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A context for error

Using conversation analysis to represent and analyse recorded voice data

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PREFACE

Cockpit voice recorders (CVRs) are installed in aircraft to provide information to investigators after an accident. They provide records of the flight crew activities and conversations, as well as a variety of other auditory information. Information from CVRs has proved very useful in determining the events leading up to aircraft accidents for many years. However, there has been little discussion in the safety investigation field about appropriate ways to analyse recorded voice communications, particularly in terms of analysing the quality of the interaction between crew members.

Following the investigation into a controlled flight into terrain accident in an Israel Aircraft Industries Westwind 1124 jet aircraft, which impacted terrain near Alice Springs on 27 April 1995, the then Bureau of Air Safety Investigation (BASI) evaluated available methods to analyse recorded voice communications.

As a result of this research, the ATSB contracted independent experts in an emerging field known as ‘conversation analysis’ to analyse the CVR from the Westwind 1124 accident. The project was conducted by Dr Maurice Nevile and Dr A.J. Liddicoat, both then of the Australian National University. The independent consultants’ report provided conclusions regarding the crew interaction which were consistent with the original BASI investigation report. More importantly, the project showed that the conversation analysis method provided a very useful approach to identify, describe, demonstrate and explain difficulties in conversation between two or more individuals.

The present research paper explains the nature of conversation analysis, and its potential for use in safety investigation, as well as its potential for demonstrating the importance of appropriate crew communication practices. To help explain the usefulness of the method, information from the original consultancy project’s examination of the Westwind 1124 CVR is included. The present research study is not an investigation into the circumstances of the accident.

It is important to note that a cockpit voice recording provides limited information about activity in a cockpit, and cannot provide a complete understanding of all activities and interactions among flight crew. It does, however, provide a good understanding of what happened and why. The analysis can be enhanced by comparing average sound recordings from normal multi-crew communication and activity on a flight with a recording from a particular flight that is being studied. This comparison can provide more detailed insights into crew activities and interactions on a particular operation despite the lack of visual information, for example from a cockpit video recording.

It is acknowledged that a perfect understanding of cockpit activity is hard to achieve without the opportunity to interview the flight crew as a part of an investigation. However, the methodology described in this paper is intended to expand the level of understanding that can be obtained from a cockpit voice recording as a part of an investigation.

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EXECUTIVE SUMMARY

Recorded voice data, such as from cockpit voice recorders (CVRs) or air traffic control tapes, can be an important source of evidence for accident investigation, as well as for human factors research. During accident investigations, the extent of analysis of these recordings depends on the nature and severity of the accident. However, most of the analysis has been based on subjective interpretation rather than the use of systematic methods, particularly when dealing with the analysis of crew interactions.

This paper presents a methodology, called conversation analysis, which involves the detailed examination of interaction as it develops moment-to-moment between the participants, in context. Conversation analysis uses highly detailed and revealing transcriptions of recorded voice (or video) data that can allow deeper analyses of how people interact.

The paper uses conversation analysis as a technique to examine CVR data from an accident flight. The focus accident was a controlled flight into terrain event involving an Israel Aircraft Industries Westwind 1124 jet aircraft, which impacted terrain near Alice Springs on 27 April 1995.

The conversation analysis methodology provided a structured means for analysing the crew's interaction. The error that contributed directly to the accident, an incorrectly set minimum descent altitude, can be seen as not the responsibility of one pilot, but at least in part as the outcome of the way the two pilots communicated with one another. The analysis considered the following aspects in particular: the significance of overlapping talk (when both pilots spoke at the same time); the copilot's silence after talk from the pilot in command; instances when the pilot in command corrected (repaired) the copilot's talk or conduct; and lastly, a range of aspects for how the two pilots communicated to perform routine tasks. In summary, the conversation analysis methodology showed how specific processes of interaction between crew members helped to create a working environment conducive to making, and not detecting, an error. By not interacting to work together as a team, pilots can create a context for error.

When analysing recorded voice data, and especially for understanding instances of human error, often a great deal rests on investigators' or analysts' interpretations of what a pilot said, or what was meant by what was said, or how talk was understood, or how the mood in the cockpit or the pilots' working relationship could best be described. Conversation analysis can be a tool for making such interpretations.

1 INTRODUCTION

It is now widely accepted that human error is a contributing factor in most aircraft accidents (Wiegmann & Shappell, 2003). For many of these accidents that involved larger aircraft and crews with two or more pilots, some of the errors related to problems in communication or task coordination between the pilots (Salas et al, 2001). Consequently, there has been a considerable amount of research that has examined the nature of crew communication and coordination (Helmreich, Merritt & Wilhelm, 1999; Wiener, Kanki & Helmreich 1993). There has also been considerable amount of effort expended in training airline pilots in crew resource management techniques (Salas et al., 2001), and a considerable amount of effort expended in developing and applying techniques to evaluate crew performance in these areas, using behavioural markers and techniques such as the Line Operations Safety Audit (Flin et al., 2003; Helmreich, Klinect & Wilhelm, 1999).

It is also widely accepted that, even though human errors may have been a factor in a particular accident, investigations should focus on identifying the reasons for such errors rather than the errors themselves (Maurino et al., 1995; Reason, 1990, 1997). These reasons may include a range of factors associated with the task and environmental conditions, as well as the broader organisational context in which the crews operated. However, to identify these underlying reasons, the nature of the crew actions needs to be examined in detail. In addition, the context in which the actions occurred also needs to be considered (Dekker, 2001a, 2001b, 2002; Reason, 1997).

This paper presents a technique that can be used to analyse recorded voice communications in context, and shows how this technique can be used to demonstrate how and why communications between two or more pilots were not effective. The technique, called conversation analysis, involves the detailed examination of interaction as it develops between the participants. We use this technique to examine the cockpit voice recorder (CVR) from an accident flight. We show how specific processes of interaction between crew members can help to create a working environment conducive to the pilots making, and not detecting, an error. By not interacting to work together as a team, pilots can create a context for error.

