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# Aviation English

## A lingua franca for pilots and air traffic controllers

Dominique Estival, Candace Farris and Brett Molesworth

Routledge

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*Aviation English* investigates the key issues related to the use of English for the purpose of communication in aviation, and analyses the current research on language training, testing, and assessment in the area of Aviation English. Based on a series of recent empirical studies in aviation communication and taking an interdisciplinary approach, this book:

- provides a description of Aviation English from a linguistic perspective;
- lays the foundation for increased focus in the area of Aviation English and its assessment in the form of English Language Proficiency (ELP) tests; and
- critically assesses recent empirical research in the domain.

This book makes an important contribution to the development of the field of Aviation English and will be of interest to researchers in the areas of applied linguistics, TESOL, English for Specific Purposes, and aviation human factors.

**Dominique Estival** is a researcher at the MARCS Institute, Western Sydney University, Australia, and a flight instructor. She investigates the impact of pilot training and language background on pilots' ability to follow ICAO regulations for radio communication.

**Candace Farris** is a doctoral candidate at McGill University, Montreal, Canada. She investigates controller–pilot interactions and language testing policy in the global aviation context. She is co-author of the book *Misunderstandings in ATC Communication: Language, Cognition and Experimental Methodology*.

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Professor Tim McNamara, *University of Melbourne, Australia*

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# Preface

This book is the product of three disciplinary perspectives on aviation communication. We are fortunate to be able to collaborate with each other and to combine our differing areas of expertise, thus offering complementary perspectives from the disciplines of linguistics and applied linguistics, human factors and language testing. In order to give the reader an idea of the lenses through which we examine the phenomenon of Aviation English, it is worth providing a brief description of our individual trajectories and how this collaboration came about. Dominique Estival and Brett Molesworth are both pilots, with commercial pilot licences. Dominique is a linguist, with a background in theoretical linguistics, more specifically syntax and computational linguistics, and she is also a flight instructor. Brett is a psychologist, specializing in human factors, who lectures in the School of Aviation at the University of New South Wales (UNSW) Australia. Dominique was one of the subjects in one of Brett's early studies of factors impacting on pilot performance and they started a collaboration to study the effect of the use of a second language on miscommunication in aviation from the perspectives of human factors and linguistics. Candace Farris is an applied linguist, language tester and currently a doctoral candidate at McGill University in Montreal, Canada. Dominique and Candace met when they both participated in the Featured Colloquium at the American Association of Applied Linguistics (AAAL) meeting, entitled 'Language tests and language policy: The case of aviation English' (Boston, 24–7 March 2012), organised by Tim McNamara. Quite independently, the design of Candace's earlier experiments had inspired the design of Dominique and Brett's flight simulator experiments.

In the conceptualization phase of this book, the title *Aviation English: A lingua franca for pilots and controllers* immediately appealed to us. Once we started writing the book, however, it became necessary to clearly articulate what we meant by 'Aviation English as a lingua franca' and we spent quite a lot of time thinking and talking about what this means to each of us and what Aviation English actually is. There were many discussions and debates, as well as questions raised. Is Aviation English a unique language, quite separate from English? Or is it English being used for a specific purpose? Is it English being used as a lingua franca? What counts as a lingua franca? Is English the lingua franca of aviation? What is the relationship between English as a lingua franca (ELF) and Aviation English? What is the difference between English for specific purposes (ESP) and ELF? Is the language of controller-pilot communications a cross-linguistic register, similar to legalese or medical discourse? What would it mean to say that a native speaker of English is a native speaker of Aviation English?

These conversations sometimes went in circles, but eventually they did bear fruit and showed us that Aviation English is more complex than we had initially thought and that it may be conceptualized and investigated from a variety of perspectives. This is an important point in relation to the applied linguistics communities of research and practice: Aviation English can be conceptualized as a lingua franca, as involving the use of English as a lingua franca, as English being used for a specific purpose and as a cross-linguistic register; all of these perspectives are legitimate, depending on the context of research or practice. We hope the responses we propose to the above questions throughout the book show the complexity of the issues involved. Our purpose here is not to provide definitions of ELF or ESP, nor definite answers to all these questions, but to explore the nature of Aviation English and to describe it from our three disciplinary perspectives. This book does not pretend to exhaust all the issues associated with either aviation communication or Aviation English (in particular, we do not attempt to evaluate or analyse current Aviation English teaching courses or material), but to provide the readers with the background necessary to understand the issues and to present some recent research which contributes to our understanding.

Candace investigates controller-pilot communications from a socio-cognitive theoretical perspective, according to which performance may vary based on social and other factors present in the context of communication. She advocates for the consideration of such factors in training and assessment designed in relation to language for specific purposes, and investigates the relationship between these factors and a context-independent construct of language proficiency in communicative performance. She was a member of the International Language Testing Association (ILTA) Aviation English Task Force, and continues to represent ILTA at the International Civil Aviation Organization (ICAO).

Brett investigates the factors that contribute to miscommunication from the perspective of the human (i.e., operator) such as: education, training, experience, design, stressors (fatigue, workload, and noise), drugs (illegal and legal), equipment (e.g., headphone quality), transmission quality, personality, and even other personnel such as air traffic controllers (ATC) or other pilots. He places Aviation English in the design category and investigates whether the language has been designed adequately for simple and easy use. As a general aviation pilot he has first-hand experience of the challenges pilots face, including communicating in aviation while performing the multitude of other tasks necessary for safe flight. Brett also lectures in the area of Human Factors in the School of Aviation at UNSW Australia and conducts research in this area, which gives him first-hand experience of the challenges native English (NES) and second language (EL2) pilots face, in terms of communicating in aviation.

Dominique is interested in the formal description of Aviation English as a language variety and in the deviations from the mandated phraseology due to contextual factors in actual practice. She investigates the impact of pilot training as well as of language background on the ability of pilots to follow the ICAO recommendations. As a flight instructor, she has first-hand experience of the difficulties student pilots, both native and second language speakers of English, experience with radio communication.

The three of us reviewed and discussed each other's chapters and, although our different trajectories and backgrounds meant we had different interpretations for certain terms and put different emphasis on certain concepts, we hope we managed to find a unified voice throughout the book, while retaining our individual voices and perspectives in the individual chapters.

These strands are woven together in this book and our different perspectives on Aviation English converge in the belief that effective communication is of paramount importance in the global aviation context, and that all interlocutors, regardless of their native language, share the responsibility of ensuring the success of air traffic controller–pilot communications in the global aviation context. In this regard, we have much in common with the studies in English as a lingua franca, according to which English may be regarded as a vehicular language, and although it may have native speakers, the effective use of English as a lingua franca requires that all interlocutors adjust, accommodate or adapt to the needs and abilities of the people with whom they are communicating.

We want to thank the many people who have helped us along the way. Thanks to Denis Burnham for his help and advice regarding Dominique and Brett's project proposals. Thanks to the MARCS Institute for the flight simulator used for the experiments conducted at the University of New South Wales, which is now having a second life in cadet training at the Australian Air League at Camden. Thanks to Alastair Pennycook for many discussions clarifying some difficult concepts and for organising the writing retreat during which Chapter 2 took shape. Thanks to David Maddock, chief flying instructor (CFI) at Gostner Aviation, for recording the ATC calls serving as stimuli in the flight simulator experiments described in Chapter 7. Thanks to all the CFIs in the Sydney Basin who allowed us to recruit participants in their flight training organisations, to all the pilots who participated in the studies and experiments reported in Chapter 7, and to the pilots and the air traffic controllers who provided the examples illustrating Chapter 2. Thanks to Carolyn Turner and Immanuel Barshi, whose mentorship over the years has contributed to the development of Candace's research agenda and her involvement with the aviation communication and language testing communities of research and practice. Thanks to Tim McNamara for inviting Candace and Dominique to the AAAL colloquium where they met. Thanks to the audiences at the various conferences, seminars and workshops where some of this work was presented and whose comments and questions helped shape the research and our thinking. Finally, thanks to Brian Paltridge and Sue Starfield for their encouragement and constructive comments throughout the process of writing this book and for inviting us to write it in the first place; this book would not exist without them.

# Abbreviations

| | |
|---|---|
| AE | Aviation English |
| AECT | Aviation English Competency Test |
| AELTS | Aviation English Language Test Service |
| AEPT | Aviation English Proficiency Test |
| ALPT | Aviation Language Proficiency Test |
| ATC | Air Traffic Control |
| ATIS | Automated Aerodrome Information Service |
| ATO | Approved Training Officer |
| ATPL | Air Transport Pilot Licence |
| AV052 | Avianca 052 |
| BAC | Blood Alcohol Concentration |
| BCAA | Bahamas Civil Aviation Authority |
| CA | Conversation Analysis |
| CAA | Civil Aviation Authority |
| CAAS | Civil Aviation Authority of Singapore |
| CASA | Civil Aviation Safety Authority (of Australia) |
| CPL | Commercial Pilot Licence |
| CTA | Controlled Airspace |
| dB | Decibel |
| EL2 | English as a Second Language |
| ELF | English as a Lingua Franca |
| ELPAC | English Language Proficiency for Aeronautical Communication |
| ESP | English for Specific Purposes |
| FAQ | Frequently Asked Questions |
| GA | General Aviation (i.e. not Military nor RPT) |
| ICAO | International Civil Aviation Organization |
| IFR | Instrument Flight Rules |
| LPR | Language Proficiency Requirements |
| NES | Native English Speaker |

| | |
|---|---|
| OCTA | Outside Controlled Airspace |
| PPL | Private Pilot Licence |
| QNH | Query No Height (barometric setting for altimeter) |
| RELTA | RMIT English Language Test for Aviation |
| RPT | Regular Public Transport |
| RT or (R/T) | Radiotelephony |
| TC | Transport Canada |
| TSP | Test Service Provider |
| UTC | Universal Time Coordinate (also known as Greenwich Mean Time or GMT) |
| VAET | Versant Aviation English Test |
| VFR | Visual Flight Rules |

Chapter 1

# Aviation English as a lingua franca

*Dominique Estival and Candace Farris*

As the title of this book is *Aviation English: A lingua franca for pilots and air traffic controllers*, we will begin by explaining what we mean by 'Aviation English' and by 'lingua franca' in the aviation context. The focus of our discussions throughout this book is on communications that take place between air traffic controllers and pilots. Such communications are conducted primarily in a very restricted variety of English, namely Aviation English (AE) which has been designed for this specific purpose. We need to emphasize, however, that English is not the only language of communication between air traffic controllers and pilots, and the International Civil Aviation Organization (ICAO) policy regarding languages to be used in aviation radiotelephony is discussed at length in Chapter 3. Although our primary focus here is on Aviation English as the lingua franca (a working language) in communications between air traffic controllers and pilots, this is not the only communication loop in the aviation context: important communications also take place between and among crew members in and beyond the cockpit: at air traffic control centres, controllers are often required to communicate with one another and with controllers at other centres; on the ground, aircraft maintenance staff must communicate among themselves and sometimes with the flight crew in the cockpit. A number of regulations and policies, either mandated (via the national Aeronautical Information Publications, or AIP) or internal to the various organisations (such as airlines, flight training schools or maintenance companies) define and constrain the language all these aviation personnel must use and how they must communicate. This makes Aviation English different from other varieties of English for specific purposes, in that it is mandated by law and heavily regulated.

We make a distinction here between English as a lingua franca (ELF) and Aviation English, which is a lingua franca and a variety of English, but is not ELF. ELF is a much broader construct, which covers many more contexts, situations and speakers than Aviation English, and is not a stable variety (see Canagarajah, 2013, for a recent discussion of the history of the concept of ELF). Aviation English is a lingua franca, i.e. a working language, but a relatively stable variety. As pointed out by Barbara Seidlhofer at the annual conference of the American Association for Applied Linguistics in 2012, it could be argued that Aviation English has no native speakers, in that it is a speech variety that must be learned even by native speakers of English. In that respect, it would fit the original meaning of 'lingua franca', a language used by speakers who have no common language (see Pennycook, 2012, for discussion of the meaning of the term). Furthermore, like other languages for specific purposes, it has a restricted domain, and is only used for the specific purpose of communication in the aviation environment.[1]

ELF often refers to the use of English as a common language between non-native speakers of English, and this is of course an important use of English as a lingua franca (see e.g. Seidlhofer, 2009). An expanded view of English as a lingua franca, however, also includes all combinations of native English speakers (NES) and non-native speakers of English (EL2), i.e. EL2–EL2, NES–NES and EL2–NES. This is certainly also the case for Aviation English. This expanded view of lingua franca that includes native speakers is not a new concept in applied linguistics. For example, as early as in the second edition of the *Longman Dictionary of Language Teaching and Applied Linguistics* (Richards et al., 1992), the definition of the term states that a lingua franca may have native speakers.[2] We conceptualize Aviation English as being a language for a specific purpose, used by both native and non-native speakers of English who communicate with each other in a context where English is the working language, although a second language for many. We discuss the role of NES in aviation communication from the point of view of the requirement that they, as well as EL2, must cooperate to ensure mutual intelligibility. In other words, being a native speaker of English does not guarantee proficiency in Aviation English.

