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Introduction

Rainer Dietrich

The complexity and the generally low chances of successful verbal communication under beneficial conditions would lead one to expect that when people are engaged with additional and difficult problems they would automatically forgo verbal communication. An excursive examination taken from everyday life strengthens this bottleneck-assumption quite well. Driving a car in bad traffic in an unfamiliar city is considered a complex cognitive and psychomotorical activity in which verbal communication with passengers is automatically restricted; see Salvucci (2002). Listening to a live concert on the radio and reading a newspaper, solving a chess problem and discussing near east politics, preparing a complicated sauce and, at the same time, discussing with the children a fight with neighbours – all of these are examples of double or multiple tasks. Task related information from different cognitive fields arrive in tight chronological succession via separate cognitive channels in central cognitive information processing. The shorter the time gap, the more strongly decelerated the processing of the second task. The so-called PRP-Effect (psychological refractory period) appears (see Pashler (1998: 5–6 and Chapter 4 and 5)).

There are few dual task experiments that have been done in which language processing is a task (see Neumann, Sangals & Sommer 2002) and none have been done with complex language tasks in natural settings. Because of the complexity and the hard to control factors that are involved in such experiments they are not done as PRP-Studies, but are more often done as an exploration led by PRP-Heuristics.

The general presumption is that the higher the mental demand made by a primary problem solving task (for example as a consequence of complexity, time pressure, or fear of danger) the less communication there will be. This sounds and is plausible. And it is worthy of analysis because theoretical arguments can also be made for the opposite.

The central event of communication is language processing – the cognitive processes in the language processing system of the participants. There is some evidence to support the idea that this system works automatically, autonomously, and at the same time reflexively. In faculty psychology, this mode of processing is explained by the fact that the procedures involved in language processing are structurally and modularly organised.

According to Fodor (1983), a cognitive module is informationally encapsulated and is domain specific (in this case language specific). The operation of input is mandatory; there is only limited central access to the processing. A module functions fast, and it's location is neurally fixed. It is acquired in a specific manner and can break down independently. The acquisition of language ability can be disturbed separately; i.e. there is no other impairment of any cognitive ability. This is called Specific Language Impairment (SLI). Conversely, under the influence of alcohol the control of motor skills is strongly reduced, while language comprehension and production remains undisturbed – with the exception of the articulatory muscles. The language ability of Alzheimer patients can remain undisturbed at the same time that the performance of the memory processes is extremely limited.

Apart from being motivated by general interest in the cognitive foundations of psycholinguistics, systematic research of communication under changing task load due to primary cognitive tasks, is also motivated by observations and investigations into professional work 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)). 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). Ungerer (in press) describes the effects of time pressure and emotions on the verbal communication of members of rescue teams.

All of the work represented in this special edition considers the quality of linguistic communication under conditions of high task load due to non-verbal tasks. The authors are members of a research project that has been funded for the last five years by the Gottlieb-Daimler and Karl Benz Foundation. With the co-operation of the individual projects, the research and investigations were carried out in three different work environments: the cockpit of a commercial airliner, the hospital operation room (OR), and the control room of a nuclear power plant (NPP). By choosing these three work places, the goal was to find results from each in which members of a team worked, at times, under high task load due to the performance of the primary task and which differed in the factors that structure communication. The setting perimeters are as follows:

level of the risk; (measured on the size or level of damage in the worst possible case)	Cockpit: middle; OR: relatively low; NPP: high
size of the teams	Cockpit: small; OR: medium; NPP: large
frame of discourse	Cockpit: face-to-face and (with ground control) only aural contact; OR: face-to-face; NPP: face-to-face and (with dislocated locations/spots) only aural contact.
social hierarchy in team	Cockpit: middle (dependant on culture); OR: strong; NPP: weak

scriptedness of the discourse	Cockpit: strong; OR: none; NPP: little
the threat to the team in danger	Cockpit: yes; OR: no; NPP: yes
the overlapping of the area of attention during the processing of the primary task	Cockpit: middle; OR: wide/extensive; NPP: low

The articles in this edition are organised according to the type of work place examined in the research. At the beginning, the work focuses on cockpit communication, followed by the investigations into the operating room. Lastly, the work addresses communication in the nuclear power plant control room. All of the investigations were carried out with empirical methods, most of them were based on a broad range of data. The data has been collected under variously controlled conditions. Authentic data was used in the work done by Silberstein & Dietrich; Dietrich & Grommes; Grote, Zala-Mezö & Grommes; and Sträter. The simulator data used in the work from Sexton & Helmreich and from Krifka, Martens & Schwarz was carried out under more formal conditions. All projects that present findings here have the ambitious aim to conduct fundamental research and, at the same time, to attain results from which they can create guidelines for the improvement of communication in the work place.