The research paper is the outcome of collaboration between an academic researcher with a background in applied linguistics and micro-sociology who has conducted a major study of routine communication in the airline cockpit (see especially Nevile 2004a), and a senior transport safety investigator with an academic background in organisational and cognitive psychology and with substantial experience investigating human factors for aircraft accidents.

2 CURRENT METHODS FOR ANALYSING RECORDED VOICE COMMUNICATIONS

Recorded voice data, such as from CVRs or air traffic control tapes, can be an important source of evidence for accident investigation, as well as for human factors research. During accident investigations, the extent of analysis of these recordings depends on the nature and severity of the accident. However, most of the analysis has been based on subjective interpretation rather than the use of systematic methods, particularly when dealing with the analysis of crew interactions. When transcriptions are conducted, they typically list only the speaker, the time at which the utterance started, and the words spoken. Detailed information about how the words are spoken is usually excluded. This is probably because investigators have limited tools to analyse this data in a structured manner. However, it may also be due in part to sensitivities associated with releasing CVR information.

Two main types of techniques have been used for more structured analysis of recorded voice communications. The first type, commonly termed ‘speech analysis’ (or ‘voice analysis’) looks at a pattern of voice information and related behaviour to identify possible factors affecting an individual’s performance. This will generally involve measurement of variables such as fundamental frequency (pitch), speech rate (number of syllables per second), intensity (or loudness), speech errors, response time, and aspects of the speech quality. The data is then compared with carefully selected samples, generally from the same person under normal conditions. Speech analysis has been successfully employed to examine the influence of factors such as stress and workload (Brenner, Doherty & Shipp, 1994; Ruiz, Legros & Guell, 1990), alcohol (Brenner & Cash, 1991) and hypoxia (Australian Transport Safety Bureau, 2001). However, it focuses on the factors affecting a specific individual, rather than the pattern of communications between individuals.

The second type of technique has involved the coding of speech acts (Helmreich, 1994; Predmore, 1991; Transportation Safety Board of Canada, 2003). This process typically involves coding each utterance in terms of its function or ‘thought unit’ (e.g., command, advocacy, observation, inquiry). It also involves coding ‘action decision sequences’ of utterances in terms of their task focus (e.g., flight control, damage assessment, problem solving, emergency preparation). This coded data is then examined in terms of how it is distributed between the crew, and how it changes over time during the flight. Where possible, comparisons are made with available data from other crews.

Although speech act coding can offer useful insights into communication dynamics, its effectiveness can be limited by a lack of available data on how other crews from similar backgrounds communicated in similar situations. Also, it does not use all the available information about how things are said or communicated, and this information can be important in establishing the context for the crew communications. A technique that focuses on this additional information is conversation analysis.

3 CONVERSATION ANALYSIS

Conversation analysis is a micro-analytical approach to the study of naturally occurring interaction. As a discipline, its origins are in sociology and are usually traced to a paper on the organisation of turn-taking in conversation, written in the mid 1970s by Sacks, Schegloff & Jefferson (1974). The early development of conversation analysis is especially associated with the ideas of Harvey Sacks (see Sacks, 1992, Silverman, 1998), and the influence of ethnomethodology (e.g. Garfinkel, 1967). Conversation analysis shows in micro-detail how naturally occurring interaction is sequentially ordered and collaboratively produced and understood by participants, moment-to-moment, in what has been described as the "intrinsic orderliness of interactional phenomena" (Psathas, 1995, p.8). Conversation analysis looks at how interaction is something people jointly accomplish 'locally' (i.e., there and then). Recent introductions to conversation analysis are provided by Hutchby & Wooffitt (1998) and ten Have (1999).

Increasingly, conversation analysis is now being drawn upon in studies of interaction for work in institutional and professional settings, such as in medicine and counselling, education, law and policing, business, human-computer interaction, and control centres (e.g., Drew & Heritage, 1992; Button, 1993; Heath & Luff, 2000; McHoul & Rapley, 2001; Richards & Seedhouse, 2004). Most relevantly, one of the present authors has used conversation analysis for a major video-based study of routine communication, or 'talk-in-interaction', in the airline cockpit (Nevile 2001, 2002, 2004a, 2004b, 2005b, in press). In the present paper, four features of conversation analysis will be central to our presentation and analyses of recorded voice data.

1. Conversation analysis is concerned with *naturally occurring data*, not data specifically generated for research purposes. It uses recordings, and the transcriptions made of them, of naturally occurring interactions. Analysts may make use of observation, interviews, or other ethnographic techniques, but their emphasis is on how the participants develop and demonstrate their actions and understandings in real time.

2. Conversation analysis uses *highly detailed and revealing transcriptions* of recorded voice (or video) data that can allow deeper analyses of how people interact. The process of transcribing is an important part of the discovery process, and involves repeatedly listening to the recording. Transcribing is undertaken with an open mind about what might be there, a process called *unmotivated looking*.

3. Conversation analysis is data driven and relies for its claims on the *evidence available in the data itself*, on what the participants themselves say and do, and just how and when they do so as the interaction develops. Claims about participants' understandings and actions must be based on, and demonstrated in, analyses of the transcription data. Conversation analysis looks at what happens, and then what happens next, and asks 'Why that now?' Analysts avoid preconceptions of participants or settings, and ascribing to participants' mental, motivational or emotional states, but seek evidence for these in the details of how interaction develops.

4. Conversation analysis examines what people say and do *in context*, seeing how these actions occur in sequence relative to one another, rather than isolating actions from their contexts of occurrence. Conversation analysis shows how

actions are both shaped by context and also shape context by influencing participants' subsequent actions and understandings of what is happening.