Regarding our use of the term 'Aviation English', we take it as covering not only communications which involve 'standard phraseology' – a prescribed, highly constrained set of phrases to be used insofar as possible in all radiotelephonic communications between controllers and pilots – but also communications which involve the use of natural English or 'plain language' – to be used in aviation situations where the standard phraseology is either non-existent or insufficient. In Aviation English, mutual understanding between pilots and air traffic controllers is of paramount importance for air safety, and all interlocutors, regardless of their native language, have a responsibility in achieving that goal. The standardization of plain language in the global aviation context is as challenging as the standardization of a lingua franca in any global context and, given the high-stakes nature of controller–pilot communications and the diverse contexts in which these communications occur, this tension between variation and standardization is particularly strong. The role of 'plain English' is further discussed in the context of the linguistic description of Aviation English in Chapter 2.

High profile accidents were instrumental in raising awareness to the importance of effective air traffic controller–pilot communications and were fundamental in the development of a standard phraseology for air traffic controller–pilot communications. As a result, the ICAO language proficiency requirements which were introduced in 2003 and came into effect in March 2011 (ICAO 2004, 2010) solidified the role of Aviation English as the lingua franca of aviation, elevating proficiency in the English-based language of radiotelephonic communications from a recommended to a required status. We discuss some of the benefits and challenges associated with this policy in later chapters. In this chapter, we provide a brief history of how Aviation English came to be the working language of aviation, answering the questions of when and why English became the basis for the lingua franca in aviation.

## History of English as the language of communication in aviation

At the beginning of aviation, there was no air traffic control and no radio communication. Pilots were unable to communicate verbally with the ground or with each other. When radios became more portable and could be taken on board aircraft, the system of communication was based on the Morse code (with combinations of dots and dashes representing letters and numbers) already in use by ships, and the structure of messages followed maritime conventions adapted as necessary. The radio medium imposes constraints of brevity and, because it is a one-way mode of communication, requires messages to be as unambiguous as possible to avoid repetitions and requests for clarification. This is especially the case when each message has to be spelled out letter by letter as with Morse code.

The 'Q Code' was created by the British Government in 1909 to codify radio communication and make it more succinct and unambiguous. One advantage is that it is independent of the language of either the sender or the receiver, and it was adopted internationally in 1912. In the 'Q Code' system, every communication starts with a three-letter group always beginning with 'Q' (for 'query'). The three-letter code is used both as question and response, followed by information as needed. For instance, the code 'QRL' corresponds to the question 'Are you busy?' and can be answered with 'QRL', meaning 'I am busy'. The code 'QRB' corresponds to the question 'What is your distance', with the answer 'QRB' followed by a number meaning 'My distance is xxx'. The Q code is still used by amateur radio operators and some remnants can be found in the aviation domain. For instance 'QNH' (which can be interpreted as 'Query No Height'), now indicates the barometric pressure at sea level (e.g. 'QNH 1015').

The Q Code was very successful in making communications clear, succinct and unambiguous. It was first tied to Morse but transferred easily to spoken radio communication, with letters being pronounced instead of being tapped. However, it is not flexible and does not allow for the creativity of natural language. A problem that became apparent when operators moved to spoken radio communication was that individual letters and numbers can be very difficult to distinguish from each other and that individual variations in pronunciation often render messages ambiguous or intelligible ('Was this a *P* or a *T*?').

Between the two World Wars, most commercial pilots were ex-military personnel who had taken part in building the air forces of their countries and who went on to develop commercial civil aviation. Thus, until World War II, aeronautical communication was a natural extension of military and maritime conventions in use in each region. The first international phonetic alphabet, assigning a code word to each letter of the alphabet (e.g. *Alfa* for *A*, *Bravo* for *B*, etc.), so that critical combinations can be pronounced unambiguously and understood regardless of the transmitter or receiver's native language, was created for maritime use and adopted by the International Telecommunications Union (ITU) Radio Conference in 1927. With some modifications, it was then adopted by the International Commission for Air Navigation (ICAN) and used in civil aviation until World War II. The phonetic alphabet code underwent several modifications until the final version was implemented in 1956, taking into account the development of alternative alphabets for military joint operations during the war as well as feedback from pilots and air traffic controllers from 31 countries after the war. As the International Radiotelephony Spelling Alphabet, or NATO Phonetic Alphabet, it remains in use by the military and by civilians in both maritime and aeronautical communication. The main issue, as with all radio communication, was to ensure brevity and clarity, avoiding any possible ambiguity or confusion.

After World War II, commercial aviation developed very rapidly around the globe and many new air routes were opened. The victory of the Allied forces and the supremacy of the USA in aeronautical engineering, due in part to the wide destruction of industrial infrastructure in Europe and in Japan, meant that a large proportion of aircraft were designed and built in the USA. Even before the end of the war, the USA had initiated a number of studies and consultations to 'secure international co-operation and the highest possible degree of uniformity in regulations and standards, procedures and organisation regarding civil aviation matters' (ICAO, 2001). The 1944 International Civil Aviation Conference in Chicago resulted in the establishment of ICAO as a permanent international body and laid the foundation for rules and regulations bringing safety to air navigation throughout the world.

Most of the regulations concerned the technologies and procedures to follow during navigation, especially given the rapid development of new technologies at the time,[3] but Annex 10 to the *Convention on International*

*Civil Aviation* deals with 'Aeronautical Telecommunications' and is the document which specifies language requirements for Civil Aviation. One of the earlier recommendations, in 1960, regarding language was that Radiotelephony (RT) Speech be recognized as the International Language for Aviation, instead of the previous Q Code. The main advantage of a natural language instead of a code is the possibility of creating new messages in new situations and of allowing some flexibility when required. A natural language is also more intuitive and may be easier to remember; however, as we shall see, its very flexibility may cause ambiguity and confusion, so it has to be codified to a certain extent. In 1987, Annex 10 was reorganised to present 'English language radiotelephony phraseology in all language versions of the regulations', which at the time were English, French, Russian and Spanish.

In the same year, in the foreword to Robertson's manual *Airspeak*, Johnson characterized what we now call 'Aviation English' as 'what is probably the world's most successful semi-artificial international language: English-based RT phraseology and procedures' and stated that 'to all intents and purposes English-based RT is the international "lingua Franca" of air traffic control'. (Robertson, 1987: viii). The distinction between 'international' and 'universal' is not always understood;[4] the idea that 'English is the universal language of communication used in civil aviation' (preface to the *Collins Dictionary of Aeronautical English*, 1999) is common among English-speaking pilots and, as we shall see in Chapter 2, contributes to the difficulties experienced by non-native speakers, because native speakers are not always trained, or sometimes do not perceive the need, to adjust their speech when communicating with non-native speakers of English – a concept that will be discussed more fully in Chapter 3. Given the widely held belief in the English-speaking world that all aeronautical communications are required to be held in English, it is worth giving in full the text of the regulations (ICAO, 2001: 5.3):

> 5.2.1.2 *Language to be used*
>
> 5.2.1.2.1 The air–ground radiotelephony communications shall be conducted in the language normally used by the station on the ground or in the English language.
>
> Note 1. – The language normally used by the station on the ground may not necessarily be the language of the State in which it is located. A common language may be agreed upon regionally as a requirement for stations on the ground in that region.
>
> Note 2. – The level of language proficiency required for aeronautical radiotelephony communications is specified in the Appendix to Annex 1.

> 5.2.1.2.2 The English language shall be available, on request from any aircraft station, at all stations on the ground serving designated airports and routes used by international air services.
>
> 5.2.1.2.3 The languages available at a given station on the ground shall form part of the Aeronautical Information Publications and other published aeronautical information concerning such facilities.

Moreover, the *ICAO Manual for the Implementation of Language Proficiency Requirements* (ICAO, 2010) clearly specifies not only that non-native speakers are not expected to attain the same English proficiency as native speakers, but that native speakers must share the burden of making all communications intelligible to the international aeronautical community. More specifically, the ICAO Manual states that ICAO took 'a principled decision that native speech should not be privileged in a global context' (ICAO 2010: 4.8) and that 'native speakers of English, in particular, have an ethical obligation to increase their linguistic awareness and to take special care in the delivery of messages.' Indeed, 'native speakers are under the same obligation as non-native speakers to ensure that their variety of English is comprehensible to the international aviation community' (ICAO, 2010: 5.4).

Nevertheless, proficiency with the English language has been identified as an integral part of international aviation safety (MacBurnie, 2004) and, as we shall see in the next section, effective communication using Aviation English is now considered crucial.

## Communicating for air safety

Given that the radio medium is for the foreseeable future the primary means of communication between air traffic controllers and pilots,[5] effective oral communication is crucial for aviation safety. Awareness of communication as an important factor in aviation safety came to the public's attention in the wake of a major aviation accident in Tenerife, Canary Islands, in 1977. The accident investigation revealed that the Dutch-speaking pilot's level of proficiency in English (the language of communication between the captain and the Spanish-speaking controller) may have, among several other factors such as workload and fatigue resulting from the day's irregular operations, contributed to the accident. While this accident, in which two Boeing 747 passenger planes collided, resulting in 583 fatalities, is perhaps one of the most widely known accidents in aviation history, it is important to note that most misunderstandings get resolved and do not result in such tragic outcomes. Nevertheless, based on the analysis of data collected from the ICAO Accident/Incident Reporting System (ADREP), the United States National Transportation and Safety Board reports, the United Kingdom Mandatory Occurrence Reporting System (MORS), ICAO determined that language proficiency plays an important role in effective air–ground communications, and introduced the International Civil Aviation language proficiency requirements (LPRs) in 2003 (ICAO, 2004).

The ICAO LPRs' policy and development process will be discussed fully in Chapter 3, but, briefly, the ICAO LPRs stipulate that controllers and pilots must demonstrate an operational level of proficiency in the language of operations. For pilots and controllers operating in airspace where the crew and the ground do not share the same native language, that language of operations is often English. While it is clear that proficiency in the language of communications is fundamental to the effectiveness of controller–pilot communications, we must consider the nature of this proficiency, and how it relates to the particular context in which controllers and pilots communicate. In this book, we discuss controller–pilot communications in relation to: the use of Aviation English, including standard phraseology, in Chapter 2; the ICAO LPRs' policy in Chapter 3; aviation language testing in Chapter 4; the context of controllers' and pilots' jobs in Chapter 5; contextual factors such as noise, workload, stress and fatigue in Chapters 6 and 7.

We discuss these contextual factors because aviation accidents are rarely, if ever, the result of a single causal factor. On the contrary, aviation accidents are almost always the result of a complex combination and interaction of factors. This complex interaction of factors contributing to aviation accidents involving miscommunications due to language proficiency has been acknowledged (e.g. Barshi and Farris, 2013; Cookson, 2009, 2011; Farris, 2010; Farris et al., 2008; Molesworth et al., 2014). Cookson (2011) provides a detailed discussion of three of the high profile accidents in which language proficiency was cited as a factor in the accident reports (Zagreb 1976, Tenerife 1977 and Cove Neck 1991) and Helmreich (1994) also provides an analysis of the Cove Neck accident. All of these analyses converge on the finding that, while language proficiency was likely to have been a factor in each accident, the context in which these communications took place played an important role in the tragic outcomes. As Cookson (2011) points out, in all three cases the accidents took place under conditions characterized by non-routine operations and high workload conditions. For the purpose of illustrating this complex interaction of factors, we provide here a brief analysis of the crash of Avianca 052 in Cove Neck, New York. The data sources for this analysis include a transcript of the accident[6] and the official accident report of the United States National Transportation Safety Board. The accident transcript is labelled in terms of the time of each utterance according to the 24-hour clock, so references to specific utterances are stated in relation to the time of the utterance.

### *Avianca 052: an accident involving miscommunication*

On 25 January 1990 Avianca 052 (AV052), a Boeing 707 originating from Bogotá, and carrying 9 crew members and 149 passengers, crashed into the hillside of a residential area of Long Island, New York. The plane impacted after being kept in a holding pattern around JFK airport for 77 minutes due to poor weather conditions. Of the 158 occupants on board, 73 perished (8 crew members and 65 passengers). The accident investigation revealed that the main factor leading to the accident was loss of controllability due to fuel exhaustion, with poor communication and bad weather as contributing factors. As discussed below, the nature of this 'poor communication' illustrates the importance of accuracy and timeliness in controller–pilot communications. Although the communications were conducted in English between a native Spanish-speaking crew and a native-English-speaking controller, the miscommunication cannot be attributed, at least directly, to a lack of English language proficiency on the part of the first officer, who was responsible for radio communications with ATC. Rather, the communication error can be attributed to a lack of accuracy in the use of prescribed phraseology for the declaration of an emergency, and a lack of timeliness in conveying the message to ATC.