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Cockpit Communication under High Cognitive Workload

Dagmar Silberstein and Rainer Dietrich

1 Background[1]

This article investigates the effects of high cognitive workload on communicative interaction in the cockpit. We report our findings from a study that served to identify stress-sensitive aspects of communication. The article is organised as follows: First, we give some background information on communication research in aviation – how it evolved and how it approaches its topic. Then, we argue for a different perspective and describe the methodology we used to analyze the data. We go on to introduce the different situation types relevant to our investigation, the linguistic categories found to be affected by high workload, and the quantitative results. Finally, we describe some methodological problems, summarise the results and briefly relate them to a model of language production.

When asked about the effects of time pressure on his communicative behaviour an air traffic controller, whose exposure to high workload conditions is similar to that of pilots, spontaneously told us: "I talk faster, a lot faster – I talk so fast that they have to slow me down because they don't understand me any more." In addition to the accelerated rate of speech, another obvious effect of high workload is the shortening of utterances. Just a superficial look at cockpit-voice-recorder transcripts reveals that under conditions of stress the utterances become shorter and that more reduced linguistic structures are used than under normal conditions.

In addition to this anecdotal evidence, experimental work has shown that language processing can be seriously impaired under conditions of high cognitive workload: Blackwell & Bates (1995), for example, show that normal subjects display ungrammatical profiles under a dual task condition, which is a very disturbing finding, in particular with regard to the importance of communication when dealing with dangerous situations in high-risk environments like the cockpit of an airplane – compare Sexton & Helmreich (1999) who show that the more the crew members communicate the better they perform.[2]

[1] The study presented in this paper was conducted within the framework of the international research project *Group Interaction in High Risk Environments* which is sponsored by the Gottlieb Daimler- and Karl Benz-Foundation.

[2] The existence of a correlation between the amount of communication and performance was first suggested by Foushee & Manos (1981) who found that better performing crews communicate more overall.

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The importance of communication for efficiency and safety in aviation has been recognised for a long time. In the 1970's, several accidents had happened that had been mainly related to crew co-ordination, communication, and team-building factors in the cockpit, e.g. the crash of Eastern Airlines Flight 401 into the Everglades during its approach to Miami International Airport in 1972. This accident had resulted in part from a misunderstanding between controller and crew: The members of the flight crew were distracted by a landing-gear warning light and they didn't realise that the autopilot had disconnected and that the aircraft was descending. The approach controller had seen the aircraft's apparent decline in elevation indicated on radar. He wanted to check with the crew and asked: "How are things coming along out there?" In his utterance, he intended the word things to refer to the decline in elevation but the crew appears to have taken it to refer to the nose-gear problem they had been preoccupied with. The crew remained unaware of the declining elevation, and finally the plane crashed into the Everglades. The uncertainty about the reference of the indefinite noun things – that is, a linguistic ambiguity – had contributed directly to the accident (compare Cushing (1994: 18–19)).

Another key accident was the crash of United Airlines Flight 173 in Portland (Oregon) in 1978. In this accident, the poor use of crew resources played a crucial role. Because of a malfunction of the landing-gear warning system, preparation for an emergency landing preoccupied the captain and, despite warnings by other crew members about the low fuel level, he delayed the landing. The airplane crashed because of total fuel exhaustion, but a contributing factor was also "the failure of the other two flightcrew members either to fully comprehend the criticality of the fuel state or to successfully communicate their concern to the captain." (Kanki & Palmer (1993: 101)). In this respect, the accident resulted partly from the poor information sharing within the crew.

These two accidents contributed to a re-evaluation of cockpit organisation. As a result, the US National Transportation Safety Board (NTSB) has increasingly paid attention to the possible impact of crew communication and crew coordination on accident patterns. Increased efforts have been undertaken to raise the safety level by developing the concept of crew resource management (CRM) – a specific training program that focuses on interpersonal and communication skills.[3] The increased interest in language-related issues has led to a still growing volume of studies that investigate communication processes in the cockpit.

