Human Factors in Risk Communication: Exploring Pilot-Controller 'Communication Awareness'

Abstract

Following the 1977 Tenerife disaster, Billings and Cheaney (1981) concluded that pilots/controllers are not aware enough of the extensive problems involved in transferring information between each other which contribute to miscommunications. Since then, extensive advances have taken place regarding pilot-controller communications, including Crew Resource Management training, improving radiotelephony phraseology, and redesigning English language training/assessment. Despite these measures though, miscommunications still abound with increasing safety risks (e.g. Eurocontrol, 2006a, 2006b; Barshi and Farris, 2013; Bajaj and Majumdar, 2016). Bajaj and Majumdar have raised the question of why there are still so many problems considering the substantial improvements made and surmise that Billings and Cheaney's observation of a lack of awareness being contributory could still be valid. Although occasionally mentioned, this notion has barely received attention in pilot-controller communication studies. Hence, this research aims at establishing a fundamental understanding of communication awareness. Following the review of related work, voice recordings containing miscommunications from an accident flight are analysed to see whether communication awareness is detectable and to establish its impact. As there is no common method for analysing it, Nevile's (2006) conversation analysis method for communication in interaction appears the most feasible one. The results show that communication awareness is identifiable by cues signalling it and contributed to the miscommunications. Training pilots/controllers to be more communicatively aware could therefore reduce the risks miscommunications pose. The insights into communication awareness gained here are transferable to safety-critical communicative situations in other domains.

Keywords: communication awareness, conversation analysis, human factors, pilot-controller communications, risk communication

1. Introduction

Since the Tenerife runway collision in 1977 with 583 fatalities, caused by bad weather and miscommunications, there have been extensive efforts to improve pilot-controller communications through various measures. However, in recent years numerous studies have shown that problems still abound (e.g. Eurocontrol, 2006a, 2006b; IATA *et al.*, 2011; Barshi and Farris, 2013; Bajaj and Majumdar, 2016; CAA, 2017). The British Confidential Human Factors Incident Reporting Programme for Aviation (CHIRP) has recently highlighted this again, underlining that voice communications appear to be here to stay although they are fraught with problems.

> In some senses it is odd that aviation makes so much use of traditional voice communications when considering the weaknesses inherent in such media. Listening out for one's own callsign amid a torrent of messages for other aircraft, frequently delivered in accented English, all competing for attention with other flight deck routines, noises and alerts, isn't the best use of pilots' mental capacity. Can we really not improve on this? In fact, notwithstanding the introduction of Controller Pilot Data Link Communications, the mandating of radios with 8.33 kHz channel separation suggests more, not less, use of this medium. (CHIRP, 2018: 1)

The measures that have been brought in during the past four decades to improve pilot-controller communications cover two main areas: Aviation English (AE) and Crew

Resource Management (CRM). AE can be described as comprising not only the standard radiotelephony phraseology but also the use of plain English in non-standard situations (cf. CAA, 2016a; Estival *et al.*, 2016). Research into AE has largely focussed on two aspects of pilot-controller communications. On the one hand, the focus has been on improving[1] standard radiotelephony phraseology by both pilots and controllers who are native English speakers (NES) and pilots and controllers with English as a second language (EL2), e.g. by reducing message lengths, disambiguating terminology, and so on. On the other hand, raising the level of plain English[2] of both NES and EL2 pilots and controllers has also been of particular interest, as well as improving AE language training, testing and assessment. In addition, in the late 1970s a new training program for flight crews was conceived. CRM is geared towards aiding pilots to make full use of all available resources, e.g. by consulting with all crew, drawing on information from procedures, checklists, instruments, computers, and so on, and by knowing that they as humans have individual strengths and shortcomings (cf. CAA, 2016b). In short, CRM aims at reducing human error and at ensuring safe operations since it is human behaviour and performance in terms of communication, leadership, decision making, teamwork, listening, and so on, that are frequently cited as causal or contributory factors in accidents. As such, CRM comes under the umbrella term of human factors which is the knowledge about human performance at the human-technology interface with a view to providing safety and efficiency, whereby design, training, and procedures are geared towards optimising human performance (CAA, 2002).

It is undisputed that language and communication are ‘human factors’ issues and thus critical components of aircraft operations and aviation safety, resulting in miscommunications often being involved in accidents (e.g. CAA, 2016b). Among the most recent ones are, for example, the Linate runway collision in 2001 (118 deaths), the Gol Transportes Aéreos/Embraer Legacy mid-air collision in 2006 (154 deaths), and the LaMia crash in 2016 (71 deaths). Pilots in particular have commented on how much of an impact communication issues with controllers have on the pilots’ workload and situation awareness, especially during safety-critical phases of flight, which means that more accidents are waiting to happen (Eurocontrol, 2006a; IATA *et al.*, 2011; Bajaj and Majumdar, 2016; CAA, 2017). For instance, communications, among other risk factors, “have been known to be contributors to the risk of runway incursions for more than 30 years” (ALPA, 2007: 8).