Analysis of the cockpit voice recording of the 30 minutes leading up to the crash indicates that, although crew members were aware for several minutes prior to the crash that they were in an emergency situation due to low fuel, they failed to declare an emergency to ATC. Analysis of the cockpit voice recording transcript reveals that the flight engineer expressed his concern regarding the low fuel situation to the captain, who was piloting the plane, and the first officer several times leading up to the crash, but that the captain did not take up the flight engineer's concerns and the first officer responsible for radio communications did not accurately convey the gravity of the situation to ATC by declaring MAYDAY (to declare an emergency) or PAN-PAN (to signify a state of urgency). Rather, in response to ATC instructions following a missed landing due to wind shear, the first officer replied to ATC with the following readback: 'That's right to one eight zero on the heading, and, ah, we'll try once again. We're running out of fuel.' There are at least two problems with the first officer's readback. First, the readback suggests compliance with the controller's instructions, despite those instructions reflecting an unfeasible course of action due to the low fuel state of the aircraft. Second, while in plain English 'we're running out of fuel' may sound like a declaration of emergency, in the context of controller–pilot communications, where there is a specific prescribed phraseology for the declaration of an emergency, this statement would not be interpreted as such. In ATC–pilot communications, the statement 'we're running out of fuel' could, and apparently was, interpreted as a mere concern, similar to noting that the gas tank of one's car is less than a quarter full and that it would be a good idea to stop at the next gas station. Therefore, though the matter of low fuel was noted and later mentioned by ATC, it was not interpreted as an emergency situation. In fact, an emergency was never officially declared to ATC at any point prior to the crash. It is important to note, however, in order to highlight the importance of shared understanding through effective communication in the aviation context, that the first officer believed he had declared an emergency, as in the minutes leading up to the crash the captain instructed the first officer to declare an emergency and the first officer responded that he already had. Nevertheless, ATC did not prioritize AV052's landing and just 12 miles SE of JKF airport the plane's four engines ran down due to fuel exhaustion and the plane crashed. Although the primary cause of the accident was clearly fuel exhaustion, a leading contributing factor was the crew's failure to communicate to ATC that the aircraft was in an emergency situation, which resulted in AV052 receiving inappropriate landing priority.

The question of the captain's heavy reliance on the first officer for comprehension of communications with ATC is an important one. Although it is not unusual for first officers to communicate with ATC, it is unusual for the captain to be unaware of the content of the communications. Throughout the transcript, on several occasions the captain asks the first officer or the flight engineer to repeat their utterances and/or indicates that he either cannot hear or cannot understand communications between the cockpit and ATC (2104:09; 2105:34; 2105:39; 2105:52; 2109:27; 2117:42; 2117:47; 2120:10; 2120:21; 2124:17; 2125:28; 2126:46; 2130:56). Several times, these clarification or repetition requests concern controller communications issued in English, but this is not always the case. Furthermore, once he explicitly asks the first officer to speak more loudly as he has difficulty hearing him (2117:55), and this is in relation to an utterance in Spanish. The reason for the captain's lack of awareness of the communications with ATC cannot be ascertained; however, it appears that one or a combination of the following factors was responsible for this lack of comprehension:

1 he could not hear the transmissions due either to aircraft noise or a faulty headset;
2 he was too preoccupied with other tasks to monitor the communications; or
3 he lacked adequate command of the English language to comprehend the communications.

It is likely then that the captain's poor problem-solving and decision-making performance was due in part to his inability to perceive and/or comprehend the communications with ATC.

Although English language proficiency may have been a contributing factor in the accident, in that the captain may have had an inadequate command of the English language, and the first officer may have lacked the necessary command of Aviation English standard phraseology to declare an emergency (although this seems unlikely), it was a complex interaction of factors that caused this disaster:

- linguistic (language proficiency, code-switching);
- cognitive (high workload, concurrent task performance, decision making, problem solving);
- social and sociolinguistic (chain-of-command protocol, assertiveness);
- affective (stress, fatigue);
- environmental (weather);
- organisational (air traffic congestion); and
- technical (pilot's inability to hear communications).

Many of these factors contributed to the ineffective communications which led directly to the fatal lack of shared understanding between the crew and ATC. Given the complexity and the highly situated nature of aviation communications exemplified in this brief analysis, we have extended the range of factors we consider in our investigations of effective controller–pilot communications. In this book, particularly in Chapters 5, 6 and 7, we discuss contextual factors inherent in the controller–pilot communications, along with more purely linguistic factors, and their impact on communication in the aviation context.

## Previous research in aviation language

In this section we provide a brief overview of the research conducted to date in the field of aviation language and language testing. Prior to the introduction of the ICAO LPRs, most research in controller–pilot communications was conducted from the perspective of either aviation human factors or linguistics. With the introduction of the ICAO LPRs, the phenomena of English for specific purposes and of English as a lingua franca in aviation became of great interest and consequently a growing body of research is being conducted in the fields of applied linguistics and language testing. Furthermore, research in the field of human factors also continues to grow and now reflects an increasing interest in the issue of language proficiency and the use of English (e.g. Molesworth et al., 2014; Prinzo and Thompson, 2009; Seiler, 2009; Tiewtrakul and Fletcher, 2010), narrowing the gap between human factors aviation research and research in aviation language pedagogy and assessment – a development that we consider crucial to the development of aviation language teaching and testing. ICAO states the following regarding the purpose of the ICAO LPRs:

> The purpose of the ICAO language proficiency requirements is to ensure that the language proficiency of pilots and air traffic controllers is sufficient to reduce miscommunication as much as possible and to allow pilots and controllers to recognize and solve potential miscommunication when it does occur.
>
> (ICAO, 2010: 4.1)

If language courses and tests are to be truly reflective of the goal of the ICAO LPRs, thus ensuring that controllers and pilots can communicate effectively in non-routine aviation situations, they must be relevant to the operational environment. A clear understanding of the factors inherent in this operational environment and their impact on communication is therefore fundamental to the ongoing development of language training and testing in response to the ICAO LPRs.

In the 1990s, awareness of communication as an important element of aviation safety was evident in the aviation human factors literature, and a number of issues thought to contribute to miscommunications were empirically investigated. Anecdotal evidence collected from pilots suggested that the manner in which controllers delivered their messages, such as rate of speech and accent, contributed to miscommunications (Cardosi, 1993). Several researchers investigated the effects of controller message length on pilot readback accuracy (e.g. Barshi, 1997; Morrow and Rodvold, 1993), and prosodic elements of speech such as speech rate and pausing (Barshi, 1997). One of the objectives of these studies was to empirically research the effects of controller speech characteristics on pilot comprehension that were suggested in anecdotal evidence. Both Barshi and Morrow determined that controller message length was a strong predictor of pilot readback accuracy, and using a psycholinguistic theoretical approach, Barshi determined that controllers should limit the length of their messages to three instructions in order to ensure that pilots would accurately retain those messages. In other words, when controllers' messages were too long, pilots could not accurately read back or repeat their content.

Barshi and Healy (1998) extended Barshi's 1997 study of length and prosodic effects of controller messages on pilot retention and comprehension to include non-native speakers of relatively low and high levels of proficiency in English. Interestingly, they concluded that prosodic elements such as speech rate and pausing did not negatively impact pilot comprehension of controller messages, as the anecdotal evidence had suggested. Barshi and Healy's study was particularly relevant to the field of applied linguistics because it investigated the effects of the participants' second language proficiency on performance in the aviation context. More recently, a number of studies investigating issues related to second language proficiency and performance in the aviation context have emerged, bridging the gap between applied linguistics and human factors in aviation language research. A complete review of the research in aviation human factors research in communications is outside the scope of this chapter, but see Barshi and Farris (2013) for a comprehensive review. Recently, Jang et al. (2014) investigated the effects of cockpit noise on communications, comparing the effect of noise on the performance of native and non-native English-speaking pilots and they found that noise affects non-native speakers more than native speakers (see Chapter 6 for an in-depth discussion).

In the field of applied linguistics and language testing in particular, research has burgeoned in direct response to the ICAO LPRs. Both the applied linguistics and language testing research communities have expressed keen interest in the phenomenon of English as a lingua franca in aviation and the implementation of the ICAO LPRs, and in both fields symposia and colloquia on the topic have been held at major conferences (e.g. Testing Aviation English, chaired by Charles Alderson at the Language Testing Research Colloquium, 2010, and Language tests and language policy: The case of Aviation English, chaired by Tim McNamara at the 2012 conference of the American Association for Applied Linguistics). In 2009 an issue of the *Australian Review of Applied Linguistics* (Vol. 32: 3) was dedicated to the topic of aviation English (Cookson, 2009; Estival and Molesworth, 2009; Huhta, 2009; Kim and Elder, 2009; Moder and Halleck, 2009; Van Moere et al., 2009; Read and Knoch, 2009) and book chapters (e.g. Moder, 2013) and articles (e.g. Alderson, 2009; Downey et al., 2010; Estival and Molesworth, 2012; Falzon, 2009; Farris et al., 2008; Knoch, 2009; Sullivan and Girginer, 2002) in various peer-reviewed journals in both fields have begun to appear over the past few years.

A broad range of issues has already been addressed in the field of language testing. For example, in his surveys of language tests developed in response to the ICAO LPRs Alderson (2009) discusses challenges inherent in the worldwide implementation process and expresses concern regarding the quality and monitoring of language tests developed in response to the ICAO LPRs. Knoch (2009), Huhta (2009), Van Moere et al. (2009) and Downey et al. (2010) each report on their experiences with Aviation English testing. Knoch reports on a post-hoc ICAO rating scales validation study conducted using stakeholder participants (i.e. users of the ICAO rating scales and pilots) and she concludes that post-hoc validation and further refinement of the ICAO rating scales are needed. Huhta reports on his personal experience as part of the development team for the Finnish Civil Aviation Authority's test of Aviation English in response to the ICAO LPRs. He highlights the short timeline for development as one of the challenges faced by the Finnish CAA test development team, which began its work in 2007, just one year in advance of the original ICAO deadline for compliance with the LPRs. Huhta also provides an interesting discussion of the Finnish CAA's test accreditation system. Van Moere et al. and Downey et al. both report on the validation of an unconventional and innovative automated Aviation English test developed within a psycholinguistic framework. Each of these perspectives enhances our understanding of the challenges associated with worldwide language proficiency requirements for pilots and controllers, and it is clear that many member states and test developers consider conformance to the ICAO LPRs a high priority and are responding with a high level of professionalism. Nevertheless, a number of challenges clearly remain to be addressed and research in aviation language testing is in its infancy. Many important questions are still unanswered, and we attempt to discuss some of them in Chapter 8.

In the fields of linguistics and applied linguistics, a number of studies have investigated aviation language using various methods of discourse analysis. As part of a needs analysis for an ESP course, Sullivan and Girginer (2002) analysed controller–pilot recordings obtained at a Turkish ATC centre and found that the range of language used often differed considerably from the ICAO-prescribed language outlined in *Airspeak* (Robertson, 1987). Kim and Elder (2009) provide a comprehensive analysis of a conversation between a native-English-speaking pilot and a Korean controller, pointing out the need for native English speakers to develop accommodation skills for effective communications in the international aviation context. This is an important point to which we return in our discussion of ICAO policy in Chapters 3 and 4. Several studies have employed the method of conversation analysis (CA). For instance, Nevile (2001, 2004, 2005, 2006, 2007) used CA to analyse cockpit recordings, while Hinrich (2008) also used CA to analyse the use of questions in communications between air traffic controllers and pilots. Goguen and Linde (1983), Goguen et al. (1986) and Sassen (2005) used speech act theory as a framework for their analyses. Goguen et al. investigated cockpit communications, while the focus of Sassen's work was on communications with air traffic control. All of these studies make valuable contributions to our understanding of the linguistic foundations of aviation communications – a topic discussed in more detail in Chapter 2.

This section does not aim to provide a comprehensive review of the literature in Aviation English, but rather an overview of the breadth and scope of research in this domain, highlighting its interdisciplinary nature and the wide range of topics that have been addressed empirically using a variety of methods. The other chapters in this book elaborate on some of the topics we have touched on here and provide more in-depth reviews for specific areas.