Using conversation analysis meets recent calls to analyse human error in context (e.g., Dekker, 2001a, 2001b), to "reconstruct the unfolding mindset" of the people involved "in parallel and tight connection with how the world was evolving around these people at the time" (Dekker, 2001a, p.39). With conversation analysis, the analyst can use highly detailed transcriptions of spoken data (or even visual data) as the evidence for how the pilots *themselves* create particular patterns of communication, and interpret and understand what they are doing and what is going on, in context. The technique therefore offers a means for describing, in terms that are defensible because they are grounded in the voice data, how members of a flight crew are working together.

4 THE FOCUS ACCIDENT

We will focus on data from one accident, and use this accident as an example of what can be done, and what can be found, using methods and principles of conversation analysis. This paper is not an attempt to outline and understand all the complex factors that contributed to the accident. Instead, we only focus on the way in which the pilots interacted with one another.

The accident was a controlled flight into terrain event involving an Israel Aircraft Industries Westwind 1124 jet aircraft on a night cargo flight (Bureau of Air Safety Investigation, 1996).[1] The two-pilot crew was conducting a practice non-precision approach in clear moonless conditions. The approach involved a stepped descent in three stages using three navigation aids. The flight proceeded normally until the aircraft passed over the final approach fix, at which point the pilot in command (PIC) asked the copilot (CP) to set the 'minima' in the altitude alert selector. The copilot responded by calling and setting 2,300 feet, and this action was acknowledged by the pilot in command. However, the relevant minimum height that applied to the accident aircraft at that stage in the approach was 3,100 ft. Shortly after levelling off at 2,250 feet, the aircraft struck the top of a mountain range and was destroyed.

The pilot in command was a former airline pilot with 10,108 hours total flight experience, and 2,591 hours on the Westwind aircraft. The copilot had 3,747 hours total flight experience, most of which was conducted in helicopters. He had 80 hours of experience on the Westwind. The pilot in command was the handling pilot for the flight.

The accident investigation identified a number of factors that contributed to this accident, including that the technique employed by the pilot in command in flying the approach involved a high cockpit workload. A number of the contributing factors involved problems in the communication between the crew. The report concluded that there were difficulties in the cockpit relationship between the pilot in command and the copilot, and that the level of crew resource management demonstrated by both pilots during the flight was low. Most of the evidence for these conclusions came from the 30 minutes of recorded voice communications on the aircraft's CVR. Although the investigation team considered that there was ample evidence to support the conclusions, it experienced difficulty in clearly substantiating the conclusions in a precise manner. Based on this experience, the Bureau subsequently explored a variety of techniques that could assist the analysis of recorded voice communications. One of these techniques was conversation analysis.

A transcript of the CVR for the accident flight was included in the BASI report on the accident. The present paper contains no substantially new information on *what* was said, but contains new information in terms of *how* things were said. This additional information has been released by the ATSB for the purposes of enhancing aviation safety.

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[1] The Australian Bureau of Air Safety Investigation (BASI) became part of the newly formed the multi-modal Australian Transport Safety Bureau (ATSB) on 1 July 1999.

5 THE VALUE OF DETAILED TRANSCRIPTION

Prior to reviewing segments of conversation from the focus accident, we need to outline the nature of conversation analysis transcription. Conversation analysis has developed particular notation for representing systematically many details of talk (or nontalk activities) that studies have shown to be significant to participants themselves (i.e., for how participants interpret what is going on, as evidenced in what they do next). One advantage of transcribing recorded data by using notation developed in conversation analysis is that the transcriptions can show much more about what is actually happening, and why. In short, conversation analysis shows how transcribing voice data involves much more than recording what people say - it involves showing just how they say it. Typically, conversation analysis transcriptions of audio data can indicate at least the following:

- how talk is sequentially ordered as turns, or how and when participants exchange roles as speaker and listener (recipient);
- exact measures of silence in and between utterances (timed to the tenth of a second);
- periods when two or more people are talking at once (overlapping talk), and the exact points in talk when such periods begin and end;
- features of the manner of talk, such as lengthening of sounds, pitch contours and marked rises and falls in pitch, talk that is faster or slower, or louder or quieter than surrounding talk, talk that is incomplete (e.g., cut-off), and aspects of voice quality (e.g., breathiness, creaky voice);
- ‘tokens’ such as ‘oh’, ‘um’ and ‘ah’; and
- laughter (in individual pulses), and exactly when laughter begins and ends.

To highlight some of the features of conversation analysis transcription, we show for comparison two transcriptions of the same segment of talk from the focus CVR. The first is a basic transcription, in the form it appeared in the investigation report (Bureau of Air Safety Investigation, 1996). It shows mainly who is speaking to whom, the words spoken, and the time of speaking. PIC is pilot in command, CP is copilot.

Example 5.1: A basic transcription

TIME	FROM	TO	TEXT
1934.05	PIC	CP	we’ll go down to forty-three hundred to there and if you can wind in thirty-four fifty and when we when we get over there wind in twenty-seven eighty that’ll be the minimum we’ll see how it looks for a giggle and you can put the steps in now too if you wouldn’t mind but you only need to put the steps in below the lowest safe (non-pertinent transmissions)

Now we present the same segment of talk but transcribed using notation developed in conversation analysis. The conversation analysis notation is given in the Appendix.