Communication research in aviation is mostly not interested in language as such, but in the social dimension of communication and the psychological categories behind actual language use. Language is understood as a behaviour marker. This means that communication patterns are interpreted as indicators of social aspects of behaviour, for instance as an indicator of a person's role, attention focus, and so on. In addition to the social component, this kind of research is also related to performance. It investigates which communicative

[3] For a description of CRM see Helmreich & Foushee (1993).

patterns contribute to effective teamwork, and whether differences in crew performance are reflected by particular communication patterns. One typical example for this approach is a study conducted by Kanki, Palmer & Veinott (1991), that analyses the links between a captain's personality, communication, and team performance.[4] We call this direction of research the psychologically-oriented approach.[5]

A different approach is taken by Steven Cushing. He is interested in the structural properties of language itself that might lead to misunderstandings, especially in situations of high cognitive workload. Cushing (1994) analyses language-related misunderstandings in air-ground communication that have been a crucial contributing factor in aviation accidents. We call this direction of research the linguistically-oriented approach.

This paper is indebted to both approaches. Studies in both lines of research yielded valuable results. They constitute the background to our own study.

2 Perspective, Goal, and Guiding Questions

The ultimate goal of aviation-related communication research is to apply the theoretical findings to the real aviation world in order to improve its safety. In other words, its aim is to "enable researchers, trainers, line pilots, government regulators, engineers, and designers to make recommendations that enhance the safe and efficient operation of aircraft." (Kanki & Palmer (1993: 126)). This application perspective includes the aspect of developing training patterns for aviation personnel – an aspect that constitutes a fundamental objective for researchers from the psychologically-oriented approach. Their studies try to crystallise those communication patterns that are associated with effective CRM principles, and they aim at transforming these findings into training programs. Those studies *presuppose* that effective communication patterns can be trained. But they don't take into consideration the impact of stress on human *ability* to communicate. Up to now, it is not clear how stress affects our ability to communicate and whether it impedes trained patterns. We do not know well enough the exact character of natural limitations which might inhibit human beings from communicating reliably under growing pressure. In order to draft appropriate training programmes, we not only need a fuller understanding of which communication skills *should* be trained but also whether they *can* be trained at all.

Therefore, we decided to take a different perspective: We investigate and describe linguistic performance under varying degrees of stress in order to find out whether linguistic patterns change in relation to the amount of workload.

[4] This study finds out that those captains who were characterised as having less achievement motivation in interpersonal and flying skills were also the captains who initiated communications the least and who lead crews that performed least well.

[5] The most important studies that belong to this approach are described in Kanki & Palmer (1993).

Our goal is to learn more about the effects of stress on the mechanisms that underlie communication. In order to achieve that goal, the following questions should be looked into:

- How does linguistic interaction vary in relation to the level of workload?
- Which elements of the utterances and which mechanism of language production do persist and which are eliminated under the conditions of high workload and danger?

Answers to these questions could serve as a basis to determine for which aspects of communication and for which situations training is possible, and for which it is not.

Our article does not, however, provide ready-made answers to these questions. Its main point is just to offer first hypotheses generated on the basis of empirical data. A lot of work is still required to convert the descriptive findings reported in this paper into substantial empirical evidence, including experimental tests of the hypotheses.

3 Data and Method

As Kanki & Palmer (1993) point out, cockpit-voice-recorder (CVR) data are a valuable source for communication research. Being real-time accounts of events unfolding, they are a primary resource for learning what happened in the accident sequence, and they often reveal what went wrong during the flight. The analysis of CVR-data identifies critical communication problem areas: "The communications contained in CVR data have pointed to a wide range of CRM problems related to command authority, maintenance of vigilance, monitoring and cross-checking, briefings, planning, and crisis management in addition to assertiveness and participative management." (Kanki & Palmer (1993: 102)).

Taking this into account, we decided to use authentic CVR data. From 20 authentic flight documentations, stemming for the most part from the US National Transportation Safety Board (NTSB), 14 typical examples were selected.[6] We applied the methods of Conversational Analysis[7] to identify potential stress-sensitive linguistic categories that show up in the selected transcripts. That is, we conducted a detailed analysis of each single transcript, of its formal and semantic structure. This method allowed us to detect utterances and passages that are conspicuous in some way, e.g. because of a strange structure or because of a content that does not fit into the thematic flow. Each transcript was screened for those marked passages, and we analysed what went wrong in these passages from a linguistic point of view. The following excerpt which is taken from the transcript of the Birgenair accident in 1996 might serve

[6] The criterion for selection was the completeness of the transcript.