It may thus be deduced that the improvements made in CRM training, radiotelephony phraseology, and training/assessing pilots in AE have not had the desired outcome of achieving clear, concise, and effective communication with as few as possible issues of miscommunication. The question that has to be asked is what specifically is it that still allows communication problems between both groups of professionals to continue? To date, except for Billings and Cheaney (1981), no study has made the attempt to ask this question until it was raised again by Bajaj and Majumdar (2016) who have theorised that lacking awareness of the pitfalls of passing on information during pilot-controller communications could indeed be at the root of the miscommunications. This appears to be in line with what was originally pointed out by Billings and Cheaney, who concluded that one of the reasons for the problems between pilots and controllers may be their inadequate awareness of the problematic nature of transferring information (1981: 92-93).

1. This includes “the unnecessary retransmission of simple instructions and information” (CAA, 2016a: 2/2).
2. How to avoid verbose transmissions is also covered (CAA, 2016a).

Not much is therefore known about what constitutes this ‘awareness’ – called **communication awareness** by Bajaj and Majumdar (2016). In the relevant literature it is sometimes referred to but only marginally (e.g. Mathews, 2012; Bieswanger, 2013). Hence, in pilot-controller communications the concept of communication awareness has so far been neglected and should be examined more closely. Consequently, this chapter describes a first attempt at establishing the fundamentals of communication awareness. Furthermore, another reason for examining communication awareness is that communication systems based on automatic speech recognition and neural machine translation as proposed in Bajaj and Majumdar (2016) will not be available for some time. Since “misunderstandings [between pilots and controllers] occur with an alarming frequency” (Barshi and Farris, 2013: 15), it is vital to reduce these in the meantime.

Besides this introduction, there are five further sections. The question of what constitutes communication awareness is addressed in Section 2 by conducting a review of related work. The insights gained will then form the basis for formulating a revised definition. In Section 3, the method chosen for examining communication awareness is described. Section 4 then details the analysis and its results, followed by a discussion of these in Section 5. Section 6 concludes the paper.

2. Related Work

The process of **communication** is complex and is described differently depending on the discipline. Linguists such as Linke *et al.* view communication as rules that have to be observed if the transmission of a message is to be successful (2001: 173). They emphasise that any form of speaking represents a form of action since words result in specific actions. This perlocutionary view of language can be interpreted to mean that it is important for anyone engaging in communication to be aware of the consequences that words can have in terms of resulting actions, as will be seen later. From a psychological perspective, communication is described in terms of its process. For example, in its most basic sense, communication is the process of “when one organism (the transmitter) encodes information into a signal which passes to another organism (the receiver) which decodes the signal and is capable of responding appropriately” (Beattie and Ellis, 2017: 3). From a mathematical position, communication can be seen as the efficient information transfer between a transmitter and a receiver, whereby the focus is on three types of problem that can occur during communication: technical, semantic and effectiveness (Shannon and Weaver, 1998). In contrast to this, experts in human factors, who deal with the mental and physical capabilities and limitations of people when interacting with machines, equipment, and environments, take the approach of looking at the consequences that can arise from communication. For example, Hawkins (2010) is concerned with the interface between human beings and their environment (e.g. their relationship to co-workers) as a potential source for errors. Communication to him is the basis for the development of an interpersonal relationship between two people. Hence, errors can occur if the communication between them goes wrong.

The above descriptions of communication can be seen as valid for any communicative situation, regardless of whether they occur in general or subject-specific settings. Successful communication in the latter setting, however, also depends on specific training to learn the language of a particular field (Crystal, 1998). In the present case this means that both pilots and controllers have to learn the specific radiotelephony phraseology to be able to communicate with each other and undergo radiotelephony exams. This is vital since pilot-controller communications are geared towards attaining "specific operational goals such as ensuring safe and efficient flow of traffic" (Morrow and Rodvold, 1998: 427).

Since miscommunications play a crucial role in this chapter, it is important to look at what can cause them. **Communication barriers** can occur, for instance, if one of the communication partners does not have adequate command of the special language including its terminology used in the field. In terminology science and studies dealing with Languages for Special Purposes (LSP), *vertical* and *horizontal levels* of specialist communication are distinguished (Hoffmann, 1985). The vertical structuring refers to information being exchanged between participants with different levels of expertise and differing command of terminology, e.g. between an instructor and a student pilot. Communication at a horizontal level can occur (a) within a domain whereby experts have the same or similar level of knowledge and terminology, e.g. between two controllers, or (b) across domains with experts at the same knowledge level but the type of knowledge and terminology they share only overlap to a certain degree, e.g. between a pilot and a controller. Coming from the area of psychology of language and communication, Beattie and Ellis (2017: 3-4) address the issue of communication failures differently. They list impediments to successful communication in terms of what could go wrong during the process, e.g. *faulty encoding* (slip of the tongue), *faulty transmission* (overlapping radio calls), *faulty decoding* (mishearing), and a *mismatch between the encoding and decoding process* (mismatch in accent/dialect between transmitter and receiver, or transmitter assumes the receiver has the same knowledge). The above-described communication barriers are compounded in multilingual contexts, for example, in the case of transmissions between EL2 and NES controllers. As will be seen later, lack of communication awareness can also be added here as an obstacle to communication.