## The need for a common language

It is clear that using a common language presents enormous advantages in high-risk situations where effective communication is a factor for successful operations, such as in aviation. In fact a common language is a crucial factor for aviation safety in situations where several aircraft share the same airspace. Assuming radio communication is possible, a shared language enables shared situation awareness for the pilots and crews of the different aircraft. The ICAO regulations permit the use of languages other than English, when a local language is shared by ATC and the pilots, precisely because a shared language will permit better communication and thus potentially increase air safety. This is what happens regularly in general aviation (GA) around the world. French pilots communicate with air traffic controllers and other aircraft at their local airport in French, while Russian or German pilots use Russian or German, respectively, within their own airspace. This model is considered a better option for safety than requiring the use of a second language for everyone.

However, in situations where a language is shared by only some of the occupants of the airspace, for instance when a German pilot flies through France, or a US pilot flies through South America, the use of the local language may lead to decreased situation awareness if the crew cannot understand the exchange of transmissions around them or, even worse, the instructions from ATC directed at them. Therefore, the regulations still recommend that English be used. 'The English language shall be available, on request from any aircraft station, at all stations on the ground serving designated airports and routes used by international air services' (ICAO, 2001: 5.3). Even for general aviation, all ATC stations must be able to provide service in English if requested by an aircraft.

Having a designated common language, Aviation English, obviates the need for stations and aircraft to negotiate which language to use in multilingual situations, for instance when an Italian and a German aircraft approach a French airport: the choice has already been made. Even if the French ATC were able to communicate in Italian or German with each of the aircraft, they will switch to English. It is expected that everyone else in the airspace would also be able to switch to English, although in fact that may not be the case for all general aviation pilots. English is also often the common language within multilingual crews, when pilots do not share the same L1, which is quite common in many airlines or companies, unless another language has been designated as the working language for the company.

Thus, a default common language in theory ensures a greater ease of communication between controllers and pilots and should lead to increased situation awareness and improved air safety. Nevertheless, there are still a number of issues to be addressed in those multilingual situations. For instance, the French or German crew who request a switch to English while flying through Italy will be able to better communicate with ATC and will receive the information they need; the local pilots who were using Italian to communicate in that airspace, however, may not be able to understand or use English to a level that allows them to maintain adequate situation awareness. Or the crew of a small local airline may not feel as comfortable communicating with their English-speaking colleague in the cockpit as they would in their own local language, thereby decreasing communication efficiency and possibly performance. Still, prescribing the use of a common language in those situations is certainly a better option than allowing individual choices which would render communication impossible; thus the standardization of Aviation English has proven to be an important factor in aviation safety.

## Defining the common language

Aviation English is generally considered to consist of prescribed exchange formats, standard phraseology, which is defined as prescribed vocabulary and syntax, and specific pronunciation. Each of these elements is an attempt at solving problems of communication that could be critical for safety. These rules result from experience, and the rules of Aviation English result from communication errors which could compromise safety or efficiency. Like any language or language variety, Aviation English can be described at different levels of linguistic analysis: phonology, lexicon, syntax, pragmatics and discourse. In Chapter 2, we give a more precise linguistic description of these different levels and show where this prescribed language differs from Standard English. Here, we present the specific factors which have contributed to the definition of Aviation English and which differentiate it from other Englishes for specific purposes. As with Maritime English, Aviation English has been shaped by the specific constraints of the operational environment. In both maritime and aeronautical environments, communication occurs over the radio between distant stations, and in both environments communication is crucial to safety.[7] There are three main factors to consider in the creation of a common language such as Aviation English:

1 the impact of the technology, i.e. radio communication;
2 the constraints of the operational environment, i.e. managing a flight for pilots and managing air safety for ATC; and
3 the human factors, e.g. cognitive load and human performance.

The constraints of the operational environment and the factors that impact on human performance are addressed in detail in the rest of the book. Here we will consider the technological aspects of radio communication which gave Aviation English it distinctive shape.

### *The impact of technology on Aviation English*

The actual technology used for aviation communication has an enormous impact on the form of the language. As described earlier, when radio communication was limited to Morse code, although long messages were possible when sending telegrams over a wire for instance, maritime and aeronautical radio operators had to devise the three-letter Q code to ensure that communications could be both short and unambiguous. Even with modern facilities, the radio medium imposes a number of constraints.

The first constraint is that a potentially large number of operators (air crew or ground stations) share the same few radio frequencies. As a result, to avoid what is called ‘congestion of the frequency’, each operator is limited to short messages and turn-taking is standardized.

The second constraint is that radio communication is one-way, which means that only one station can broadcast at a time. If two or more stations transmit at the same time on the same frequency, the transmissions become unintelligible but the transmitting stations are not aware their message was not received, because they hear only themselves and cannot hear the others. They will only become aware of the problem if a third party alerts them to it when the frequency finally becomes free. The one-way nature of radio transmission is the main factor in the constraints of brevity and clear turn-taking. Not only is the structure of the message standardized but the way in which each participant indicates that their turn is complete must be unambiguous. Each station must listen to the transmissions of the others and determine when it is appropriate for them to start transmitting. There can be no overlap between transmissions, and the complete set of dialogue turns between two stations must be complete before a third station can start transmitting. These factors are important for shared situation awareness among pilots in a sector. It is considered very rude and showing bad airmanship to ‘over-transmit’ and student pilots often find it very frustrating to try to ‘get their radio calls in’ in a busy environment while learning to fly at the same time.

Finally, radio communication is noisy and the sound is distorted. In spite of modern high-quality headsets, the sound level in a cockpit is much higher than in a normal office or even a car. Chapter 6 explores in more detail the impact of noise on communication but, from the point of view of the definition of Aviation English, the impact of noise on phoneme perception has led to some modifications in the pronunciation of highly confusable words. The best known examples are those of *five* pronounced as *fife* due to confusion between voiced and voiceless fricatives because of the narrower frequency range, and *nine* pronounced as *niner* in order to avoid confusion with *five* and with German *Nein*.

### *The role of ‘plain’ language*

Despite the constraints imposed by the technology already described, communication over the radio can be conducted in a more spontaneous manner. Indeed, the regulations recognize that it is sometimes necessary to resort to ‘plain English’, also called ‘Standard English’ or ‘conversational English’, in emergency or unusual situations which may require communications that are not covered by the phraseology. ‘Plain English’ is not well defined in the regulations, being described only as 'clear and concise plain language', and native speakers of English have a distinct advantage in those situations.[8] This is one area of concern for training and assessing the language proficiency of pilots and controllers. As we will see in Chapter 2, 'plain English' is not merely natural conversation in English or in ELF, it is also subject to the constraints of radio and aviation communication.

It is important to point out that while 'plain language' in other domains involves simplification and avoiding technical jargon, this is not the case with 'plain English' in aviation. In the medical or legal environments for instance, 'plain language' is aimed at making specialized language intelligible to patients or clients; by contrast, 'plain English' in aviation is not aimed at outsiders and does not preclude the use of technical terms. Plain English can be considered a linguistic fiction, in that it does not exist as a language but is an ideal which aviation personnel are encouraged to aim for when there is no strict phraseology available. Figure 1.1 attempts to clarify the relations between communication in aviation, Aviation English, ELF and plain English.

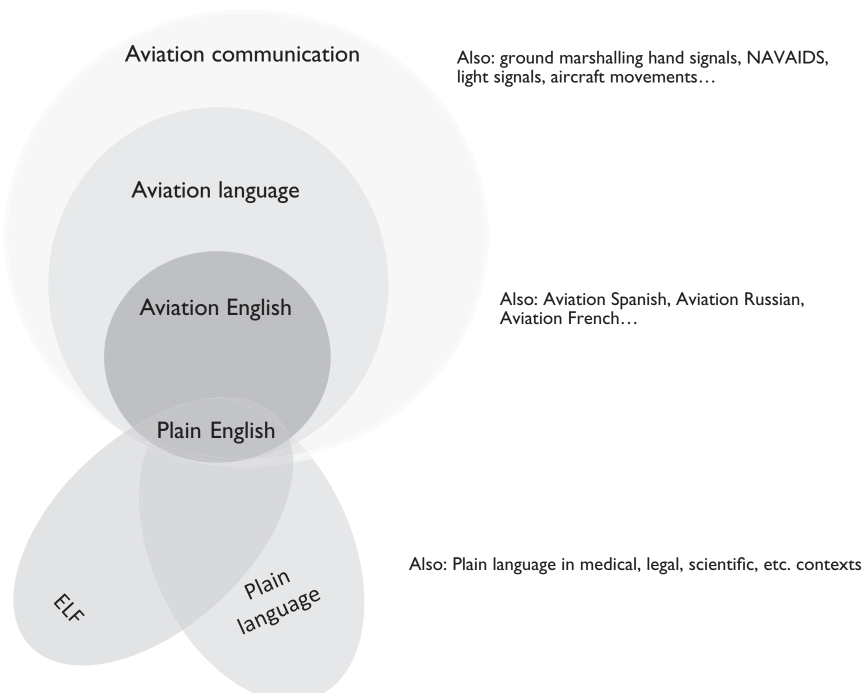


*Figure 1.1* Relations between aviation communication, aviation language, Aviation English, ELF and plain language

In summary, Aviation English is one of the aviation languages designed for aviation communication while aviation communication itself also includes a range of other types of non-verbal systems. Plain English in aviation is part of Aviation English and is a subset of plain language while English as lingua franca (ELF) is much broader than Plain English and does not cover all of Aviation English.

## Notes

1 Regarding the question of native speakers, we agree with Piller (2001: 112) who points out that: 'In trying to square the common-sense notion of the native speaker with this common sense notion of the standard language, a most striking fact emerges: a native speaker of Standard English is logically impossible! A native speaker is supposedly born into the language while the standard is supposedly attained through superior education.' This contradiction is also inherent for any variety of English for specific purposes, especially when it is highly specialized and requires training. Nevertheless, we use the term NES throughout the book as if the notion of a native speaker was uncontroversial.

2 According to the *Longman Dictionary of Language Teaching and Applied Linguistics*, the definition of lingua franca is as follows: 'A language that is used for communication between different groups, each speaking a different language. The lingua franca could be an internationally used language of communication (e.g. English), it could be the native language of one of the groups, or it could be a language which is not spoken natively by any of the groups but has simplified sentence structure and vocabulary and is often a mixture of two or more languages (see PIDGIN)…' (Richards et al., 1992: 214).

3 New advances in radio navigation, such as the ADF (Automatic Direction Finder), VOR (VHF Omnidirectional Range), ILS (Instrument Landing System) and more recently the adoption of the GPS/GNSS, introduced new terminology and procedures in both commercial and general civil aviation.

4 It is also worth heeding the following advice: 'I would certainly never advise you to pursue the bizarre conceit which has taken hold of you to follow the dream about universal language.' (Francesco Soave. 'Riflessioni intorno all'istituzione di una lingua universale, 1774), given in epigraph by Umberto Eco 'The search for the perfect language' (1995).

5 The technology of datalink obviates the need for spoken communication in many situations when available, but cannot completely replace it and is not available for many non-commercial aircraft.

6 See http://aviation-safety.net/investigation/cvr/transcripts/cvr_av052.php, retrieved 20 September 2015.

7 'In a study in 2007 it was estimated that one third of shipping accidents occurred due to poor levels of maritime English, thus reemphasising the importance of communication where safety procedures are involved' (Cairns, 2011).

8 Inevitably, pilots make a number of jokes about 'plane/plain English'.

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Chapter 2

# Aviation English

## A linguistic description

*Dominique Estival*

In this chapter, we present a linguistic description of Aviation English (AE), from the level of pragmatics and discourse to that of phonology and intonation. As noted by Feak (2013), AE is a spoken variety of English, with no written version except for the phrases documented in the regulations describing it, for instance the ICAO manuals and the legislation for each individual country (the *Aeronautical Information Publications*, or AIP), or in teaching materials (Lopez, 2013). A restricted version of AE is used with controller–pilot data link communication (CPDLC) technology, which allows air–ground text messages on a computer screen but, as messages transmitted via CPDLC are selected from a menu, rather than typed, they will not be considered here.

It is important to define what AE is and what it is not. Some studies have looked at aviation communication and the impact of voice and language on the safety or efficiency of Air Traffic Control (Barshi, 1997; Barshi and Farris, 2013; Lopez et al., 2011; Moder, 2013). This is not our purpose here and we make a clear distinction between AE and aviation communication.[1] Aviation communication includes language, with English designated as the main international language to be used, but it also encompasses other modes of communication, such as: light signals, used when radio communication fails; navigation aids, e.g. ADF, ILS, VOR or GPS/GNSS; the codes for weather forecasts and weather reports. Our purpose in this chapter is to describe AE from the point of view of English for Specific Purposes (ESP) and to examine the linguistic characteristics of that language variety.