[7] *Conversational Analysis* is a strictly empirical field of research that investigates the structure of conversation. Its major advocates are Sacks, Schegloff & Jefferson.

as a first example[8]. It illustrates communication under high workload conditions:

Example (1)

(1)	Captain:	There is something wrong, there are some problems.
(2)	Co-Pilot:	Direct Pokeg? [i.e.: "Should we head for the navigational fix POKEG"]
(3)	Captain:	Okay.
(4)	Captain:	There is something crazy, do you see it?
(5)	Co-Pilot:	There is something crazy there at this moment. Two hundred only is mine and decreasing, Sir. [i.e.: refers to the speed of the aircraft]

This passage is linguistically marked because of its communicational dynamics: In this segment, the co-pilot is confronted with a dual task situation. He has to solve two communicative tasks. One is standardised and the other unexpected: In (1) the captain informs him that a problem has just occurred. The co-pilot does not respond to this unexpected turn but continues in the standardised procedure which requires to determine the current heading (2) – that is, he solves first the communicative task that corresponds to the script. It is only after the captain refers to the problem again (4) that he takes up the unexpected topic.

This observation suggests that the capability to adjust readily to unexpected events might be hindered by the existence of competing standardised tasks. When faced with competing communicative demands we do not respond to the unexpected task but prefer the one that belongs to the script. To depart from the script requires higher processing capacity, which is particularly difficult in situations of already high cognitive workload. The potential stress-sensitive linguistic category revealed here is called responsiveness (cf. chapter 5.4).

This kind of text analysis was applied to the whole data base of 14 transcripts. As we looked at communicative behaviour in different types of situations we were able to find out which aspects of communication were impaired in situations of high workload and danger. The case-by-case study yielded altogether nine linguistic categories that were affected by stress. They will be introduced in chapter 5. After identifying these categories, we investigated how often each category was affected by high workload in the other transcripts. The results were quantified in order to find out which of the categories are stress-sensitive on a level beyond the single-case study. The above mentioned category responsiveness, for example, was not found to be affected by stress and danger in the other transcripts (cf. chapter 6.1.4).

[8] The complete transcript can be found in appendix (1).

4 Situation Types

We will now introduce the situation types that were relevant in our study. Although not all of the recordings span the entire flight (no recording exceeds 30 minutes) and not all flights include all types of situations, the data as a group do show a clear typology of five different situations: normal low workload, normal high workload, danger 1, danger 2, and danger 3. These different situation types are defined by external criteria: the amount of workload and the degree of danger.

- "Normal low workload" (N1) describes situations of normal working conditions and low cognitive workload. Typical examples are: taxi, cruise.
- "Normal high workload" (N2) refers to situations that are characterised by high cognitive workload under normal working conditions, for instance takeoff, approach, and landing.
- "Danger 1" (D1) is marked by the occurrence of an unexpected incident, e.g. the malfunction of some minor instrument. The flight behaviour of the plane is not impaired, and there are no warning signals.
- "Danger 2" (D2) is a much more dangerous situation. The plane is difficult to control, its flight behaviour is impaired, and there are warning signals.
- "Danger 3" (D3) refers to highly critical situations. Vital systems of the airplane do not function any more and the plane is hardly controllable. The flight behaviour of the plane is seriously impaired, and there are several warning signals.

5 Linguistic Categories

This chapter introduces the linguistic categories that were found to be influenced by the high workload condition in the single-case studies. It explains to what aspect of communication each category refers and by which values they are characterised. If appropriate, examples will be included. The categories discussed under (5.1) and (5.2) are central concepts in the psychologically-oriented approach. Therefore, some of the major findings from that approach will be included.

5.1 Information Sharing

Our first category refers to the information flow within the cockpit crew. The transcripts were analysed with respect to the question of whether the individual crew members tell each other what they observe, think, and intend to do. The category was used to evaluate in how far external stimuli (events, situations) and internal stimuli (thoughts) prompted the crew members to produce an utterance. The category is characterised by the values [*yes*] and [*no*]. In a sense, this category reflects the decision whether or not to speak. The processes that guide this decision are located at a pre-linguistic, higher cognitive level.