What makes pilot-controller communications particularly difficult is the fact that they are almost solely based on **verbal communication** while **non-verbal communication** is hardly involved.[3] The phrase 'hardly involved' is chosen deliberately here because in the relevant literature on pilot-controller communications the argument is usually made that these communications are only verbal (Morrow and Rodvold, 1998: 428-429; Sahliger, 2013: 73) and that non-verbal signals such as gestures and facial expressions are unavailable. However, this is not entirely correct if one takes Beattie and Ellis's view (2017) into account that non-verbal communication signals also include *prosodic* (e.g. high/low pitch, slow/fast speech) and *paralinguistic* elements (e.g. unnaturally long speech pauses, hesitation markers), which are in fact non-verbal elements that are available to both pilots and controllers, as long as they are willing to be aware of them. As will be seen later, some of these non-verbal communication signals will indeed play a salient role in the analysis of the voice recordings.

Pilot-controller communications are a case of **safety-critical** or **risk communication**. The aviation industry, together with the nuclear and healthcare industry, is seen as a high-risk environment (Reason, 2008), which means that pilot-controller communications have to be as faultless as possible since errors could have disastrous consequences. In particular, if a communication error occurs in conjunction with other problems, the likelihood of an accident causation chain, or error chain, being created rises (Reason, 2008; 2009). In cascading crises, this means that if a hazard creates a chain of effects any of these effects can also be seen as a hazard and may

3. In addition to voice communications over the radio, Controller-Pilot Data Link Communications, with which controllers can send messages as text, are also available.

generate more effects (Alexander, 2016). For example, if vital information is not transferred properly due to language barriers, post disaster services following airline crashes might be affected as they rely on efficient communication. Reason, who investigates human error from the perspective of psychology, emphasises that it is rarely a single error from an individual which causes an accident, but it is usually the complex system that is behind the failure (2008; 2009; 2013). This means, for example, that the behaviour of pilots and controllers involved in an accident has to be examined in relation to flight controls, operating procedures, controller-workstation interfaces, and so on. Within this context, Reason recognises **active** and **latent errors** (2009: 173). The consequences of the former show up instantly whereas the latter "whose adverse consequences may lie dormant within the system for a long time, only becom[e] evident when they combine with other factors to breach the system's defences" (Reason, 2009: 173).[4] Active errors tend to be made by what Reason calls 'front-line operators' of a complex system, e.g. pilots, controllers, and engineers, whereas latent errors tend to be made by those who are removed in time and space, e.g. by aircraft system designers, airline managers, regulators, and so on. The reason for mentioning active and latent errors here is that, as will be seen later, although pilots and controllers are the ones who make active errors in their communications, some of them could in fact be down to a latent error in the system. Hence, mitigation measures for safety-critical issues of communication can in turn revolve around enhancement of the systems removed in time and space.

Communication awareness as such is not explicitly referred to in the literature on pilot-controller communications, except for Billings and Cheaney (1981) who, as already mentioned, were among the first to highlight a problem with awareness (see also Grayson and Billings, 1981). Following the Tenerife disaster, they investigated information transfer in the aviation system and concluded their report with remarks that still have validity in view of today's continuing communication issues.

> These and previous studies lead us to conclude that there is a real and present need for better information transfer […]. […]. We conclude that there is insufficient awareness of the pervasive nature of the information transfer problem in its various manifestations, and that this lack of awareness may be in part responsible for nonstandard and inadequate communications practices on the part of both controllers and pilots. (Billings and Cheaney, 1981: 92-93)

Bajaj (1997) has emphasised that "communication barriers highlight […] that it is crucial to increase awareness with respect to the fact that communication difficulties can and do arise. Depending on the situation, experts have to adapt their modes of communication" (1997: 165). If they do not, the consequences could be serious. For example, despite English being the default common language, pilots and controllers are routinely exposed to multilingual situations in which accents, dialects, and the use of local languages in radio communications are "a concern and routinely cause[…] misunderstanding" (IATA *et al.*, 2011: 7-8) and can contribute to accidents. Bajaj, however, does not go into detail about the notion of awareness. Having analysed pilot-controller voice recordings of a mid-air collision using applied linguistic means, Mathews concludes that with one of the crews "a lack of awareness of the applicability of ICAO [International Civil Aviation Organization] language requirements for native speakers" can be detected as can "a lack of awareness of the threats inherent in cross-

4. He refers here to his Latent Failure Model, also called Swiss Cheese Model (2008: 97-98).

cultural and cross-linguistic communications" (2012: 6). She does not go any further into this, except for saying that air accident investigations should include more in-depth language analyses. In contrast, Bieswanger (2013) is more explicit and emphasises that "it is particularly conscious perception and sensitivity in language use that is instrumental in facilitating effective and efficient communication between ATCs [Air Traffic Controllers] and pilots from different linguistic backgrounds" (2013: 15). He goes on to say that the lack of language awareness displayed by both NES pilots and controllers has a definite negative impact on the effectiveness and efficiency of pilot-controller communications. He also laments the fact that they do not acknowledge the need for improved language awareness. It is important to point out though that Bieswanger speaks here of language awareness[5] which, while related to communication awareness, nevertheless differs from it.