Example 5.2: A conversation analysis transcription

	(18.0)
PIC	we’ll go down to fortythree hundred to there, (0.5) and if you c’n wind in thirtyfour fifty,
	(0.6)
PIC	and when we- (0.9) when we get over there wind in twentyseven eighty.
	(0.3)
PIC	°that’ll be the minimum°.
	(1.8)
PIC	see how it looks.
	(2.5)
PIC	just for a ↑giggle,
	(6.4)
PIC	ah::: you c’n put the steps in there too if you wouldn’t mind.
	(1.5)
PIC	>but you only need< to put the steps in <below the lowest safe>.
MELB	*Gulf Air one (triple/two four) eight, (0.2) contact me on one two eight decimal one ( ).*
	(1.4)

To highlight the key differences, we can see that the conversation analysis transcription does the following:

- represents the pilot in command’s talk as a number of separate turns, rather than as one long turn - the breaks in talk, shown on separate lines as periods of silence between turns, represent points where the copilot could have heard the pilot in command’s talk as complete in some way, and so the copilot could have taken a turn to talk (e.g., even if just to say ‘yeah’ or ‘okay’);

- shows and times all silences, and their lengths in seconds, both within and between the pilot in command’s turns e.g., (1.8);

- shows details of the manner of talk, including marked rises in pitch (↑), and intonation that is falling (.) or slightly rising (,) (i.e., hearably incomplete), also talk which relative to surrounding talk is louder (“wind”), or quieter (“°minimum°”), or faster (“>but you only need<”), or slower (“<below the lowest safe>”), and shows talk that is lengthened (“ah:::”), or cut-off (“we-“), or repeated (“when we- (0.9) when we”);

- includes overheard radio talk i.e. an ATC transmission directed to another flight, as part of the communicative environment in which the pilots are working; and

- includes the token “ah”.

6 EVIDENCE OF A CONTEXT FOR ERROR: SEGMENTS OF CVR DATA

Our suggestion in this paper is that the final crew errors that contributed to the accident emerged from an immediate work environment that was conducive to errors occurring and not being identified. The ways in which the pilots communicated with one another created a context for error. We will discuss, with some segments of representative CVR data, the following features of interaction.

1. There were many instances of overlapping talk (i.e. both pilots speaking at the same time).

2. There were many instances when the pilot in command said something and the copilot said nothing in reply (i.e. the copilot is silent), even though some form of a response would have been a relevant and projectable (expected) next action.

3. The pilot in command often corrected (or *repaired*) the copilot's talk or conduct when there was no sign of any problem, from the copilot's point of view, in the copilot's talk or conduct itself.

4. Many aspects of how the two pilots communicated to perform routine tasks suggest that the pilots were not working together in harmony as a crew.

Individually, each of these features may mean little, but together they can have a cumulative effect. It is not our intention and it is not necessary to conduct a quantitative analysis of particular features of the talk data. This is usually difficult or impossible with the limited data available in recorded voice data. However, these features were identified because they were noticeably recurrent in the CVR data, and can be taken as evidence of the patterns of interaction developed by these two crew members over a period of that accident flight. We have no interest in making wider claims about the pilots' talk or conduct other than in relation to the CVR data for this flight.

Unless we specify a source, we will be grounding our comments on well established principles and findings of conversation analysis, as emerging in research over the past three decades and discussed in general texts such as Hutchby & Wooffitt (1998) and ten Have (1999). We will also refer to research on routine cockpit communications using conversation analysis, focussing on airline crews, conducted by one of the present authors (especially Nevile 2004a). The CVR data here are from a cargo flight, not an airline flight, but we will assume that there are in common shared mission goals (safe landing) and activities (flight tasks), and so preferred practices for clear and effective communication for flying multi-engine commercial aircraft.

Note that *many or most data examples exhibit more than one of the features we focus on in this paper*. However, to avoid repetition of data in most cases we have placed examples under just one or other of the main headings.

6.1 Overlapping talk

In both ordinary conversation and talk in work and institutional settings, it is common for there to be points when more than one person talks at a time. Such instances of ‘overlapping’ talk often occur at points where one person is heard to be possibly coming to the end of their turn at talk. The *overlapping talk* occurs as someone other than the speaker begins to talk, and often emerges as the next speaker and produces the next turn at talk. Overlapping talk at the end of turns is usually *not* treated by participants as interruption, but as part of the normal flow of talk to exchange turns and switch speaker/listener roles.

However, Nevile (2004a, 2005a) has found it to be unusual for flight crews to overlap their talk. That is, pilots usually do not begin talking when another pilot is still talking. This was seen to be the case even when pilots were talking and exchanging turns very quickly, for example during the performance of a checklist. Pilots seem oriented to allow one another’s talk to emerge in the clear. Overlapping talk does occasionally occur, but relatively rarely in task-oriented talk, perhaps only two to three times per flight.

In the CVR data for the accident flight, there were more than twenty instances of overlapping talk. On its own this is a noticeable feature of the accident flight. The great majority of these instances of overlapping talk occurred when the pilot in command began to talk when the copilot was already talking. That is, the pilot in command was the participant responsible for initiating the overlapping talk. Many of these instances were at points in the copilot’s talk where the pilot in command could expect that the copilot’s turn was coming to a close. That is, the pilot in command was predicting or projecting the end of the copilot’s turn and beginning his own turn at talk in response (see examples 6.1.1 and 6.1.2). As we have said, this kind of overlap is common in everyday conversation, but is uncommon in cockpit communication. Overlapped talk is shown by [square brackets].

Example 6.1.1

```
             (10.1)
PIC         now the minute we go over Spring Hi:ll, (0.6) or whatever it’s called
            Simp- err=
CP           =Simpsons [ga:p
PIC                    [Simpson is it?
             (0.2)
PIC          yea:h.
             (1.4)
```

Example 6.1.2

```
        (2.2)
CP      gear’s down (.) three greens co[nfirm?
PIC                                    [c:o:::nfi::rm.
        (4.3)
CP      okay hydraulic pressure’s checked in two:::, anti[skid,
                                                         [((tone, 1 second))
PIC     one to run.
        (0.4)
```

More significantly however, there were also numerous instances in the data where the pilot in command began to talk even though the copilot had not finished his turn at talk, where there was potentially *still talk of substance to be uttered and heard* (see examples 6.1.3-5). In lay terms, the pilot in command could be heard as interrupting the copilot. This occurred even at times when the copilot was presenting important information for the pilots' joint conduct and understanding of the progress of the flight.