One important aspect of AE, which is emphasized in all aviation training courses and which cross-cuts the practical flight training, is the use of correct 'phraseology', prescribed by ICAO and the national legislations (e.g. AIP Australia, UK AIP, or FAA AIP for the USA). The term 'phraseology' covers not only the required terms and phrases, as is commonly understood, but also prescribes special pronunciation and syntax, as well as discourse and dialogue structures. The phraseology is the standard expected in normal routine communications. This standardization is the product of decades of experience drawn from accidents and incidents resulting from confusion and misunderstandings by pilots and ATC, both native and non-native speakers of English (Cushing, 1994; Estival and Molesworth, 2012). We first describe this specific code by showing how it is taught and used.[2] In situations not covered by the restricted phraseology, the regulations specify that 'plain language' must be used: 'When circumstances warrant, and no phraseology is available, clear and concise plain language should be used to indicate intentions' (AIP, GEN 3.5, 4.1.4).

What 'plain language' is and how it relates to 'natural' or 'general' English is still a source of debate and discussions (Lopez, 2013; Moder, 2013). We attempt to address those issues when giving examples of plain language after describing the more restricted code. For now, we will only note that 'plain English' in aviation is not meant to be natural conversation in English (or in ELF), but the use of simple English following as much as possible the guidelines provided by the phraseology and obeying the constraints of aviation communication described below.

Other studies of Aviation English focus on Air Traffic Control (ATC) communication, in particular on issues of miscommunication between pilots and ATC (Barshi, 1997; Barshi and Farris, 2013; Kent, 2003; Lopez, 2013; Lopez et al., 2011; Moder, 2013; Moder and Halleck, 2009; Philps, 1991; Sänne, 1999).[3] While communication between pilots and ATC is probably the most salient aspect of aviation communication for the general public, it is not the only context in which AE is used. The ICAO regulations describe communication between pilots and any air traffic services (ATS) station, and between pilots, for flights outside controlled airspace as well as for flights within controlled airspace. Airline passengers are mostly aware of flying through controlled airspace (CTA), where pilots must communicate with ATC, but a large amount of flying takes place outside controlled airspace (OCTA), as part of general aviation (GA). This includes private flying but also commercial flights such as agricultural operations, aerial photography, scenic flights at touristic locations, medical evacuations in country areas, search and rescue operations, fire-spotting, fire-fighting and flight training among other activities. During those flights outside controlled airspace, it is not unusual for an aircraft to contact ATC for information or to converse with the crew of another aircraft. When arriving at an uncontrolled aerodrome, aircraft are expected to broadcast their intentions. All these communications also follow a prescribed script and are expected to use AE. In this chapter we will look at AE as used in both controlled and uncontrolled airspace and will consider its use in general aviation, particularly from the point of view of flight training.

## Aviation English as a restricted code

At the outset, it is important to note that AE is not simply a subset of 'general' English but that it is a specific code with conventions outside of 'natural' English, which needs to be learned on its own terms.[4] Even Native English Speakers (NESs) must learn AE, and there are two types of evidence to support this observation. First, NESs do not understand AE when they are exposed to it without training. Everyone hearing radiotelephony (R/T) communications for the first time, even when being told what is happening, will comment that they cannot understand most of what is being said and it does takes a certain amount of time for student pilots to get used to it. In this respect, AE is different from, for example, Business English (Bargiela-Chiappini and Zhang, 2013). Even though the latter might also be termed a 'jargon' and may contain some domain-specific vocabulary which has to be learned, it is less likely to be unintelligible to NESs. For AE, all speakers, whether NES or EL2, must learn not only the special vocabulary and the scripted phrases, but also the specialised pronunciation and the organisation of the speaker turns.

Second, in order to become proficient at R/T communication, it is necessary to practise, just like second language learners must practise when they learn another language. Although the amount of practice required is less than for a foreign language, practice is required to attain any level of proficiency. Most student pilots indeed 'practise their calls' when they are not flying so they can produce them smoothly when in the air. Those who do not practise, whether they are NES or EL2, always struggle on the radio and they are rebuked for not being proficient until they have mastered the code and can then not only understand the transmissions directed at them, but can produce acceptable transmissions themselves.

As evidence that English-speaking student pilots need to learn and practise AE, the following advertisement for a brand of radio headsets in the *Australian Flying Magazine* (September 2013: 19) shows a young pilot, apparently studying, with a radio headset over her ears, and musing:

(1) 'I just soloed. But as my flight instructor reminds me, there's still a lot more to learn. And he's right. Ground reference manoeuvres. Cross-wind landings. They need more practice. Plus, I'm still learning the radio lingo, which is almost more difficult than flying. That's why when it comes to a headset that lets me hear what I need to hear…'

This advertisement is targeted at English-speaking pilots, presumably NESs, who know they had to struggle to 'learn the lingo'. The underlying assumption is that 'learning the lingo' is hard and that pilots need all the technical help good equipment can provide.[5]

More evidence that AE is a code which has to be learned comes from the international environment. AE is one of the versions of the 'aviation language' whose characteristics are mandated by ICAO regulations (see Chapter 4) and of which there are other versions for the other languages used in air communications. For speakers of other languages, it is quite easy to learn another 'aviation language' version when they already know one. It is the same code with different (predictable) lexical items.[6] In this respect, aviation communication can be seen as an instance of a cross-linguistic register, similar to medical language.[7]

As pointed out by Goh (2013: 58), in order to understand what they are hearing, second language listeners 'need three types of knowledge: knowledge about the language (phonology, syntax and vocabulary), knowledge about language use (discourse and pragmatics), and knowledge about context, facts and experiences (prior or background knowledge, or "schema")'. In this chapter, we will focus on the first two types of knowledge: knowledge about language and language use, and introduce context and experience, i.e. the content of the communication and the radio environment, as necessary during the discussion.

Rather than presenting a traditional linguistic description, starting from the sound system and going up to the pragmatic and discourse levels, we will go through an example interaction and show first how it is analysed and interpreted, and then how we teach students to use that code. Although the most difficult aspects of AE for new pilots are not the syntax or the phonology, but the new vocabulary and the speaker turn conventions, students nevertheless struggle with the specific ordering of items in their transmissions and with the elimination of unnecessary words.

(2) *Example interaction*

a. *Pilot*: Camden Tower, Jabiru Lima Sierra India, Mayfield, 2000, inbound with information India.

b. *ATC*: Lima Sierra India, maintain 1800, join right base runway 24, report 3 miles.

c. *Pilot*: 1800, right base 24, report 3 miles, Lima Sierra India.

### *What does this mean?*

In (2.a) the pilot of an aircraft, of type 'Jabiru' with call-sign 'LSI' (pronounced 'Lima Sierra India'), is calling the Air Traffic Control (ATC) at Camden airport to inform ATC of their position (at an inbound reporting point called 'Mayfield', with an altitude of 2000 feet) and of their intentions ('inbound', i.e. for arrival at Camden, having received the latest aerodrome information named 'India'). In (2.b) ATC responds with specific instructions about altitude and procedures for arrival at Camden, which the pilot then repeats as a 'readback' in (2.c).

This is a very simple, routine exchange but it illustrates quite clearly a number of the linguistic characteristics of AE and how aviation communication is structured.

## Dialogue level

### *Dialogue structure*

First, at the dialogue level, it is clear that this exchange is composed of three parts: the first radio call, initiated by the pilot in (2.a); the response from ATC in (2.b); and then the readback by the pilot in (2.c). This is the general structure of any pilot-initiated exchange, as shown in (3).

(3) *Dialogue structure – pilot-initiated exchange*
   a. Pilot initial call
   b. ATC response
   c. Pilot readback

Pilots must learn that an exchange is not complete until they have produced a correct readback of the required information, which ATC expects to be acknowledged. If the pilot does not produce a readback or does not read back correctly, ATC will prompt them until all the required information has been returned satisfactorily. ATC monitor the accuracy of the readback and know they have to guard against 'hearback complacency', i.e. the tendency to hear what you expect to hear. Similarly, pilots who are very familiar with an environment must guard against complacency in that environment, because the instructions given by ATC on any given occasion might be different from the usual ones.

### *Dialogue turns*

Unlike in conversations with friends or at the dinner table, where turn-taking may follow certain social conventions but is not scripted, and where the contents of a turn is largely up to the individual speaker, each dialogue and dialogue turn in aviation communication is strictly structured. The information is transmitted in a strict sequence with the information given in a prescribed order. To teach this sequence, we break down each transmission into its logical discourse components and the simple way we teach student pilots to remember this structure is given in (4):

(4) *Dialogue turn structure: initial call*

| | |
|---|---|
| **Who I am talking to:** | Receiving station: aircraft or ground station |
| **What I am:** | Emitting station: aircraft or ground station |
| **Who I am:** | Name or call-sign |
| **Where I am:** | Position / Altitude |
| **What my intentions are:** | Route, arrival, etc. |

We will call the elements of a dialogue turn (e.g. 'Where I am') 'dialogue turn components', and the elements of a turn component (e.g. 'Altitude') 'information items'. Applying the dialogue turn structure of (4), we can interpret the initial call in (2.a) as follows:

(5) *Pilot (first contact)*

| | |
|---|---|
| **Who I am talking to:** | 'Camden Tower'<br>(could be 'Canberra Approach', 'Melbourne Centre' or 'Cessna XYZ' …, etc.) |
| **What I am:** | 'Jabiru'<br>(could be 'Cessna', 'Cherokee' or 'King Air' …, etc.) |
| **Who I am:** | 'LSI'<br>(could be 'ABC', 'YAZ', or '4785' …, etc.) (with each letter or number pronounced separately using the international phonetic alphabet) |
| **Where I am:** | –Position: 'Mayfield'<br>(could be 'Prospect Reservoir', or '2RN', etc.)<br>–Altitude: '2000 feet' (pronounced 'two tousand') |
| **What my intentions are:** | –'Inbound'<br>(could be 'Tracking overhead', 'Inbound for circuits', etc.)<br>–'with information India'<br>(automated aerodrome information – automated terminal information, or ATIS – given throughout the day in alphabetical order, referred to with the international phonetic alphabet) |

The response from ATC in (2.b) follows a similar structure, as shown below:

(6) *ATC's response*

| | |
|---|---|
| **Who I am talking to:** | 'LSI' (call-sign of the aircraft calling) |
| **Instructions:** | –Altitude to maintain: '1800 feet'<br>(pronounced 'one tousand eight hundred') |

| | |
|---|---|
| | –Circuit leg to join: 'Base' (could be 'Upwind', 'Crosswind', 'Downwind', or 'Final') |
| | –Runway to use: '24' (pronounced 'two four') |
| | –When to contact ATC again: '3 miles' (from the airport) |

Finally, the pilot's readback in (2.c) repeats the instructions given by ATC, followed by confirmation of the station calling, i.e. 'Who I am', as shown below.

(7) *Pilot readback*

| | |
|---|---|
| **Instructions:** | –Altitude: '[maintain] 1800' |
| | –Circuit leg: '[join] Right Base' |
| | –Runway: '24' |
| | –Report point: '[report] 3 miles' |
| **Who I am:** | 'LSI' |

Professional pilots are encouraged to minimize the number of words in each transmission and will omit the verbs given within square brackets in (7). Private pilots will tend to repeat the complete instructions and to include those verbs in their readbacks (see Chapter 7 for examples from the flight simulator experiments). Similarly, some elements of the instructions given by ATC do not strictly need to be repeated but are often heard, as in (2.c), where the pilot of LSI read back the reporting point, which is not obligatory. Many pilots prefer to repeat the whole set of instructions rather than risk omitting one item.

In the case of ATC-initiated exchanges, the structure of the exchange is similar, but not exactly reversed. The roles of pilots and ATC are quite distinct pragmatically and most often there is a strongly felt power imbalance between pilots and ATC. Pilots give information about their flight and their intentions to ATC and they request clearances, which they know may or may not be granted. They depend on ATC and must obey ATC instructions, unless it would be unsafe to do so. On the other hand, ATC request information from pilots, which must be provided, and they give out important information about traffic and conditions during the flight or at destination, which pilots need. Moreover, ATC can also withhold clearances which have been requested. Even though the role of ATC is acknowledged to be one of support and help, it is sometimes the case that pilots, especially during their training, are apprehensive about interacting with ATC, mainly because they are afraid of making mistakes. Because of the public nature of radio communications, everyone on the frequency will hear every transmission and this knowledge can be daunting, even for experienced pilots.