However, the notion of communication awareness as such is mentioned in disability communication. Some hospitals publish guidelines to ensure that their staff display communication awareness and undergo appropriate training geared towards people with learning disabilities. Staff is required to be conscious of the fact that such people may have problems with expressing and/or articulating themselves, with comprehending complex sentences and abstract concepts, and so on (e.g. NHS/Ashford and St. Peter's Hospitals, 2014).

Finally, let us now look at how communication awareness can be defined. In Bajaj and Majumdar (2016), the following working definition was put forward.

> It is vital to know exactly the nature of the communication situation we are in, to know what needs to be communicated, how it should be communicated, and when exactly. It also means that we are as fully informed as possible about the other person's communicative environment and that we are *willing* to communicate appropriately. (2016: 306; author's emphasis)

Having looked at the literature, the common features of communication awareness that can be captured are that people (a) need to be able to adapt their modes of communicating, (b) need to know about language requirements, (c) need to know of the threats intrinsic in multilingual and cross-cultural communication, and (d) need to be conscious of and sensitive to language use. Drawing these and all of the above threads together, we can now propose a reworked definition.

> Communication awareness is the conscious and active perception of a given communicative situation in terms of what type of information is to be transferred, to whom, in which manner, at what point in time, and within which time frame. The transmitter of the information knows as much as possible about the receiver's communicative situation and is willing to communicate appropriately employing adequate, attentive, and anticipatory communicative action. This includes being cognizant of each other's proficiency in the language being used for communication. Both the transmitter and receiver are mindful of being part of a team working towards their common goal, which is achieved by efficient and effective communication based on concise and unambiguous information transfer.

5. Language awareness is the "explicit knowledge about language, and conscious perception and sensitivity in language learning, language teaching and language use" (ALA, 2018). There is also the notion of linguistic awareness, which is a learner's knowledge about language by giving thought to and negotiating the language code (Masny, 1997).

3. Method for analysing communication awareness in pilot-controller communications

As already mentioned, this research aims at establishing a fundamental understanding of communication awareness. Having suggested a definition of it, the research question can now be posed: How can communication awareness be identified in pilot-controller communications and what is its impact?

We have seen earlier that communication is a salient human factors concept. Any analysis method therefore ought to reflect this. However, there is no common method with which to identify communication awareness in pilot-controller communications.[6] Current methods for analysing voice communications tend to belong to two types, i.e. speech analysis and coding of speech acts (Nevile and Walker, 2005). The former ignores the communication interaction between individuals, and the latter is restricted in terms of being able to uncover how the communication occurred despite this being vital for re-creating the correct context for the communication. Hence, in order to capture communication awareness a more appropriate method is required. Conversation analysis offers an approach to investigating communication as language in interaction. According to Nevile and Walker, it "shows in micro-detail how naturally occurring interaction is sequentially ordered and collaboratively produced and understood by participants, moment-to-moment" (2005: 3), e.g. *speaker turns, overlapping talk, prosody, length of silences*, and so on, are examined.

Conversation analysis was for the first time considered as a potential qualitative investigation method for analysing voice communications by the Australian Bureau of Air Safety Investigation in 1995 following an accident when they assessed various methods. It was concluded that "the conversation analysis method provided a very useful approach to identify, describe, demonstrate and explain difficulties in conversation between two or more individuals" (Nevile and Walker, 2005: v).

Since it is well-known that prosodic features such as *rising pitch*, *speaking faster*, and so on, can indicate stress and heavy workload, it is reasonable to assume that certain conversation features could also signal a lack of communication awareness. As a result, given the exploratory nature of this research, the conversation analysis method is deemed feasible. In addition, Nevile and Walker (2005) mention that this method is suitable for small datasets. Unlike Nevile and Walker though who included intra-cockpit communications, this research does not. The data analysis focused solely on communication awareness while awareness of technical difficulties or of issues other than those to do with communication is not examined here.

The materials used consisted of a recording of voice communications from an accident flight and the respective transcript. Transcripts, which form part of published air accident reports, are in the public domain as is the recording used for this research. The selection of the accident had to fulfil three criteria: (1) the voice communications had to include miscommunications that were considered contributory to the accident; (2) the recording of the voice communications had to be available for analysis; and (3) the original transcript of the recording could be obtained. Finding accidents fulfilling criterion (1) was unproblematic. However, finding accidents that satisfied both criteria

6. Investigators from both the US-American National Transportation Safety Board (NTSB) and the British Air Accident Investigation Branch (AAIB) confirmed that no investigative methods which include human factors are used for pilot-controller communications (Personal communications with a retired NTSB investigator, May 2018, and an active AAIB inspector, July 2018). However, investigators seem to be aware that "changes in operator vocalizations, potentially reveal […] much about operator performance (Strauch, 2004: 128).

(2) and (3) proved difficult since permission to use recordings from more recent accidents needed to be sought from the relevant authorities, neither of which could be received in time for inclusion in this research. Hence, the selection had to be made on the basis of what was available online. As a result, the accident chosen for this analysis that fulfilled the above criteria was Avianca Airlines Flight 052[7] in 1990. Regarding the datedness of this accident's data, it needs to be borne in mind that communication awareness in pilot-controller communications has not been investigated yet and, as will be recalled, improvements and training have focused on standard phraseology, CRM, and AE learning/testing.