The transfer of information within the crew is essential to establish shared knowledge of the current situation. It is particularly crucial in high-workload or dangerous situations because crew members must gather and use all available information in order to act upon a shared mental model if they want to resolve an ongoing or potential problem.

So far, it has been demonstrated that correlations between the amount of information sharing and performance outcomes exist: Foushee & Manos (1981), for example, found that increased performance was associated with increases in observations about flight status. Orasanu & Fischer (1991) show that crews perform best in a cockpit environment in which pilots share and acknowledge information about the state of the aircraft and thereby minimise the amount of uncertainty about communication. They conclude that in good-performing crews, captains create a context in which their commands and information requests take on meaning. These findings have been applied to the creation of training programs: One basic maxim in current CRM training is to communicate all relevant information to the other crew members. But so far, the effects of work overload on the ability to share all essential information with the crew members has not been investigated.

Our analysis of the transcript of the Birgenair crash has revealed that this ability can be impaired by high cognitive workload and danger, which is illustrated by the following segments:

Example (2)
Normal High Workload (N2)
(1) CO:[9] power's set
(2) CA:[10] okay checked

Danger 1 (D1)
(3) CA: my airspeed indicator's not working
(4) CO: yes, yours is not working
(5) CO: one twenty
(6) CA: is yours working?
(7) CO: yes sir
(8) CA: you tell me

Danger 2 (D2)
(sound of overspeed warning)
(9) CO: now it is three hundred and fifty yes
(10) CA: let's take that like this

[9] CO = Co-Pilot
[10] CA = Captain

Danger 3 (D3)
(11) CA: thrust levers, thrust, thrust, thrust, thrust
(12) CO: retard[11]

In the situation types N2, D1, and D2, problems of information transfer do not occur. The crew members inform each other about their actions (N2), about problems and strategies (D1), and about their perception of the situation (D2). Until then, they share a mental model even if this model is wrong: Both pilots assume that the plane has overspeed, whereas, in reality, it flies too slow. They have been misled about their actual speed by defective instruments and a false overspeed-warning.

But in D3, crucial information is not transferred. We can conclude from the transcript that the captain finally must have realised that they are too slow because he orders to increase speed. But he has failed to communicate this essential insight to his co-pilot, which leaves them with a fundamentally different conceptualisation of the situation. As a consequence, the crucial command "thrust levers" does not take on meaning for the co-pilot. It is in contradiction to his own mental model, and he demands the contrary action: "retard".

The question is why information transfer problems do arise. In a study on information transfer between pilots and controllers, Billings & Cheaney (1981) argue that such problems often arise because: "The person who had the information did not think it necessary to transfer it" (1981: 2). We think that in our case, this explanation does not hold. It is very unlikely that the captain consciously decided not to share his insight with his first officer. Our analysis has shown that the problem surfaced in the situation type that was characterised by the highest amount of workload and danger. This situation apparently impeded the captain to communicate with the co-pilot in greater detail as regards their actual speed. What remains to be investigated is whether this result of extreme overload and danger can be generalised, that is whether we can find similar tendencies in the other transcripts.

5.2 Initiation of Crew Resources

This category investigates the linguistic means (and their effects) that are used to organise teamwork within the crew. On the captain's side, we are interested in the style of directing the crew, how the crew's actions are coordinated, how tasks are distributed, and how the team members are involved in the process of problem-solving. On the co-pilot's and first officer's side, we are interested in how they contribute to this process. The category is characterised by four different values: [*activate resources*], [*react*], [*order*], and [*none*]. To [*activate resources*] means for the captain that language is used in a way that creates an

[11] For the full text, please refer to appendix (1).

open atmosphere – an environment in which each crew member feels free to seek and give suggestions. On the side of the subordinate crew members it means that suggestions are indeed provided. The label [*react*] is given to utterances of crew members who don't give any own suggestions but who only act out what has been stimulated by somebody else. Utterances that are not open for suggestions get the label [*order*], and [*none*] means that there is no linguistic interaction which aims at organising the teamwork.

There are various linguistic clues that indicate which label should be selected: the speech act, the sentence mode, and other formal features of the chosen construction. The speech acts express the communicative function of the utterance. They reveal the speaker's intention: whether the utterance is intended as a question, a request, or a command.[12] On the formal side, the following correlations between sentence mode (indicates the grammatical function) and category value exist: the interrogative mode correlates with the value [*activate*], and the imperative mode correlates with the value [*order*]. Other linguistic means indicate whether the speaker is open for suggestions: for instance question tags ("isn't it?", "will you?"), polite ("please", subjunctive) and informal (address by first name) forms.

