
15.33:58		<Clack>
15.34:01	PNF	Hundert. (One hundred [meters away from the end of the runway])
15.34:02	PF	Weiter bremsen. (Keep braking]
15.34:05	PF	Scheiße.
15.34:06	PF	Was machen wir jetzt? (What now?)
15.34:08	PNF	Tja, du kannst nix mehr machen. (Well! There is nothing to do.)
15.34:10	PF	Ich möcht nicht da gegen knallen. (I don't like to crash against this wall.)
15.34:11	PNF	Dreh´n weg. (Turn it aside.)
15.34:12	PF	Was? (What?)
	PNF	Dreh ihn weg. (Turn it aside.)
15.34:16	PF	Scheiße!
15.34:17		<Krachen>

Red marks the two most striking utterances of this communication:

The situation seems to be hopeless. At a speed of 130 km/h the airplane moves towards the massive wall. And the pilot flying makes the statement that he is not willing to crash against the embankment. While –certainly not very informative, this speech act may well have saved the lives of 70 people. We do, of course, not know whether or not this statement triggered the co-pilot's idea of steering the plane off the runway into the field.

A more reliable answer to the question of whether just speaking makes cockpit life safer requires results of systematic analyses of a larger basis of relevant data.

The two linguistic GIHRE projects undertook qualitative and quantitative analyses of two sets of flight simulator data.

2.3 Some findings

The results of the analyses point in two directions:

Observation Nr. 1: Team members speak more simply under conditions of high task load.

Cockpit crews change their communication strategies under conditions of increasing task load. For example, the pilot who happens to be flying talks less than the pilot who is not flying. The data show a significant task load effect, for instance, on the frequency of question types used in the task related verbal behaviour.

Teams in high risk environments often use questions. In our data (seven hours flight time; 6900 thought units) 9.8 % of all utterances were yes/no questions, like *Is your's (=airspeedindicator) working?*, and constituent questions and wh-questions, like *What do we have (engine oil pressure)?*). Other question forms included alternative questions, like *You level off or do you need descending?*, and and echo questions. But 87.7 % of all questions were yes/no and wh-questions. Now, yes/no questions were used more frequently than wh-questions, about 70% of the time. This frequency even increased under conditions of high task load.

This observation was also tested in experiments and the punchline result is:

Under the same dual task conditions, yes/no-questions are less impaired than wh-questions when cognitive demands increase, such as the amount of knowledge or the working memory load, involved in the question-answering task .

Other observations seem to point in the opposite direction.

2. There were more utterances per minute in the segments of high workload, and the utterances were longer, leading to a substantial difference of speech time per minute.

On the basis of these findings you may ask whether speaking more and simpler is a good communication strategy or a bad one. The mere fact that teams react this way to the increase of workload is not a strong argument per se. It would be interesting to know more about the reactions of good teams versus poorly performing teams. More refinded analyses show that there are clear differences, indeed. Here are the most noticeable observations:

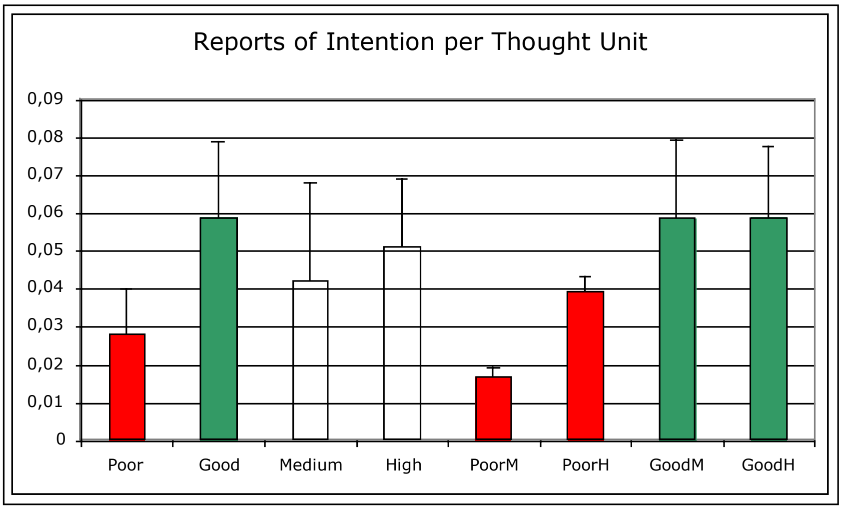
3. Good teams speak more.