In contrast to typical 'cockpit voice recorder'[8] (CVR) transcripts which contain only text and normally no punctuation, a transcription carried out with conversation analysis techniques contains much more detail. The advantages of such a transcription are, for example, that silences are made visible by timing them, that rises and falls in pitch can be shown, that it is indicated if some words are spoken loudly, quietly, fast, or slow, and that some of the speaking is lengthened, repeated, or cut off. Any of these features could be useful in signalling a lack of communication awareness. In order to mark such features in text a specific notation was used, part of which can be seen below the analysis text in Section 4. The full notation is found in Nevile (2006: 15-16).

Using the above materials, both of which were analysed manually by one coder[9], the procedure for the analysis of the voice recordings involved the following steps.

(1) If the selected recording and corresponding original transcript did not match in terms of what was covered by them, they had to be matched to ensure that the written version was an exact copy of the spoken version. This meant that the transcript had to be edited manually. Once this was completed the conversation analysis transcription could start.
(2) Using the conversation analysis notation, the recording was then listened to with the aim of (a) marking speaker turns, (b) determining turn sequences, (c) noting silences and how long they are, and (d) identifying the manner of speech (e.g. pitch changes, speed, sound changes, cut-off words, repetitions, quality of voices, laughter). In order to be able to identify each feature it was necessary to focus on just one of them during each listening run, as advised by Nevile (2006). As a result, the recording was listened to for more than 33 times as there are 33 items in Nevile's notation, including several runs in the beginning to hear the recording in its entirety.

4. Results

Pilot-controller communications follow a prescribed structure in which either the pilot or the controller begins an exchange. For example, if the controller starts by giving an instruction, the pilot must read back the message, either completely or an appropriate part of it, and then receives a reply acknowledging or correcting it. For the Avianca accident the complete transcript of the pilot-controller exchanges forms part of the

7. Near New York, Avianca's pilot advised ATC of their low fuel state. After a missed approach, the aircrafts' engines shut down during the subsequent approach and it impacted on a hillside. "[T]he probable cause […] was the failure of the flightcrew to adequately manage the airplane's fuel load, and their failure to communicate an emergency fuel situation to air traffic control before fuel exhaustion occurred" (NTSB, 1991: v).
8. CVRs record the audio signals of pilots' microphones and earphones on their headsets and the signals of an area microphone on the flight deck. The recordings cover the last 30 to 120 min (Skybrary, 2019).
9. The coder was the author herself, who has an EASA Private Pilot licence and is training for a Commercial Pilot licence.

official accident report published by the National Transportation Safety Board (NTSB, 1991). These exchanges were in English and did not include any intra-cockpit conversations, which were held mostly in Spanish, as will be seen later. A recording[10] could be located online which, however, was incomplete since only parts of the exchanges were available and they were not consecutive. Hence, the analysis could only focus on the extracts of the transcript that corresponded to the recorded exchanges. The NTSB transcript was adjusted accordingly.

It should be emphasised that apart from the general synopsis of the accident report, the coder had deliberately not read the report. This was deemed important to avoid hindsight bias since knowing too many details about an accident is likely to influence the way past events are examined (Reason, 2009: 215). The idea was to base the analysis of communication awareness only on the radio exchanges since pilots and controllers only have each other's voices at their disposal during their communications.

The results of the analysis of Avianca's recording using Nevile's notation (2016: 15-16) are shown below. Given the aim to reveal communication awareness, however, the notation needed to include emotions and physical states. Since Nevile does not provide a symbol for these it was decided to use curly brackets for them. To facilitate the presentation of the results and ensuing discussion the transcript's lines were numbered.

Line	**Time**	**Source**	**Content**
(1)	2125:02	FV	>Avianca zero five two heavy New York good evening. climb 'n' maintain
(2)			three thousand<
(3)			(0.8)
(4)	2125:07	AVA052	Climb and maintain three thou::sand? and uh:: (.) {we'::re ↑>running?< out
(5)			of? fuel} {enthusiastic, cheery} sir
(6)			(0.6)
(7)	2125:14	FV	<Okay:> ah fly heading of zero eight zero
(8)	2126:36	FV	And Avianca zero five two heavy? ah::: I'm going to bring you about fifteen
(9)			miles northeast and then turn you back onto the approach. (0.3) is that fine
(10)			with you and your fuel?
(11)			(1.3)
(12)	2126:41	AVA052	{↑<°I. ↓guess. ↓ so°>. thank. ↓you. ↓very much.{resigned}
(13)			(1.8)
(14)	2130:36	FV	Avianca fifty two climb and maintain three thousand
(15)	2130:40	AVA052	{Ah ne::gative sir}{cheeriness} we-:: (.) {<we're just:: (0.4) ↑running ↓out.
(16)			↓of fuel>.}{resigned} (0.6) we:: ok::ay {three¿ thousand now we could,}
(17)			{cheery}
(18)			(.)
(19)	2130:44	FV	Okay turn left heading three one zero (0.3) °sir°.
(20)			(.)
(21)	2130:46	AVA052	{Three. one. zero. thank. you. very. much sir.} {resigned}
(22)	2132:51	AVA052	Avianca zero five two we just ah:: lost ↑ two engines and ah we need priority
(23)			please
(24)			(.)
(25)	2132:56	FV	>Avianca zero five two turn left heading two five zero intercept the
(26)			localizer<.
(27)			(0.8)
(28)	2133:00	AVA052	{↓Roger.}{resigned}