Like information sharing, the category initiation of crew resources is crucial for effective teamwork. It is the aspect that is at the heart of the whole CRM concept. Researchers from the psychologically-oriented approach have conducted interesting studies into this category. They focus on the links between personality and performance, and between personality and communication. Chidester & Foushee (1988), for example, show that captains who are highly motivated, goal-oriented, and concerned with interpersonal aspects tend to lead crews at a high performance level in full-mission simulations. Kanki, Palmer & Veinott (1991) found out that captains who have less achievement motivation in interpersonal and flying skills are also the captains who initiate communications the least and who lead crews that performed least well.

But, again, the influence of the factor "workload" on the communicative behaviour has not been considered. It remains to be investigated in how far the ideal to involve team members in the process of problem resolution can be put into practice under conditions of threat and work-overload.

Our example illustrates some possible changes: In December 1995, a Boeing 747 was scheduled to fly from New York to Miami. Due to the wintry weather conditions, the runway was very slippery. The crew referred to its state as an "ice rink". The first phase of the take-off was normal, until suddenly the aircraft started to move to the left side of the runway. As corrections by the crew were ineffective, the captain aborted the take-off. The crew lost directional control over the airplane, and eventually they hit an obstacle. The following segments from the CVR transcript show how in this particular case the linguistic means

[12] For a classic account of speech acts, please refer to Searle (1969) and Searle (1975). A more recent theory of speech acts can be found in Vanderveken (1990).

used to organise the teamwork change in relation to the different situation types.[13]

Example (3)
Normal Low Workload (N1)

(1)	CA:	Ralph, take a little walk and check the wings for me, will you?
(2)	FE:[14]	Sure.

Normal High Workload (N2)

(3)	CA:	Set time, takeoff thrust.
(4)	FE:	Set the takeoff thrust.

Danger 3 (D3)

(5)	FO:[15]	Going to the left.
(6)	?:[16]	Going to the left.
(7)	FE:	To the right.
(8)	FE:	You're going off.
(9)	?:	Going off.
(10)	CA:	Aw #.[17]
(11)	CA:	Easy guys.
(12)	CA:	OK.
	CAM:[18]	[First sound of impact]

Let's first look at utterance (1) in the low workload condition – when the crew is waiting for the clearance to taxi to their runway. The underlying intention of (1) is: "x wants y to do z", that is: "CA wants FE to go and check the wings". The captain uses extensive linguistic means to convey this intention: In addition to the actual intention, his utterance includes the following elements: an informal address (first name), a periphrastic sequence, and a tag question. These additional elements make his utterance take on a polite form, so that it doesn't sound like a command but like a request. In this sense, (1) is a typical example for the value [*activates resources*]. In (2), the flight engineer expresses that he will comply. This utterance exemplifies the value [*react*].

As soon as the workload increases to the level of N2 – in our example, the crew has just received their take-off clearance – the linguistic means used to convey directive intentions change: The additional elements are omitted. The utterances are reduced to the "bare" expression of their underlying intention, and they take on the form of an [order], which is illustrated by utterance (3).

[13] The complete transcript can be found in appendix (2).
[14] FE = Flight Engineer
[15] FO = First Officer
[16] ? = unidentified voice
[17] # = expletive
[18] CAM = cockpit area microphone

In the D3 situation, the crew has lost directional control over the airplane. The communication that follows their loss of control does not contribute to organise team work. It consists mainly of observations (5, 6, 8, 9), swearwords (10), and attempts to calm down the situation (11). These utterances exemplify the value [none]. There is merely one utterance that initiates team work: In (7), the flight engineer says what should be done.

5.3 Receptiveness

In the cockpit, even under normal conditions, each crew member has to solve multiple tasks. In an emergency situation, the number of tasks dramatically increases: The crew has to fly the airplane, to find out what the problem is, to interpret technical information, to run emergency checklists, to decide on a strategy to solve the problem, to put the solution into practice, to talk to controllers, to change the flight plan – to name just a few. The majority of these tasks involve communication, at least to some degree. In such a situation it is particularly important to process information from different channels and to decide which is the most important one to answer.