It is even more daunting of course when the pilots or pilot trainees speak English as a second language (EL2) and are aware that ATC and other pilots are judging their performance over the radio. A number of cases of aviation miscommunication have been attributed to this pragmatic level factor and to the fear of losing face. For instance, as discussed in Chapter 1, in the case of the Avianca Airlines 1990 accident, it is believed the Spanish-speaking pilot 'not thoroughly familiar with English and all of the standard international aviation phraseologies, felt that advising ATC of an acute fuel shortage was sufficient to grant him an immediate landing clearance. Consequently he never literally declared an emergency' (Illman, 1998: 29) and crashed approximately 16 miles from JFK airport. Added to that unfamiliarity with the phraseology was the aggravating factors of being intimidated by the on-going communications between ATC (the air traffic controllers at JFK are notorious for the speed of their transmissions) and other aircraft and of having been refused the clearance he had requested earlier.

Interpersonal communication is more difficult in the context of radio, where the speakers cannot see each other and also do not know each other, even more so given the scripted nature of the interactions. To help with interpersonal communication, especially when the communication does not go according to expectations, politeness markers, e.g. greetings and thanks, are often added even though they are not mentioned in the regulations (Lopez, 2013; Moder, 2013). When they occcur, words and expressions such as 'Good morning' or 'Thanks' are found at the beginning or the end of otherwise normal dialogue turns. Such markers are not always in English: Fox (2013) gives examples of multilingual politeness, with greetings in French or Dutch during interactions at Paris-Orly and Amsterdam-Schiphol.

## Syntactic level

At the level of the dialogue turn components, the syntax of radio transmissions has been reduced to the minimum necessary for successful communication, with major simplification of structures and prescribed orderings of information items. Therefore there is not much syntax to discuss or describe, but it is important to point out where the syntax of AE is not like that of 'natural' English. The simplification makes it easier to learn, and adhere to, the conventions of AE, but it is also a source of possible unwanted variation as speakers may, and native speakers of English frequently will, revert to the standard syntax of 'natural' English.

### Syntactic structures

#### *Clauses and phrases*

Whether at the sentence level or the phrase level, the syntax of AE aims to reduce each message to its logico-semantic content. The mood and illocutionary force of each message is implied by the structure of the dialogue turn and by the turn components. At the sentential level, the most obvious characteristic of AE is that there are only main clauses, with no embedding of subordinate clauses such as relative or that-complement clauses. The different information units in a dialogue turn are not embedded in a syntactic relation, they are juxtaposed in a paratactic relation as in (8) below.

(8) *ATC*: Lima Sierra India, maintain 1800, join downwind runway 06, report 2 miles.

It is of course possible to find complement clauses when either ATC or the pilot switches to plain English, for instance in (9) below.

(9) *ATC*: LSI, you were advised to report 2 miles. You are at 3.3 NM exactly. Report 2 miles.

#### *Imperatives*

A very large proportion of ATC transmissions are in the imperative, either instructions or requests (Lopez, 2013). This implies that they will not contain a subject pronoun, thus accounting for the widespread lack of pronouns in aviation communication (see next section on *Grammatical categories*). Since a large proportion of pilot transmissions are readbacks of ATC instructions which repeat part of those instructions, they do not contain subject pronouns either. The subject of any verb is understood to be the pilot. Needless to say, pilots rarely use imperatives when talking to ATC. Exceptions are 'SAY AGAIN', which is best understood as a question marker (see below), 'STAND BY', which indicates that the station being called is too busy to reply but has heard the transmission, as shown in (10), and 'WORDS TWICE', used either as a request or as information, as shown in (11).[8]

(10) 'STANDBY'
*Meaning*: 'Wait and I will call you.' (AIP, GEN 3.4, 4.13.1)

(11) 'WORDS TWICE'
*Meaning*:
a. (as a request) 'Communication is difficult. Please send every word or group of words twice.'

b. (as information) 'Since communication is difficult, every word or group of words in this message will be sent twice.' (AIP, GEN 3.4, 4.13.1)

### *Questions*

Although Moder (2013: 234) claims that questions are not allowed by the regulations, the syntax of questions is prescribed precisely for certain circumstances and the regulations prescribe the form of exchanges amounting to question–answer pairs. Indeed, some formulaic questions are included in the phraseology, as in (12), (13) and (14) below.

(12) 'HOW DO YOU READ?'
*Meaning*: 'What is the readability of my transmission?' (AIP, GEN 3.4, 4.13.1)

(13) 'ARE YOU READY FOR IMMEDIATE DEPARTURE?' (AIP, GEN 3.4, 5.14.6)

(14) 'DO YOU WANT VECTORS?' (AIP, GEN 3.4, 5.14.3)

The phrase 'SAY AGAIN', defined as in (15), must be used either by pilots or ATC instead of the question 'What did you say?'.

(15) 'SAY AGAIN'
*Meaning*: 'Repeat all or the following part of your last transmission.' (AIP, GEN 3.4, 4.13.1)

The example in (16) is an instance of (15) from the flight simulator experiment data (see Chapter 7).

(16) *Pilot* (P17): Say again the heading, ABC.

Thus, 'SAY AGAIN' acts as a question marker and (16) is interpreted as 'What was the heading (you gave me)?', which can sometimes be heard instead.

The term 'CONFIRM' also acts as a question marker, as shown in (17). It is used to request the other station to repeat an instruction or a readback.

(17) 'CONFIRM'
*Meaning*: 'Have I correctly received the following…?' or 'Did you correctly receive this message?' (AIP GEN 3.4, 4.13.1)

Sometimes, in a subtle shift of meaning, and using the word in its ordinary colloquial sense, ATC will use the verb 'CONFIRM' to ask an aircraft to read back again an incorrect readback. Such an example of the incorrect use of 'CONFIRM' and the way it can lead to confusion for EL2 pilots was provided by an ATC instructor (McMillan, personal communication) and is explained in (18).

(18) Most controllers are sensitive to the problems of foreign pilots speaking English. Sometimes they don't appreciate how narrow the understanding of the language is, though. An example I use in class occurred when I was training another controller. The word 'CONFIRM' has a specific meaning in AIP, to query something, such as 'Confirm climbing to flight level two zero zero'. However some Australian controllers, and pilots, [mis]use it more colloquially to correct an incorrect readback.

My trainee said to a Thai pilot: 'Descend to flight level two nine zero'.

The pilot read back: 'Descend to flight level two five zero'.

To which the trainee responded: 'Confirm flight level two nine zero'.

There was a short silence, perhaps the pilots were conferring with each other, then a response: 'What is it that you want me to confirm?'

Quite a few errors here: the trainee should have said 'niner', and responded with 'Negative, descend to flight level two niner zero'. And it highlights the very specific understanding that a foreign pilot has of particular words (Estival and Molesworth, 2009: 24.14).

In this example, ATC used 'CONFIRM' as in (19.b) rather than (19.a), but the EL2 pilot could not understand the colloquial usage, nor interpret the utterance given the context. For the pilot, 'CONFIRM', as per the standard phraseology, acted as a question marker, and there was no possible question at that point in the exchange.

(19) 'CONFIRM'
   a. 'to query something' (standard Aviation English, as per the AIP).
   b. 'to correct an incorrect readback' (informal use, plain English).

Questions, both content questions (using WH-words) and Yes/No questions, are routinely used in Pilot–ATC exchanges when needed (see Hinrich, 2008, for examples from a corpus of 24 hours of routine transmissions). For instance, in (20), when the pilot informed ATC of a loss of power situation during initial climb, the tower offered another runway for landing.

(20) a. *Pilot*: Camden Tower. LSI. Change of intentions. Will turn downwind for Runway 24. Loss of power.
b. *ATC*: LSI, understood. Do you want to take Runway 10?

In example (21), ATC helpfully offers further information to a pilot who had only requested one piece of information (the QNH, i.e. sea level barometric pressure).

(21) a. *Pilot*: Sydney Centre. Cherokee IMX. Request area QNH for area 21.
b. *ATC*: IMX. Area QNH for area 21 is 1018. Do you want the amended winds for the area?

Of course, outside controlled airspace (OCTA), where pilots can talk to each other without going through ATC, we find many examples of questions, usually in plain English, as in (22.a) or (22.b).

(22) a. *Pilot*: Aircraft calling North of Goulburn, when do you expect to be in the circuit?
b. *Pilot*: Aircraft over Warragamba Dam, what's the cloud base?

When ATC is busy or when the frequency is congested with a number of aircraft trying to make their calls, situations can arise when it is not possible to get a word in at the right time. Such a situation, where ATC was clearly stressed by many aircraft arriving at the same time, some making unusual requests, gave rise to the exchange shown in (23).

(23) a. *ATC*: IMX. Join downwind 29 Right. Maintain 1500. Traffic is another aircraft doing the same.
b. *Pilot*: Downwind 29 Right. Maintain 1500. Looking for traffic. IMX.
[Several exchanges between ATC and other aircraft. The pilot of IMX wonders whether to report at the usual 3NM, although that was not requested, but there is no gap in which to make the report. Eventually, turns downwind and manages a call.]
c. *Pilot*: IMX, turning downwind 29 Right.
d. *ATC*: IMX. You did not report! IMX. Where did you come from?

In (23.d) ATC uttered a very unusual negative construction and an even more unusual question, with highly emotional intonation indicating surprise and dismay at the situation, but still used the correct address in the right position.

*Negation*

Negative constructions are very rare, because they signal 'unusual' situations, where either ATC or the pilot are unable to comply with a request or where further information needs to be provided, as in (24) below. In such cases where a negation is needed, it is imperative to avoid the English words 'no' and 'not', which are too short and phonologically weak and could easily be missed in the transmission, potentially leading to confusion with the positive form and to serious misunderstanding. Negation must be conveyed by the term 'NEGATIVE', followed by a corrective statement as in (24.b), not by a negative answer as in (24.c), even when the prior transmission was a question which did not strictly follow the phraseology.[9]

(24) a. *ATC*: LSI, is this for a touch and go?
b. *LSI*: Negative, full stop. LSI.
c. *LSI*: *No, that's a full stop.[10]

Nevertheless, this is a rule with a number of exceptions. In fact, the regulations recommend the phrases shown in (25), even though they contain the words 'no' or 'not'.

(25) a. 'CLEARANCE NOT AVAILABLE.' (AIP, GEN 3.4, 5.10)
b. 'NO DELAY EXPECTED.' (AIP, GEN 3.4, 5.12)

Conversely, an affirmative answer must start with the word AFFIRM (pronounced 'AY-firm', with the stress on the first syllable), and not with the word 'Yes', which is also too weak and could be misheard (Moder, 2013).

Philps (1991: 123) noted that 'Phraseology interweaves 2 systems: the structural system of an English sub-grammar and a system of referential values common to its domain (ATC) and to the speech community within the domain.' Philps described the syntax of AE from the dominant linguistic framework current at the time, Transformational Grammar (TG) (Chomsky, 1965, 1981), which is now outdated and would not be considered relevant to the discussion of varieties of ESP. Nevertheless the TG framework allowed him to identify the differences between AE and 'natural' English in terms of the deletion and movement transformations, the operations relating the source language ('natural' English) and the derived language (Aviation English) by analogy with the relation between 'deep' and 'surface' structures in that syntactic framework. As seen in example (2) earlier, deletion or omission of grammatical elements is a salient feature of AE and very few grammatical words are included in the phraseology, mostly prepositions as described in the next section. Because the rigid syntax of ATC messages already takes into account the small semantic contribution of those omitted elements, which is why they are not part of the messages in the first place, their omission does not result in greater miscommunication.

### *Grammatical categories*

Full lexical content word categories, i.e. verbs, nouns, adjectives and adverbs, are discussed later in the *Lexical level* section. Here we discuss the functional grammatical categories prescribed by the phraseology. As mentioned earlier, few grammatical words are included in the phraseology, mostly prepositions.

#### *Prepositions*

A wide range of prepositions is included in the standard phraseology: 'FROM', 'TO', 'AT', 'IN', 'OF', 'VIA', 'BEHIND', 'ABOVE'. Some examples are listed in (26).

(26) a. 'LINE UP RUNWAY [number] **BEHIND** [aircraft].'
b. 'NOT **ABOVE** [number].'
c. 'CLEARED **TO** [destination].'
d. 'TAXI **TO** HOLDING POINT [X] **VIA** RUNWAY [number].'
e. 'GIVE WAY **TO** [other aircraft description, e.g. the Cherokee on taxiway E]'.
f. 'CLEARED **FOR** THE OPTION.'
g. 'CLEARED **FOR** TAKE-OFF.'
h. 'HOLD **ON** THE [3 digit number, e.g. 190] RADIAL **OF** THE VOR/TACAN [name].'
i. 'HOLD **AT** [way-point, facility or fix].'
j. 'TRAFFIC **IN** SIGHT.' (AIP, GEN 3.4, 5.14)

Prepositions which would be used in 'natural' English are often omitted, especially 'TO' because of possible confusion with the numeral 'two' (and possibly with the adverb 'too'). Thus (27.a) is discouraged in the ICAO Manual and the AIP but is nevertheless heard regularly, both from pilots and from ATC.