Transcription notation

FV	New York TRACON Final Vector
AVA052	Avianca Airlines Flight 052
(0.3), (1.4)	Silences in seconds and tenths of seconds **NB:** Since the original recording with timestamps was unavailable, a digital stopwatch was used for determining the length of silences. However, this was by no means an accurate exercise, but it was deemed sufficient for the purposes of the present analysis.

10. https://www.youtube.com/watch?v=ie8kLg9Xvd8

(.)	Micro pause, less than two tenths of a second
>five<	Talk which is noticeably faster than surrounding talk
<five>	Talk which is noticeably slower than surrounding talk
five	Talk which is significantly louder than surrounding talk
°five°	Talk which is noticeably quieter than surrounding talk
fi::::ve	Stretching or lengthening of a sound, the more colons the longer the sound
fi-	Word or sound that is cut off, begun but not completed
five,	Flat or slightly rising pitch, talk which can be heard as incomplete
five?	Terminal rising pitch
five¿	Less marked terminal rising pitch
five.	Terminal falling pitch
fi::ve	Rising pitch within word
fi::ve	Falling pitch within word
↑five	Marked rise in pitch
↓five	Marked fall in pitch
{ }	Words displaying emotions and physical states

The first exchange (lines 1 to 7)

The controller instructed the pilot[11] to climb to and maintain the altitude of 3000 feet. The pilot read back the instruction and informed the controller that they were running out of fuel. However, the pilot did not use the standard phrases *minimum fuel advisory* or *Mayday Mayday Mayday* for indicating a low or very low fuel state respectively, and the controller was thus unaware of an emergency situation developing or being present. Hence, he gave them only a heading change, which the pilot did not read back. The conversation analysis revealed that the controller's manner of speaking is fast, fluent, and monotonous. In contrast, the pilot's reply is slower and his manner of speaking quickly becomes as what may be described as melodic as he utters the word *thousand* with a pitch rise at the end. He links his second message with the conjunction *and* but this is followed by the hesitation marker *uh* which can be a cue for some problem developing (Nevile, 2006: 22). Indeed, *uh* introduces the message that they are running out of fuel. However, the pilot's voice does not convey any concern or panic. In fact, his voice betrays the urgency of the situation since his intonation makes him sound cheery. It can thus be argued that the pilot's lack of communication awareness, signalled by incorrect terminology and a contradictory tone of voice, resulted in the controller being unable to develop appropriate situation and communication awareness. His lack of awareness is shown by his unalarmed response of giving a heading change and a weak acknowledgement of the running-out-of-fuel message with the word *okay*.

To sum up, the following features may be seen as cues for a lack of communication awareness:

(1) The hesitation marker *uh* may signal that the speaker is having problems to find the right words for a message or the speaker wants to convey a problem.

(2) The use of a positive emotion in a speaker's voice to convey a message with a negative meaning could be a cue that communication awareness is not present.

(3) The short silence between the pilot's reply and the controller's response indicates that the controller likely did not give the running-out-of-fuel message much thought.

The second exchange (lines 8 to13)

By telling the pilot that he would have to fly 15 nm to the north-east before being routed back onto the approach path and asking him whether this was ok, the controller acknowledged the low fuel issue. Yet, the routing instruction shows that he was unaware of the severity of the fuel problem. As a result, the pilot's reply was one of resignation, signalled by a resigned tone of voice, falling pitch, and slower speech. This

11. It is usually the 'pilot not flying' who does the radio communications.

change of tone went unnoticed by the controller, but the resignation in the pilot's voice could have alerted him to the fuel situation being more problematic given the fact that ca. 90 seconds earlier the pilot had sounded cheery. In this exchange the controller exhibits some degree of communication awareness since he asked if the routing was ok with them and their fuel state. In contrast, although there was a period of silence before his reply, the pilot displays a complete lack of communication awareness by not declaring an emergency.

To recap, the following features were identified as potential cues for a lack of communication awareness:

(1) A message spoken in a resigned tone of voice, falling pitch, and slower speech rate, could be a cue for the receiver that something is wrong at the speaker's end.
(2) Slightly longer silences indicate a delay which could be a cue for a problem the speaker has and is trying to communicate.