The category receptiveness refers to language processing in such multi-task situations. We investigated how much information from different channels (crew members: cockpit crew, flight attendants; radio: controllers, other crews) can be processed under varying degrees of workload, and in how far the ability to react to those different channels varies in the different situation types. The category is characterised by four values: [broad] = to react to all incoming information, [focused] = to concentrate on those channels that are crucial in the current situation, [selective] = narrowed or reduced attention, choice of channel does not function appropriately, and [none] = no reaction.

Example (4) illustrates the value [focused]. It is also given for another reason: It serves to illustrate the switching between the different channels in order to make the reader better understand what is meant by a multi-task situation and what an enormous degree of attention is required to "function" in such a situation. Example (5) illustrates the value [selective]. Both examples are taken from the transcript of Atlantic Southeast Airlines Flight 529 from Atlanta to Gulfport in 1995.

First some background: Twenty minutes after take-off from Atlanta a serious problem occurred. One propeller blade separated due to a defect in the material. The separated blade destroyed the whole left propeller which made it extremely difficult to control the airplane.[19] In this situation it would have been essential to work as quickly as possible through particular checklists that determine what to do in such a situation: the engine-failure checklist and the single-engine checklist. At the same time, the radio communication had to be dealt with, which was the co-pilot's task.

[19] For a detailed description of the accident, please refer to the accident report NTSB/AAR-96/6.

The complete passage that contains the processing of the engine-failure checklist is much too long to be presented here in full detail.[20] But the selected short segment in example (4) already shows that the co-pilot constantly has to switch channels. We can see that – again and again – radio communication interferes with the crew's work on the checklist. As for this checklist, the co-pilot still succeeds to manage both channels: He responds to the ground and turns back to the checklist immediately afterwards. That is to say, so far his receptiveness can be characterised as [focused]. However, due to the required multi-tasking, the completion of the checklist was slowed down enormously.

Example (4)

Time	Cockpit Communication (between captain and co-pilot)	Radio Communication (between co-pilot and ground)
1246:38 CA	Let's get out the uh ... engine failure checklist, please.	
1246:47 CO	OK, I'll do it manually here.	
1246:55 CO	OK, engine failure in flight.	
1246:57 GRD		AC five twenty-nine, say heading.
1246:59 CO		Turnin' to about uh, three ten right now.
1247:01 CO	Power levers, flight idle.	
1247:03 GRD		AC five twenty-nine, roger. You need to be on about a zero three zero heading for West Georgia Regional, sir.
1247:07 CO		Roger, we'll prob'ly try to turn right. We're having uh, difficulty controlling right now.
1247:11 CO	OK, condition lever's, feather.	
1247:13 CA	All right.	
1247:14 CO	It did feather ... NP's showing zero.	
1247:18 CA	'K.	
1247:19 CO	OK.	
1247:20 GRD		AC five twenty-nine, when you can, it's zero four zero.
1247:22 CO		Zero four zero, AC five twenty-nine.

[20] The interested reader can consult appendix (3) for a longer excerpt from the transcript.

1247:25 CO	'K, electric, yeah OK it did feather. There's no fire.
1247:27 CA	All right.

The next step, after the crew has completed the engine-failure checklist, is the processing of the single-engine checklist, which is shown in example (5). If we compare examples (4) and (5), we can observe a change in the communicative behaviour of the co-pilot: He doesn't switch between the two channels of communication any longer. Again, the example shows only a short segment of the text.

Example (5)

Time	Cockpit communication (between captain and co-pilot)	Radio communication (between co-pilot and ground)
1249:45 CA	All right, single-engine checklist please.	
1249:48 GRD		AC five twenty-nine, I've lost your transponder. Say altitude.
1249:52 CO		We're out of four point five at this time.
1249:54 GRD		AC five twenty-nine, I've got you now and the airport's at your, say say your heading now sir.
1249:59 CO		Right now we're heading uh, zero eight zero.

The segment starts with the captain's request to go through the single-engine checklist. Immediately afterwards, a competing request is issued by the ground control. The co-pilot answers the controller's request. Afterwards, he remains in that channel of communication. He does not switch back to the checklist.

For the communication that follows, he remains in the radio channel until, finally, the captain tries to get his attention back to the checklist:

1251:17 CA	Sing, single, single-engine checklist, please.	
1251:28 CO	Where the # is it?	
1251:29 GRD		AC five twenty-nine, say altitude leaving.
1251:31 CO		We're out of nineteen hundred at this time.