(27) a. *Climb **to** 7500.
b. Climb 7500.
c. Climb **to** Flight Level 75

For an altitude measured in feet using the barometric pressure at sea level (i.e. the QNH), 'TO' should not be used in front of the numerals, so (27.a) is not correct. However, 'TO' is allowed in front of 'Flight Level', for an altitude measured using the standard atmospheric sea level pressure of 1013.2 hPa, as in (27.c).

Similarly, when they 'call downwind' (i.e. during the approach to land) pilots are discouraged from using 'FOR' with the runway number, as in (28.a), but this is heard very often instead of the prescribed (28.b).

(28) a. *Pilot*: LSI. Downwind **for** Runway 24. Touch and Go.
b. *Pilot*: LSI. Downwind Runway 24. Touch and Go.

To conclude this section on prepositions, it is worth mentioning that the phrase 'Over and out', sometimes heard on the radio from people who may think it sounds professional, is an absurd contradiction, as seen in the definitions given in (29).

(29) a. 'OVER'
*Meaning*: 'My transmission is ended and I expect a response from you.' (*not normally used in VHF communication*).
b. 'OUT'
*Meaning*: 'My transmission is ended and I expect no response from you.' (*not normally used in VHF communication*). (AIP GEN 3.4, 4.13.1)

### *Determiners*

Determiners are usually omitted, although there are some examples of 'the' in the prescribed forms given in (26) earlier. Specific determiners to be used in the phraseology are 'OWN' as in (30.a) and 'THIS' as in (30.b).

(30) a. 'RESUME **OWN** NAVIGATION.'
b. 'REMAIN **THIS** FREQUENCY.' (AIP, GEN 3.4, 5.14)

### *Auxiliary and modal verbs*

Auxiliary and modal verbs are not part of the phraseology. Inability to comply with an instruction must be expressed using 'UNABLE TO COMPLY', as in (31) in which the crew gives the reason why they cannot obey an instruction.

(31) 'UNABLE TO COMPLY. WIND SHEAR ESCAPE.' (AIP, GEN 3.4, 5.1)

Understandably however, modal verbs do appear in plain English communications. For instance, in (20.a) earlier (repeated below for ease of access), in the situation where power was lost soon after take-off, the pilot used 'will' to advise ATC of the intention to return to the airfield instead of leaving for the training area as previously intended.[11]

(20) a. *Pilot*: LSI. Change of intentions. **Will** turn downwind for Runway 24. Loss of power.

For a more detailed discussion of use of modals for mitigation and politeness purposes (see Hinrich, 2008; Moder, 2013; Sänne, 1999).

#### *Pronouns*

Only first person pronouns, 'I' and more often 'we', and second person pronouns, 'you', are used in AE. There is rarely, if ever, a third person pronoun, whether 'he', 'she', 'it' or 'they', because a noun phrase (NP) is always repeated in full, for instance 'traffic' in (32.b), and not referenced by a third person pronoun as in (32.c).

(32) a. *ATC*: LSI, traffic at your 2 o'clock is a Cessna departing crosswind.
b. *Pilot*: Traffic sighted. LSI.
c. *Pilot*: *I can see it.

## Lexical level

### *The 'phraseology' proper: words and phrases to use*

The phraseology proper consists of a limited vocabulary with a restricted number of words for each lexical category: verbs, nouns, adjectives and adverbs. This vocabulary is detailed in the ICAO Manuals and the AIP, with the exception of proper names which can be found in more specialized documents such as the aeronautical charts. It also includes specified ways of expressing various units of measures, of expressing time, and the well-known 'Clock Code'. It would be tedious to give an exhaustive list of the items for each lexical category and this section only presents the most salient items, with examples of the contexts in which they are used.

#### *Adjectives*

There are very few adjectives in AE phraseology. The most important ones are 'CLEAR' and 'UNABLE'. As seen earlier, 'UNABLE' acts as a modal to express inability to comply. Somewhat surprisingly, 'CLEAR' is ambiguous between the 'clearance' meaning, as in 'Clear to land', and the meteorological use in weather information in 'Sky clear' to indicate lack of cloud, but of course in practice this ambiguity would be very unlikely to lead to any confusion.

Another adjective which seems unambiguous but needs explanation is 'VISUAL', as in (33).

(33) ‘CLEARED VISUAL APPROACH’
*Meaning*: When you have the runway visual, you can descend to circuit height, at your own discretion.

In most other instances, ‘visual’ contrasts with ‘instrument’, e.g. ‘Visual Flight Rules’ (VFR) is opposed to ‘Instrument Flight Rules’ (IFR). In (33), however, the adjective ‘visual’ does not modify the noun ‘approach’ in opposition to an ‘instrument approach’; (33) is a clearance used at Class D aerodromes which gives the pilot control as to when they decide to descend. Some pilots take it as an instruction to descend immediately, even if they don’t have the runway in sight.

The adjectives ‘EARLY’ and ‘LATE’ do not refer to timeliness, but to positions in one of the legs of the circuit pattern (i.e. Downwind, Base, or Final); they contrast not only with each other, but also with ‘MID’, as shown in (34) and (35).

(34) a. *Pilot*: LSI, Late downwind runway 06.
b. *ATC*: LSI, Number 2. Traffic is a Cherokee early base.

(35) a. *Pilot*: LSI, Downwind runway 24.
b. *ATC*: LSI, Number 3. Follow the Citabria mid-downwind.

*Adverbs*

There are also very few adverbs to express modification in AE. The most salient adverb would have to be ‘IMMEDIATELY’, as in (36) and (37).

(36) ‘STOP IMMEDIATELY.’
*Meaning*: ‘Stop a take-off in emergency conditions’. (*Used only when an aircraft is in imminent danger*.) (AIP, GEN, 3.4, 5.14.6)

(37) ‘TAKE OFF IMMEDIATELY OR VACATE RUNWAY.’
*Meaning*: ‘when take-off clearance has not been complied with.’ (AIP, GEN 3.4, 5.14.6)

Philps (1991) noted the occasional fronting of ‘immediately’ as in (38) and surmised that considerations of speed and safety led to the expression of the justification for the instruction before the instruction itself, to give the pilot a sense of urgency, unlike in ‘natural’ English where such fronting would not occur.

(38) ‘IMMEDIATELY TURN (direction) HEADING (degrees).’ (AIP, GEN 3.4, 6.15.1)

Interestingly, (38) is actually an instance of datalink communication rather than radio voice transmission, and no such fronting occurs in the phraseology for radio transmissions, nor in the voice data so far collected by the authors.

### *Verbs*

There are too many verbs prescribed in the phraseology (ICAO Manuals and AIP) to list them all. A number of them (e.g. 'climb', 'descend', 'maintain') have appeared in the examples given in this chapter and do not require further explanation. A few more deserve attention in their own right, because they may give rise to confusion. For instance, the difference between 'REQUEST' and 'REQUIRE' needs to be explained to student pilots. The verb 'REQUEST', defined in (39), may convey a request for information, as in (18.a) earlier (repeated below), which ATC supplied in (18.b),

(39) 'REQUEST.'
*Meaning*: 'I should like to know or I wish to obtain.' (AIP, GEN 3.4, 4.13.1)

(18) a. *Pilot*: Sydney Centre. Cherokee IMX. Request area QNH for area 21.
b. *ATC*: IMX. Area QNH for area 21 is 1018. Do you want the amended winds for the area?

'REQUEST' can also express a preference for a particular runway as in (40.a), which ATC did not grant (40.b).[12]

(40) a. *Pilot*: ABD request runway centre.
b. *ATC*: Negative, ABD. Runway centre not available.

Unlike a 'REQUEST', which can be denied by ATC, 'REQUIRE', as explained in (41), indicates not a preference but an operational requirement, which ATC cannot refuse.

(41) 'REQUIRE'
*Meaning*: 'A pilot in command must notify ATC if a particular turn or circuit is essential to the safe operation of the aircraft by use of the word "REQUIRE".' (AIP, ENR 1.1, 4.7)

For instance a pilot would use the term 'REQUIRE' if a cross-wind component on the runway in use was in excess of the aircraft limitations or of what the crew could safely handle. Although ATC cannot deny such a request, since it is an operational requirement in the opinion of the pilot in command, they may question the pilot's judgement and investigate the incident if it leads to a conflict which could otherwise have been avoided. Therefore, the decision to 'REQUIRE' is not taken lightly by a pilot. On the other hand, ATC can suggest to a pilot, especially a student pilot in a light aircraft, that they might want to consider the cross-wind and ask for another runway, as in (42).

(42) *ATC*: LSI. Mean cross-wind 18 knots. Runway 10 is available. Would you prefer runway 10?

Such an offer shows awareness of aircraft limitations on the part of ATC (the maximum cross-wind for a Jabiru is 14 knots) and recognition of the pilot's experience (in this case a student relatively new to the airfield whose recognizable Irish accent readily identified him to ATC).

Nevertheless, even the careful design of the phraseology cannot entirely prevent misunderstanding. The verb 'EXPEDITE' is used by ATC to convey the need to comply quickly with an instruction. Example (43) was related to the author by a student who was still amazed that neither ATC nor the instructor in the cockpit had picked up on her erroneous readback in (43.b), probably because the only exit possible from Runway 29 Right is on the right, and because she had performed the exit quickly enough.

(43) a. *ATC*: Clear to land 29 Right. Expedite.
b. *Pilot*: Clear to land 29 Right. Exit right.

The verb 'EXPEDITE' was the cause of confusion in another incident. The student pilot had never heard the phrase in (44), which is not standard phraseology, and slowed down to ask the instructor what he was supposed to do instead of exiting the runway quickly, thus forcing another aircraft to go around.

(44) *ATC*: MHF. Expedite vacating.

### *Nouns and proper names*

As with verbs, there is an extensive list of nouns prescribed in the ICAO Manuals and the AIP. The list of nouns, however, is much larger than that for verbs because it also includes location designators and proper names. The location designators and proper names to be used can be found on the aviation charts or in aeronautical publications such as the ERSA (En Route Supplement Australia) or the DERS (Digital En Route Supplement, for the USA). 'Mayfield', 'Prospect Reservoir' and 'Warragamba Dam' are some proper names found in the examples given earlier in this chapter.

*Call-signs and mistaken identities*

All aircraft and all ground stations are known by and addressed with a specific designator. The examples given in this chapter follow the pattern of Australian call-signs for GA, consisting of 3 letters (e.g. 'LSI') or 4 digits (e.g. '4868') depending on the type of aircraft. Other countries follow different patterns, with sequences of letters in Europe or sequences of digits in the USA. Commercial airlines are attributed designators which identify not the aircraft itself but the flight it is operating (e.g. AV052 mentioned in Chapter 1). The principle is the same, with only one designator for each station. In spite of the phonetic alphabet and the specified pronunciation for letters and numbers (see later), confusion of call-signs is recognized as one major cause of errors (ATSB, 2009; EUROCONTROL, 2006).

Sometimes pilots, and more rarely ATC, use the wrong call-sign when addressing another station (e.g. 'Camden Tower' instead of 'Camden Ground', or 'DGU' instead of 'DGI'). Sometimes, pilots even use the wrong designator to refer to themselves. These cases are not catered for in the phraseology and give rise to creative comments in plain English, such as the examples in (45) and (46), in which the pilots use the wrong call-sign when calling before landing. In (45), the pilot had been flying the same aircraft type during the day for similar operations (circuit training) and used the call-sign of the previous aircraft he had been flying.

(45) a. *Pilot*: RRW, downwind touch and go.
b. *ATC*: RRW, are you sure that's who you are?
c. *Pilot*: … actually, that's MWY.

In (46) the pilot, used to flying several aircraft types, including a glider with call-sign WVJ, was doing circuit training in a Piper with call-sign SWV. During that session of circuits, the glider WVJ called downwind on another runway. The similarity between the two call-signs and the familiarity of saying (46.b) as well as (46.a) caused the pilot's error in (46.c). It took ATC a couple of seconds to recognize that (46.c) was incorrect and that Pilot 1 was still flying SWV.

(46) a. *Pilot 1*: SWV, downwind for touch and go. [Several times during a training session]
b. *Pilot 2*: Glider WVJ, downwind.
c. *Pilot 1*: WVJ, downwind for touch and go.
d. *ATC*: [silence]
e. *Pilot 1*: WVJ, downwind for touch and go.
f. *ATC*: Oh, the **other** WVJ … SWV, cleared touch and go.