The third exchange (lines 14 to 21)

Again, the controller instructed the pilot to climb to and maintain 3000 feet. This shows that although he seemed to be aware of the running-out-of-fuel problem he was clearly not aware of its gravity. Climbing to a higher altitude requires considerably more fuel than maintaining an altitude. The pilot's response started with an initially cheery negation to this instruction but as he continued his voice began to sound resigned again, signalled by falling pitch. After the negation the pilot cut off and restarted his utterance by using *we-... we're*. The question is why might he have done this? Perhaps he remembered that he had used almost the exact sentence during the first exchange and that this had no effect. The cut-off could then mean that he briefly considered using a different choice of words to get through to the controller that they were severely low on fuel. The pilot though used the same sentence again, which was then followed by a further utterance in a cheerier voice that they could climb to 3000 feet after all. However, he did not say this grammatically correctly; he took one direction, and then another, and repeated some words, which could signal that he was not overly happy to do this. The pilot then received a heading change and acknowledged this, even saying thank you. The pilot's resigned tone of voice during his first reply in this exchange again went unnoticed by the controller, which could have alerted him to a problematic situation, particularly given the fact that a couple of minutes earlier the pilot had already sounded resigned. In this exchange the controller demonstrates a clear lack of situation and communication awareness since he asked the pilot to climb although this meant higher fuel usage. The pilot also exhibits a complete lack of communication awareness by still not declaring an emergency (they had ca. three minutes of fuel left).

The features in this exchange that could be seen as cues for a lack of communication awareness are as follows:

(1) A positive emotion by speakers in their voice to convey a negative message could be a cue that communication awareness is not present at the speaker's end.
(2) Using cut-offs and restarts could indicate that a speaker is rethinking what and how s/he is going to say something, signalling a lack of communication awareness.

The fourth exchange (lines 22 to 28)

This exchange is initiated by the pilot who advises the controller that they lost two engines and need priority. Such a situation is a clear emergency and he should have used the standard radiotelephony phrase *Mayday Mayday Mayday*. Except for a rise in pitch and a louder pronunciation of the word *two*, the pilot's voice sounded calm and without urgency when telling the controller about the engines. Despite the emergency the pilot still finished his message with *please*. This politeness marker can be added to make requests sound polite, but it could also express urgency and emotion. Quirk *et al.* (1994: 571) describe *please* as "the sole carrier of the intonation nucleus [that] conveys not merely emphasis but some urgency, insistence, or annoyance". In the latter three cases, they say that *please* can be either in the starting or final position. Nevertheless, standard radiotelephony phraseology specifically excludes the use of politeness markers to keep transmissions short. It can be foreshadowed that the co-pilot, who made the transmissions, was a non-native speaker of English, which may explain his incorrect use of *please* in a high-stress situation. It is a well-known psychological phenomenon that people may revert back to 'old behaviour' under stress (Reason, 1988), e.g. to what they know best or have learnt first.

Nevertheless, the pilot did not declare an emergency which signals a total lack of communication awareness. The controller's response did not overtly acknowledge the emergency, but he spoke noticeably faster, which appears to indicate communication awareness, and gave him instructions to expedite the approach. The pilot's acknowledgement sounded resigned (there was one minute of fuel left).

In short, the features below may be seen as potential cues for a lack of communication awareness:

(1) A rise in pitch as well as louder talk, both of which indicate emphasis, can be cues for the receiver that the speaker is trying to convey something of importance.
(2) The resignation in a voice can be a cue for the receiver that something is wrong.

5. Discussion

The typical CVR transcripts tend to contain little or no punctuation and only highlight unintelligible words. In contrast, conversation analysis takes a microscopic view of the communicative interactions between pilots and controllers. Using typographical symbols, this method makes the pilot-controller interaction explicitly visible in terms of what has been said and how, thereby allowing the analyst to identify potential reasons for errors made rather than just pointing out the error. Conversation analysis can thus help in shedding light on human performance and error during communications.

It has been mentioned earlier that the analysis was carried out without much background knowledge of the accident to avoid hindsight bias which could have affected the determination of what exactly indicates a lack of communication awareness. Therefore, some of the results may appear to be basic and incomplete as, for example, at the time of analysis the coder did not know that it was the co-pilot who was making the transmissions. The coder only became aware of this when reading the NTSB report following the analysis and of the fact that the co-pilot translated the controllers' instructions into Spanish for the captain (1991: 2), albeit mostly in abridged form. For example, the last instruction *Avianca zero five two turn left heading two five zero intercept the localizer* was translated as *dos cinco cero*. The reasons why he translated the controller's messages into Spanish are not explained in the NTSB report but are probably down to the fact that the captain, as the 'pilot flying', was overloaded and had no capacity to listen to the controller's messages. The captain had likely flown the Boeing 707 manually all the way from Bogotá to New York as its flight director[12] was unserviceable and he must have been under severe stress due to the fuel running out. Also, although the captain had passed his last line check only four months before the accident where communication in English was part of the check, the NTSB report states that the "captain, with limited English language skills, was dependent on the nonflying

12. The flight director forms part of the navigation and control system.

[*sic*] co-pilot to communicate with ATC. […]. Additionally, the captain asked the co-pilot to speak louder. These events are all signs of fatigue and adverse stress" (1991: 16). While it is not unusual for pilots to have cockpit conversations in their native language, it is certainly uncommon to translate controller messages into one's own language. As will be recalled, the Spanish translations could not be heard on the recording that was available for analysis as they concerned intra-cockpit conversations, which were not part of the analysis.