Example 6.1.3

(1.1)
CP >Alice on< number one,
(1.0)
PIC ye::p.
(0.4)
PIC Alice on number one,
(0.5)
CP? (yep).
(2.6)
CP Simpson's gap? (.) o:n [(0.2) number two,]
PIC [Simpson's gap's] on number two::,
(0.7)

Example 6.1.4

(0.4)
CP thrust rever[sers check(ed).]
PIC [(it's on) light's] out.
(1.0)

Example 6.1.5

(1.5)
CP below the: (.) lowest safe so, (0.5) twentynine (here) [(on the) ( )]
PIC [(twentynine)]
five and eight (two)
( )
(3.5)

These instances of overlapping talk suggest, at the very least, that these two pilots are not coordinating the timing of their communicative contributions in the smooth manner found to be typical of commercial flight crews. However, where one pilot initiated such points of overlapping talk far more than the other pilot, that pilot could be heard to be dominating the other pilot's communication, and so also their contributions to the work of operating the aircraft. Overlapping talk is also possibly a problem because it can increase the chances of something being misheard, or not heard at all. The pilots may be speaking simultaneously, but they may not both be listening.

6.2 Silence

A great deal of research in conversation analysis has shown how people speak in sequences of turns at talk, and orient to (or are sensitive to) the sequential nature of conversational exchange. This means that, overwhelmingly, when one person in an interaction produces a turn at talk (the first of a pair of utterances – or 'first pair part'), the other person produces talk that is appropriate as a response to that first turn ('second pair part'). More than this, particular types of turns at talk are associated with particular types of response, and indeed can be thought of as expecting (or 'preferring') particular types of response (e.g. question and answer, telling and acknowledgement).

Conversation analysis studies have consistently found that silences between the turns of a sequence, from as little as 0.3 or 0.4 of a second, are noticeable to participants and are interpreted by participants as meaning certain things, and can prompt action of some kind. For example, the silence possibly signals a problem with the first turn, such as it was not heard, or was not understood, or was unexpected, or will be disagreed with or declined. The lengths and meanings of silences in work settings can vary significantly from ordinary conversation, but in work settings people also talk in sequences, and the cockpit is no exception (Nevile 2004a, 2005b). When one pilot talks the other usually responds, and in a way that can be heard as appropriate.

In the CVR data from the accident flight, there were many instances where the pilot in command said something, the first pair part of a sequence (e.g., a telling/informing, an instruction, or a question), but the copilot did not produce any appropriate and expectable spoken response (e.g., an acceptance/acknowledgment, or compliance, or an answer). An excellent example of this was presented above as example 5.2, but see also examples 6.2.1-3.

Example 6.2.1

	(1.2)
PIC	so you can put the inbound course up there::.
	(22.8)
PIC	thank you::.
	(5.5)

Example 6.2.2

	(9.8)
PIC	okay you can take the rnav out tha:nks:::
PIC	just put Alice up,
	(high pitch tone, 1 second))
	(18.8)

Example 6.2.3

	(8.4)
PIC	okay we're assuming we've got the ah::: (0.9) the ident on a- (.) all the time okay? (.) if you just identify 'em and then (1.9) turn them off,
	(21.1)

Some examples of the copilot's silence occurred after the pilot in command corrected the copilot's performance of some action, or failure to do something (see example 6.2.4). Also, a pattern of pilot in command talking with no spoken response from the copilot was seen to occur even when the pilot in command appeared explicitly to pursue a response from the copilot, as in example 6.2.5 (and see especially "'n fact it's a fair way out isn't it?"). This example occurred after a problematic exchange of turns where the pilot in command corrected an error by the copilot and the copilot attempted to defend his conduct. In short, the copilot appeared to choose to be silent, and finally only spoke when he must, to complete a prescribed sequence of reciprocal turns for setting the speed bugs (“set on the right.”).

Example 6.2.4

	(8.6)
PIC	okay if you can put the rnav (0.3) up thanks::.
	(1.4)
PIC	whoo::::h.
	(0.6)
PIC	do that fir:::st.
	(1.6)
PIC	bring em both out,
	(0.4)
PIC	o:kay.
	(4.3)
	((alert sound - beep))
	(0.8)
PIC	righto.
	(46.6)
PIC	ah::: have you got the ILS preed up there just in ca:se::?
	(34.8)
PIC	thanks.
	(35.3)

Example 6.2.5

	(0.5)
PIC	yeah I dunno how we’re gonna get rid of tha::t.
	(1.5)
PIC	I guess: all you can do if it doesn’ go away::, (1.0) is:: ah:: (1.0) put my information on your si:::de.
	(2.7)
PIC	it’s no good the way it i:s:.
	(5.8)
PIC	‘n fact it’s a fair way out isn’t it?
	(33.8)
PIC	>there you go.<
	(1.9)
PIC	’s got rid of it for a whi::le anyway.
	(1.6)
PIC	okay we’re gonna do this: (.) for a bit of a giggle,
	(1.3)
PIC	u:::m (.) elevation’s eighteen hundred feet, (1.5) we got enough fuel to ho:ld for one point four hours if need be, (1.5) a::nd ah:: we gotta vee ref of one twenty set on the left,
	(0.2)
CP	set on the right.
	(4.8)

In some of these cases it is possible that the copilot could indeed have been responding, but with a nontalk activity (e.g., a nod, or an activity at an instrument panel). The cockpit is a workplace where the response to talk is often nontalk activity, however such activity is also almost always accompanied by talk (Nevile 2002, 2004a, 2004b, 2005b). A possible exception to this is during a formal briefing when pilots can speak in longer (extended) turns, but even in briefings there is usually evidence of the pilots acknowledging one another's contributions and orienting to a need to communicate verbally as they work together (Nevile 2004b). Other than during briefings, it is extremely unusual to have a string of turns at talk where one pilot talks and the other pilot says nothing at all in reply.