We might ask even more specific questions: Are there particular contents of communication, that are related to the teams flight performance?

A speech act analysis of parts of the same data yields a clear result: The frequency of report of intention is related to the overall performance of the primary task:

4. Crews whose members communicate their intentions more frequently achieve better scores in flying their planes. [Klick]

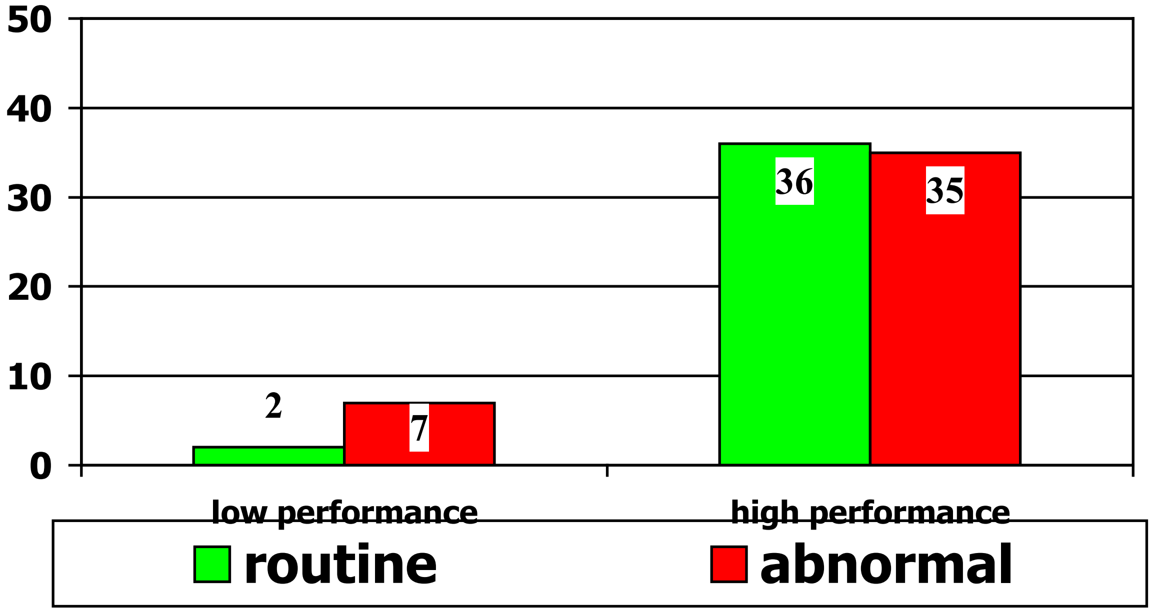
Look at the data in this table (Krifka, Martens Schwarz (2003):



5. For the whole crew, speech acts of seeking reassurance occurred more frequently in the good crews, and so did positive speech acts of agreement or negotiation, like acknowledgments and affirmations.

In addition to these differences between the crews in general, there are more differences in the way captains and first officers or flying and non-flying pilots react to the increase of workload:

6. Under conditions of high workload the proportion of problem solving utterances of the captain is significantly higher in good teams than in poorly perfoming teams
[Klick]



7. Acts of indicating interest and affirming acts were typical for good captains. Obviously, good captains were more encouraging towards contributions from their first officers, which goes along with first officers talking more in these crews.

Summary

- Standardisation of phraseology was not observed to be correlated with errors or more severe events (incidents, accidents) in high risk environments.
- The efficiency of team external communication is improved by standard communication formats, feedback and redundancy.

An increase in task load makes a team change the communication strategies.

- More Simple linguistic means are used.
- Good teams communicate more than poor performing teams in spite of the resulting additional cognitive costs.
- Good teams perform more positive speech acts of agreement or negotiations and more speech acts that initiate the other team members' cognitive resources for problem solving.