The above alone may explain the intense workload and stress not only the captain but also the co-pilot were under which could have contributed to the co-pilot's fatal omission of declaring an emergency. The co-pilot's extreme workload and stress might also explain his cheery sounding running-out-of-fuel messages since pilots often try to sound as calm and unconcerned as possible when facing serious situations but might inadvertently go over the top in doing so.[13] Since the aim of this research was to establish whether or not communication awareness between pilots and controllers was present, it was hence important to do the analysis only by listening to the recordings because, for instance, the New York controller dealing with Avianca did not possess the above information either and could only act on what he heard over the radio.

The analysis results of this exploratory research indicate that it was possible to detect a lack of communication awareness in the four exchanges between the controller and the pilot. As the crash of Avianca 052 proves, the impact of communication awareness not being present can have fatal consequences. Several cues that have the potential of signalling a lack of communication awareness could be revealed. It can be seen among the results that the cues identified have either occurred on their own, e.g. *resigned voice*, or several have occurred together within a speaker's turn, e.g. *pitch rise* and *louder voice*. This raises the question of whether more cues in a message have the potential of increasing a receiver's communication awareness.

In evaluating the cues as potential signals for a lack of communication awareness, it has to be mentioned again that the pilots of Avianca 052 were non-native speakers of English and that the element of culture likely played a role during the communications. It is also necessary to highlight that the accident happened 29 years ago when different types of generational behaviour prevailed in that professional environment. All these considerations add to the inherent complexity of the notion of communication awareness.

From the analysis, it shows that what speakers say, how they say it, and at what time can have a profound effect on the other participants in terms of their response and actions. For example, this was the case during the first exchange where the pilot's use of incorrect terminology and contradictory tone of voice resulted in the controller being unable to develop appropriate situation and communication awareness. Words alone cannot always guarantee that the correct information is transferred, particularly if situationally inappropriate words are chosen, as was the case with the running-out-of-fuel messages. The pilot's sentence did not convey the meaning intended since the controller only understood that they were low on fuel. By simply hearing the words that have a specific meaning the controller could not deduce what was really going on. Had he, however, been sensitised to and conscious of information transfer issues, he might have caught the cues in the pilot's voice and manner of speaking that something much worse was going on. It is therefore likely that communication awareness in pilots and controllers could be improved with specific human factors training. Moreover, it is

13. Personal communication with a long-haul training captain of a major British airline (March 2019).

imperative for pilots and controllers to consistently remind themselves to remain communicatively aware during radiotelephony communications.

In this context it is important to note that pilots and controllers ought to be aware of the fact that they form a team and should act with the joint goal of conducting a safe flight. Here, Billings and Cheaney words should be remembered.

> Complacency is not widespread in reports of information transfer failures, but it can be a serious problem when it **is** present. We urge controllers and pilots alike to be aware of its insidious nature and of the marked decrements in perceptivity and thinking that it can cause. The system does ***not*** always work, and the only protection against potential disaster when it fails is alertness and forethought regarding alternative ways of accomplishing the objective. (1981: 92; authors' emphases)

Returning to the topic of errors, the fact that the pilot's use of incorrect terminology caused the controller's lack of communication awareness could be seen as a latent error in the system since the NTSB report criticised the Federal Aviation Authority as the regulator for not having provided "standardized and understandable terminology for pilots and controllers for minimum and emergency fuel states" (1991: v).

Finally, the limitations of this research are in its size. As it was exploratory research, the results are and can only be considered as indicative and need to be confirmed statistically through larger analyses. Also, further coders would enable more objective results, i.e. coding reliability, and the complete original CVR recordings should be available for analysis. Nevertheless, the analysis of the communicative patterns suggests that the method has potential to make very targeted and specific recommendations.

6. Conclusions

It is undisputed that language and communication are critical for aircraft operations and aviation safety, which has led to communication problems often being cited as contributors to accidents. It is hoped that the analysis of communication awareness carried out here is a step towards identifying a systematic method to gain better understanding of it. Such understanding has to aim towards ultimately improving the levels of communication awareness and diminish the communicative problems. The insights gained here are transferable to safety-critical communicative situations in other domains.

The results show that in the communications that were analysed it was possible to identify cues relating to language and the manner of speaking that have the potential to signal a lack of communication awareness. Such cues are, for example, *a resigned tone of voice*, *louder talk*, *falling/rising pitch*, *faster/slower talk*, and so on. It was also shown that a lack of communication awareness contributed to the miscommunications that had occurred.

Despite the necessity to carry out more analyses of pilot-controller exchanges to confirm such cues and to identify others, the fact that it was possible to identify some of them in the first place allows us to start thinking about potential training methods to improve communication awareness among pilots and controllers. Future work will also investigate devising a semi-automatic tool based on existing speech analysis software for carrying out analyses of cockpit voice recorder communications. Such an approach should not only speed up the analyses but may also allow the development of an investigative method for accident investigations.

Given that effective risk communication is salient in terms of disaster prevention management particularly in multilingual environments, it is hoped that the insights into communication awareness gained here will aid in breaking down the language and communication barriers in such multi-language settings.

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