Conversation analysis discusses silence in terms of 'conditional relevance'. The copilot's silence can be seen as an absence of speech in a context where the pilot in command's talk made it relevant for the copilot to say something. The copilot was entitled to say something, indeed could be expected to say something. In conversation analysis terms, speech from the copilot would have been a 'projectable' next action. In these instances silence is not simply a case of no-one speaking, but a case of the copilot not speaking. In terms of verbal communicative exchange between fellow pilots, for whatever reason one party, the copilot, regularly withheld talk and opted out.

6.3 Correction (repair)

Conversation analysts have identified a general conversational practice, *repair*, which may be of particular relevance to understanding error in aviation and how it is managed. *Repair* refers to those points in spoken interaction where participants deal with communicative problems of some sort. Conversation analysts have found that in everyday conversation people do not normally correct each other. There is a marked tendency for *self-repair* (Schegloff, Jefferson & Sacks, 1977); that is, for the person who produced the 'problem talk/conduct' (the *repairable*) to repair that talk or conduct, and to be granted the opportunity to do so by the other person. Conversation analysts have shown that participants distinguish between the *initiation* of the repair (i.e., showing that there is a problem) and *actually doing* the repair (i.e., fixing the problem). So, even where the *other* might initiate the repair, there is still the tendency for self-repair. This 'preference' for 'self-repair' is seen in data for flight crews (Nevile 2004a). Conversation analysts have shown that, when another person *both* initiates *and* performs a repair (called *other-initiated other-repair*), that repair is typically delayed, hedged or qualified in some way. The person doing the repair softens the blow.

In the CVR data for the accident flight, there were many instances of *other-initiated other-repair*. The pilot who produced the problem talk or conduct did not initiate repair and did not repair that talk or conduct. Overwhelmingly, the pattern of these instances involved the pilot in command both initiating and performing the correction/repair of the copilot's talk or conduct (see examples 6.3.1 and 6.3.2 below, and 6.2.4 earlier). The pilot in command repaired the copilot's talk/conduct when there was no sign of any trouble, in the copilot's talk/conduct itself, from the copilot's point of view. The first the copilot knew that there was something to be corrected in his talk or conduct was when the pilot in command corrected it. More than this, the pilot in command did not delay, hedge, or qualify his repairs of the copilot. The pilot in command gave the copilot no or little opportunity to correct the problem for himself.

Example 6.3.1

	(0.4)
CP	and it’s a seven mile f-f-
	(0.5)
?	( )=
CP	=seven mile final.=
PIC	=no:: el↑even.
CP	eleven.
	(6.9)

Example 6.3.2

	(6.2)
CP	the only trouble we might get is, (0.5) if they lea::ve.
	(1.3)
CP	if they leave before us (0.3) they might depart out on, (0.4) one two.
	(0.7)
PIC	well they ca::n’t, (0.2) we got their freight.
	(1.6)
CP	°(that’s right)°
	(9.3)

Example 6.3.1 is a clear example of *other-initiated other-repair* and warrants further explanation. Here the copilot, as part of his preparation for the approach, informed the pilot in command that it will be a “=seven mile final.=”. The copilot had two goes at saying this, abruptly stopping his first attempt with “seven mile f-f-“. The pilot in command corrected the copilot’s ‘seven’ by saying “=no:: el↑even.”. The ‘=’ symbols indicate that the pilot in command’s turn is ‘latched’ to the end of the copilot’s turn (i.e., the pilot in command produced his talk with no delay whatsoever after the end of the copilot’s turn). Recalling that in interaction there is a tendency (or ‘preference’ in conversation analysis terms) for self-repair, the copilot was given no opportunity, after completing his problem turn, himself to repair the incorrect number. That is, the pilot in command did not say something like ‘Seven?’, or ‘Are you sure it’s seven?’, or ‘Is that right?’, or even just wait a second or so to give the copilot a chance to rethink and possibly identify and say the correct number himself. Note that the copilot actually said the problem number, ‘seven’, twice, the first time in the turn that he cut off. Therefore it is possible that the pilot in command heard the problem ‘seven’ twice and let it go the first time, giving the copilot the chance to get it right. However, that first talk by the copilot was not completed (“seven mile f-f-”), and it is when he completed his turn and presented the number he had actually settled on (“=seven mile final.=”) that the pilot in command *immediately* corrected him.

Not only did the pilot in command do the repair himself immediately, with no delay, no hedging, and no qualification, the repair began with an explicit marker of negation. This had its prominence increased because it was said with increased volume and was also lengthened (“no::”). The pilot in command continued his turn by simply saying the repaired number ‘eleven’, and in the following turn the copilot accepted this repair without question, indeed without delay. The pilot in command’s saying of ‘eleven’ was a claim that this number was the correct one, and this claim was immediately accepted by the copilot. So, a possible problem of crew understanding about the length of the final leg was resolved by one individual telling another, effectively, that he was wrong, and the other individual accepting this without question.

6.4 Performing tasks

Finally, we consider how the two pilots generally performed routine flight tasks for this period of the flight. Our general finding is that it was typically the pilot in command who talked to initiate tasks, and he did so in ways that can make prominent his authoritative status as pilot in command for the flight, and the other pilot's junior status. That is, the pilot in command's wording can be heard to present tasks as being performed *for* him, as the pilot in command, *by* the copilot, rather than as being performed collaboratively for both pilots as a crew, and by both pilots as a crew, albeit that it is often appropriately the case that the copilot is doing the required task activity. Such wording could be heard as creating a sense that the copilot was serving the pilot in command, rather than that the two pilots were working together as team members with different but equally necessary and valuable contributions to flight tasks. The nature of the copilot's participation in task performance could deepen this sense of how the pilots were working.

To demonstrate these points we describe a number of specific aspects of the pilots' communication and interaction as they performed routine tasks. We stress, however, that many segments actually exhibit more than one of the aspects described below. The collection of segments makes it easier to understand how, over time, the effect of particular aspects of communication can accumulate and create a context in which the pilots seem not to be working together but instead more according to their individual statuses and roles. We do not have scope here to discuss any segments in detail.

Firstly, the pilot in command typically initiated tasks with commands to the copilot. In grammatical terms he used imperative structures that communicate 'Do X' (see examples 6.4.1-3).

Example 6.4.1

	(10.1)
PIC	now the minute we go over Spring Hi:ll, (0.6) or whatever it's called Simp- err=
CP	=Simpsons [ga:p
PIC	[Simpson is it?
	(0.2)
PIC	yea:h.
	(1.4)
PIC	ah:::m (.) set the next altitude ↑u:p, (0.5) and the nex:t:, (0.5) NDB.
	(2.5)

Example 6.4.2

	(4.7)
PIC	keep going.
	(4.8)
PIC	keep going. (.) checks th[anks.
CP	[okay vee ref (0.2) one three set. (.) fuel balance,
PIC	it's within limits:::.
	(1.4)

Example 6.4.3

	(1.4)
HT?	*hotel tango* ( ) *good night (and thanks)*.
PIC	he said to call Adelaide no:w didn't he?
CP	yeh.
	(0.3)
PIC	well you can go off, (0.5) go (on/off) tha:t.
	(4.5)
?	(s-) (respond).
	(9.5)

The pilot in command also very frequently used the first person singular personal pronoun 'I', which presented him as central to the task and as the recipient for performance of the task, and the second person pronoun 'you', which presented the copilot as the one doing the task. That is, the pilot in command's usual wording can convey the sense that 'you are doing the task for me'. Such use of 'I' and 'you' by a pilot in command and handling pilot is not in itself exceptional as a means for making salient relevant individual cockpit identities (Nevile 2001, 2004a). However their use almost to the exclusion of more inclusive plural forms (e.g., we/our/us) can mark this CVR data as unusual for cockpit talk. Coupled with his use of 'I' and 'you' pronoun forms, the pilot in command regularly used verbs such as 'want' and 'have' (e.g., 'I want X', 'Can I have X'), making further salient his individual roles on this flight as the pilot in command and handling pilot, and the other pilot's individual role as copilot doing actions *for* him (see examples 6.4.4 and 6.4.5).

Also, the pilot in command's wording often included some form of instruction, tutoring or unsolicited advice to the copilot on how, when, or why some activity should or should not be done. These were done in ways that can be heard as directive. The pilot in command's wording also rarely included a politeness or mitigation marker when initiating a task and calling on the copilot to do some activity.[2]

[2] Sometimes the pilot in command said 'thank you' or 'thanks' (e.g., examples 6.4.6 and 6.4.7), but it should not be assumed that these conveyed appreciation. Our comments here are less securely based on existing conversation analysis research, and therefore more tentative, but the interactional impact and meaning of 'thanking' depends greatly on the prosody (i.e., *how* the 'thanking' is said). Certain prosodic patterns can convey appreciation, others mere acknowledgement, and others might even imply sarcasm, complaint or some other action. Appreciation is usually expressed with rise-fall or falling intonation, with the stress and pitch rise early in 'thanks' or on 'thank' in 'thank you', and falling pitch and stress for the end of 'thanks' or on 'you' in 'thank you'. The CVR transcription data of the accident flight showed many departures from this usual pattern, and we hear them as making salient the copilot's role in doing tasks for the pilot in command, tasks that are required of him as the copilot. We hear in the thanking a sense that the copilot was understood to be performing an obligatory duty. The 'thanking', especially when occurring last in the sequence of turns at talk for a task, acted as an acknowledgement that this duty had been done.

Example 6.4.4

	(9.3)
PIC	okay.
	(1.3)
PIC	on number one, (0.5) I want ah::: (1.3) Alice NDB?
	(3.2)
CP	°(alright)°
	(2.9)
PIC	number two I want that one,
	(3.5)
PIC	so we want tha::t, (0.9) and tha::t, (2.5) and that one [( )
	[((static sound))
EAO	*Melbourne control good evening echo alpha oscar posit[ion quebec*
PIC	[that to
EAO	*[two three bravo one zero zero two, (0.5) maintaining flight level three*
PIC	[number one, (0.5) that to number two, (0.4) and that is (0.2) pree::d
EAO	*[f i::ve zero]*
PIC	[up, (0.7) on number two.]
	(0.5)
EAO	*(correct) two three charlie [(0.2)] one zero two seven.*
CP	[okay::.]
	(1.3)

Example 6.4.5

	(0.7)
PIC	can I have? (0.7) an rnav (0.3) fo:::r, (0.2) <an eleven mi:le (.) fi:nal?,>
	(1.1)
PIC	runway one: (.) two:.
	(1.8)
CP	yep,
	(5.8)
PIC	I only want it (.) preed up.
	(0.6)
CP	okay.
	(3.2)

The pilot in command often included an assessment such as ‘that’ll do’ or ‘that’s fine’, presenting himself as an assessor of the copilot’s talk/conduct for a task (see example 6.4.6, and perhaps 6.2.4 earlier).

Example *6.4.6*

	(0.8)
PIC	next one, (0.2) and [the altitude thanks::.]
	[((tone, 1 second))]
CP	thirtyfour fifty I'll put in thirtyfi::[:ve.
PIC	[ye::p.
PIC	that's fine.
	(2.5)
CP	an:::,
	(2.3)

The copilot often responded by performing the called-for activity in silence, as noted earlier, or made only a minimal and non-explicit verbal response such as 'okay' or 'yep'.

Example *6.4.7*

	(4.4)
PIC	'kay thirty mi:les we're tracking to the RNAV position to start the approa:ch:.
CP	okay.
	(1.2)
PIC	so you can put the inbound course up there::.
	(22.8)
PIC	thank you::.
	(5.5)

Example 6.4.8

	(0.9)
CP	complete to pre-landing=
PIC	=okay we're cleared down, we know the traffic so you can <set our steps up tha:nks::.>
CP	okay::.
	(2.9)

Example 6.4.9

	(1.6)
PIC	now the minute we get close to Simpsons gap s- (.) minute we get he::re, (0.6) can you read, (0.5) whatta we gotta be at forty three:?
	(0.3)
CP	yep.
	(0.3)
PIC	okay.
	(0.5)

As we consider the pilots' talk to perform tasks, we are not saying that the aspects exemplified in the examples above are not found in other crews, or that different aspects of communication are not found elsewhere in the talk of this crew. Also, each aspect occurring on its own, or occurring only on occasion, could contribute to quite a different sense of working relationship. However, our suggestion is that these aspects, taken together, and occurring over a substantial period on the CVR for this flight, point to a tendency for tasks to be performed in a way that can emphasise the pilots' different individual statuses and roles, rather than a harmonious collaborative team working relationship.[3]

[3] The difference in status between pilots is often referred to as the trans-cockpit authority gradient. Gradients which are too flat or too steep are generally considered to contribute to less effective crew coordination and communication (Hawkins, 1987).

7 CONCLUSION

Our aim has been to describe the context for a human error, or to consider how an error can be understood as emerging from the immediate working environment as created by the pilots, in the ways in which they communicated and interacted with each other. We used a specific approach to naturally occurring communication and interaction, conversation analysis, to transcribe and analyse CVR data of one aviation accident, involving a commercially operated jet aircraft. We did not focus on the moment of error itself, but instead on the context in which it occurred, or what we have called *an interactional context for error*. We used segments from the CVR data, transcribed in rich detail using notation from conversation analysis, to suggest that aspects of the pilots' interaction show the pilots to be acting according to, emphasising, their individual statuses and roles as pilot in command and copilot, rather than a sense of working collaboratively as a team.

We suggest that such aspects of interaction contribute to a working relationship that can be conducive to an error occurring and not being identified: they can allow for a *collaborative construction of error*. The error that contributed directly to the accident, an incorrectly set minimum descent altitude, can be seen as not the responsibility of one pilot, but at least in part as the outcome of the way the two pilots communicated with one another. We considered the following aspects in particular: the significance of *overlapping talk* (when both pilots spoke at the same time); the copilot's *silence* after talk from the pilot in command; instances when the pilot in command *corrected* (repaired) the copilot's talk or conduct; and lastly, a range of aspects for how the two pilots *communicated to perform routine tasks*. It is significant to note that in pointing to evidence that the pilots' communication was problematic for their work as a team, it was not necessary to rely on analysing instances of overt conflict or communication breakdown. Communicative problems can build up, and be evidenced, over time.

We hope to have demonstrated the value of looking closely at recorded voice data as a means for interpreting human performance, and for interpreting human error in aviation in the light of the world evolving around the pilots at the time (Dekker 2001a), and indeed as the pilots themselves create it. The approach we have used is a way to avoid what Dekker (2001a) calls "disembodying data" when analysing human factors accidents. It can allow systematic and data-based assertions about human action. How one represents data affects greatly what one is able to see in it, and subsequently say about it. Conversation analysis is a micro-approach to the transcription and analysis of naturally occurring interaction, and richly detailed transcriptions using notation of conversation analysis can make maximally visible how pilots themselves develop and understand their respective contributions to interaction and to the work required to operate their aircraft. This paper has shown what kind of analyses and findings conversation analysis transcriptions can make possible.

When analysing recorded voice data, and especially for understanding instances of human error, often a great deal rests on investigators' or analysts' interpretations of what a pilot said, or what was meant by what was said, or how talk was understood, or how the mood in the cockpit or the pilots' working relationship could best be described. Conversation analysis can be a tool for making such interpretations. A particular value of conversation analysis as a qualitative method is that it can be applied to even very small amounts of data, even a single exchange of turns. By drawing on transcription and analytic methods arising from conversation analysis it is possible to eschew attempts to get into people's heads and conjecture what they are thinking and feeling. Actually analysing language in use in aviation, or any other work setting, can involve much more than classifying and counting this or that type of utterance or action. It can involve seeing how language emerges in interaction in context, and serves to create context.

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9 APPENDIX: TRANSCRIPTION NOTATION

The transcription notation used here is adapted from a system originally developed by Gail Jefferson. Recent variations and explanations of the system can be found in Hutchby & Wooffitt (1998), ten Have (1999), or Lerner (2004).

PIC	pilot in command
CP	copilot
ADL	Adelaide control
MELB	Melbourne control
(.)	a micro pause, less than two-tenths of a second
(0.3), (1.4)	pauses represented in seconds and tenths of seconds
bravo one	talk in italics is spoken over the radio
>five<	talk which is noticeably faster than surrounding talk
<five>	talk which is noticeably slower than surrounding talk
five	talk which is noticeably louder than surrounding talk
°five°	talk which is noticeably quieter than surrounding talk
five,	flat or slightly rising pitch, talk which can be heard as incomplete
five.	terminal falling pitch contour
five?	terminal rising pitch contour
fi::ve	rising pitch within word
fi::ve	falling pitch within word
you:.	rise fall pitch
you:.	fall rise pitch
↑five	marked rise in pitch
=	talk which is latched to other talk i.e. follows immediately
[alpha]	talk produced in overlap (simultaneous) with other talk (or noise). ‘[’ indicates beginning of overlap, ‘]’ indicates end of overlap
( )	talk which could not be transcribed
(five)	doubt about the talk transcribed
(now/yeah)	doubt about the talk transcribed, with possible alternatives indicated

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