In both of these examples ATC sounded quite amused and neither situation was a cause of concern. ATC knew the pilots and their flying habits, recognized the voices and the types of aircraft and was able to maintain a picture of the situation. Pilots and ATC enjoy telling such stories, partly because they are rare events and partly because they allow some humour on the frequency, breaking the monotony of the usual exchanges.

### *Expressions of time*

Time in aviation is expressed according to the universal time coordinate (UTC), which for all intents and purpose is the same as Greenwich Mean Time (GMT). All flight plans, weather forecasts and other expressions of time, e.g. for arrival and departure, are expressed using the 24-hour clock in UTC, thus avoiding confusion between local times at different locations. There are 24 time zones around the globe, designated alphabetically, with UTC as Z (ZULU). The weather forecast (TAF = Terminal Area Forecast) for Bankstown (YSBK) in (47.a) shows the date and time format, and is to be interpreted as spelled out in (47.b).

(47) a. TAF YSBK 062257Z 0700/0712
b. Terminal Area Forecast for Bankstown (created at) 06 (day) 22 (hour) 57 (minutes) ZULU (i.e. UTC) (valid from) 07 (day) 00 (hour) (to) 07 (day) 12 (hour)

The time of creation (062257Z) is given in the 6-digit date–time group, while the period of validity is given with two 4-digit time groups. If these had to be read or given over the radio, they would be pronounced as in (48).

(48) a. 0700: zero seven zero zero
b. 0712: zero seven one two

During many radio communications, however, time is given using only minutes because the hour is understood to be the current hour. Thus, for instance, when giving the expected time for arrival at Goulburn in (49.a), the time will be given as ‘four two’ to mean, e.g. 05:42. If the time of arrival falls in the next hour, as in (49.b), it is still given as a two-digit group (pronounced ‘zero two’).[13]

(49) a. Goulburn traffic. LSI 10 NM to the East, 5500. Expect overhead at 42.
b. Goulburn traffic. LSI 10 NM to the East, 5500. Expect overhead at 02.

When recording flight times in a pilot's logbook, or engine time in the aircraft maintenance documents, time is usually expressed using the decimal system, with one-tenth of an hour equal to 6 minutes. Thus '3.6 hours' equals '3 hours and 36 minutes', while '.5' means 'half an hour' or '30 minutes'. This is not always as transparent as one might wish.

### *Clock code*

The so-called 'clock code' is probably well known by anyone who has watched action or war movies. It does not express time, but relative position using the image of a traditional clock face with numbers around a circle. 'At 2 o'clock' thus means 'at 60 degrees to the right', while 'at 9 o'clock' means 'at 90 degrees to the left'. Student pilots who have only ever used digital watches sometimes have difficulties learning to use this system of reference.

The following example shows the type of difficulties experienced by even highly trained EL2 pilots. The incident described in (50) was provided by a military ATC who was working on a joint exercise with New Zealand and French forces.[14] Since she knew French, she was able to understand that the French liaison officer used a direct translation from the French '6 heures', instead of the standard English '6 o'clock'.[15]

(50) Yesterday I was asked by the French liaison if I would allow a helicopter to fly over 6 hours. What he meant to say was, request permission to fly over your 6 o'clock.

### *Units of measure*

While not strictly speaking a linguistic issue, units of measure are a notorious area of potential confusion in aviation. Pilots, and sometimes engineers,[16] have been known to confuse litres with kilograms, pounds with gallons, and feet with metres. The problem is two-fold: different units of measures for the same type of measurement (i.e. weight, distance or speed) depending on the purpose of the measurement (e.g. horizontal or vertical distances), and different units of measure depending on the country (e.g. fuel quantities in US gallons, imperial gallons or litres) or on the country of manufacture of the aircraft (weight in pounds for British or US aircraft, kilograms for others).

Distances on the ground are measured in nautical miles (NM) for navigation and in metres (sometimes feet) for runway length and width. Vertical distances, e.g. aircraft altitude, mountain elevation or vertical distance from cloud, are measured in feet. Thus, horizontal speed is measured in knots (NM/hour) while vertical speed is measured in feet/second (or metres/second in some glider instruments). However, horizontal distance from cloud is given in metres. Moreover, statute miles are often used in the USA for distances on the ground (1 NM = 1.852 km; 1 SM = 1.609 km).

Quantities of fuel can be measured in litres or in gallons (either US or imperial), depending on the aircraft manual and company policy. Weight, including weight of fuel, is calculated in kilograms or in pounds, again depending on the aircraft manual and company policy. Pilots become adept at converting one unit into the other but this takes time and requires constant vigilance as to what unit is used when calculating take-off weight (TOW) and fuel for endurance.

Headings, tracks and bearings are expressed in degrees. The difference between magnetic North (compass indicating the magnetic North) and true North (map showing the North Pole) also requires calculation, but further discussion would take us into the operational rather than linguistic domain.

### *Non-standard phrases*

As stated in (Estival and Molesworth, 2012: 360):

> The most important linguistic factor for aviation communication is the choice of lexical items or phrases. This has long been standardised – to a greater or lesser degree in different countries depending on the country (e.g. foreign pilots sometimes complain that US pilots do not use the ICAO standards they are used to) and the type of operations (commercial or GA) – and all pilots are trained in the use of R/T (radio-telephony) procedures, i.e. the correct use of calls and readbacks. … Many reported cases of non-standard terminology involve the use of local or colloquial names for locations.
>
> Example [(51)] was heard by the first author in the circuit at Bankstown Airport: ATC knew the pilot of aircraft ABC (not the real call-sign), who was requesting a clearance for Sydney (in an abbreviated format because of a prior exchange), and used a non-standard colloquial term instead of the standard location designator.

(51) a. *ABC*: … Request clearance.
b. *ATC*: Tower, Alpha Bravo Charlie. Cleared for the Smoke.

Most English NSs and many of the local pilots would probably understand that ‘The Smoke’ refers to the city of Sydney. The problem is that an early EL2 student pilot might not understand this local designation and would lose the required situation awareness regarding other aircraft in the airport airspace. In such cases, as pointed out by Illman (1998), the issue is that, even when a message is not addressed directly to other pilots, ATC communications need to be understandable by other pilots who may also need the information.

### *Changes in the phraseology*

The phraseology is not fixed once and for all: there are regular updates to the AIP every 3 months and ICAO is constantly reviewing possible modifications. When a possibility for confusion has been recognized, ICAO and other bodies may recommend changes which then become part of the regulations (see Chapter 3). Some recent examples are given below:

- 'GO AHEAD'
  'Go ahead' was often used by ATC to ask an aircraft to resume communication after an interruption, for instance after 'STANDBY' (see (10) earlier) but the 'use of the words 'GO AHEAD' is no longer considered appropriate due to the possibility of misconstruing 'GO AHEAD' as an authorization for an aircraft to proceed.' (AIP, GEN 3.4, 4.3.2, 5 June 2008)

- 'LINE UP AND WAIT' / 'POSITION AND HOLD'
  In the case of these two phrases, the confusion was due to a discrepancy between differences of usage in the USA (the FAA is the US Federal Aviation Administration) and the rest of the world. This was found to contribute to runway incursions, i.e. incidents when an aircraft enters a runway without a clearance. The new regulations, applicable around the world, now make it clear the USA must adopt the international terminology:

  > Differences in phraseology contribute to runway incursions. Analysis by the National Transportation Safety Board (NTSB) revealed that differences between FAA and International Civil Aviation Organization (ICAO) air traffic control phraseology contribute to runway incursion risks. NTSB recommended that the FAA adopt the international standard terminology: 'Line Up and Wait' to replace 'Position and Hold'.
  >
  > … Beginning on 30 September 2010, the words 'Position and Hold' will no longer be used to instruct a pilot to enter the runway and await take-off clearance. (http://www.faa.gov/airports/runway_safety/news/current_events/lauw/)

- 'AT PILOT'S DISCRETION' / 'WHEN READY'
  This is another example of discrepancy between usage in the USA and the rest of the world. 'AT PILOT'S DISCRETION' is a phrase used in the USA and is not the same as 'WHEN READY'. The recent circular in the Australian AIP (8 August 2014), clarifies the usage and explains the possible risk of confusion:

  > ATC use the phrase 'WHEN READY' to authorise a pilot to execute a level change 'when convenient'. This means the pilot can start the

> authorised level change when they wish, conduct it at any rate but cannot level off at any intermediate altitude even temporarily. The phrase is defined in the same terms in ICAO Doc 4444, PANS-ATM.
>
> 'AT PILOT'S DISCRETION' is a phrase used exclusively in the US and means a pilot can start a climb or descent when they wish, conduct it at any rate but, importantly, allows the pilot to temporarily level off at any intermediate altitude.
>
> 'AT PILOT'S DISCRETION' is not permitted for use in Australia.
>
> Use of the phrase 'AT PILOT'S DISCRETION' has the potential to result in ATC and/or pilots not fully appreciating the requirements of a level instruction.
>
> The potential for confusion has been recognised by EUROCONTROL and the International Federation of Air Line Pilots' Association (IFALPA). (AIP, AIC H20/14)

EUROCONTROL (2014) gives further recommendations regarding the use of these two phrases:

> Non-US air navigation service providers are also invited to:
>
> - Note the subject and share any relevant operational experiences concerning the issues described.
> - Note the availability of both 'AT PILOT'S DISCRETION' and/or 'WHEN READY' type phrases for specific CPDLC messages and CDO operations.
> - Consider using the voice phrase 'WHEN READY', as per PANS ATM Chapter 12 Phraseologies, rather than 'AT PILOT'S DISCRETION' when it is appropriate to do so.
> - Exercise caution in approving verbal requests from pilots to climb/descend 'AT OWN DISCRETION'.

## Phonological level

### *Pronunciation*

The aspect of aviation language with which the general public would already be most familiar is probably the 'International Phonetic Alphabet' (not the IPA familiar to linguists), which is sometimes mistakenly thought to apply only in military contexts. It was designed to provide unambiguous words for each letter of the alphabet. The pronunciation of these words is further specified to eliminate difficult English phonemes and the regulations also specify stress placement to limit possible ambiguities. The pronunciation guide, with stressed syllables in uppercase, is given in (52).

(52) Radiotelephony pronunciation of the Phonetic Alphabet shall be as follows:

| | | | | | |
|---|---|---|---|---|---|
| A | ALFA | AL fah | B | BRAVO | BRAH voh |
| C | CHARLIE | CHAR lee | D | DELTA | DELL tah |
| E | ECHO | ECK ho | F | FOXTROT | FOKS trot |
| G | GOLF | GOLF | H | HOTEL | ho TELL |
| I | INDIA | IN dee A | J | JULIETT | JEW lee ETT |
| K | KILO | KEY loh | L | LIMA | LEE mah |
| M | MIKE | MIKE | N | NOVEMBER | no VEM ber |
| O | OSCAR | OSS cah | P | PAPA | pah PAH |
| Q | QUEBEC | keh BECK | R | ROMEO | ROW me oh |
| S | SIERRA | see AIR rah | T | TANGO | TANG go |
| U | UNIFORM | YOU nee form | V | VICTOR | VIK tah |
| W | WHISKY | WISS key | X | X-RAY | ECKS ray |
| Y | YANKEE | YANG key | Z | ZULU | ZOO loo |

(AIP, GEN 3.4, 4.9.1)

Because of the greater confusability of certain sounds (e.g. those represented in English by the letters 'M'/'N', 'B'/'P', 'S'/'TH', 'TH'/'T', 'F'/'V', 'F'/'N'), the pronunciation of certain words in the phraseology, in particular numerals, is prescribed to minimize known sources of confusion. The main examples are given in (53):

(53) a. 'five', 'nine' pronounced as 'fife', 'niner'
b. 'three' pronounced as 'tree'
c. 'thousand' pronounced as 'tousand'

The lexical stress prescribed for certain words is also not always the one found in 'normal' English. Again this is especially the case with numbers, in order to avoid possible confusions with disastrous consequences, see (54).

(54) NUMERALS

| | | | | | |
|---|---|---|---|---|---|
| 0 | ZE-RO | 5 | FIFE | Decimal | DAY-SEE-MAL * |
| 1 | WUN | 6 | SIX | Hundred | HUN-DRED |
| 2 | TOO | 7 | SEV-EN | Thousand | TOU-SAND |
| 3 | TREE | 8 | AIT | | |
| 4 | FOW-ER | 10 | NIN-ER | | |

(AIP, GEN 3.4, 4.10.1)

*Note: 'decimal', not 'point'; thus 'frequency 121.7' becomes 'one two one decimal seven', not 'one two one point seven'.

It is fair to say that English NESs find these pronunciations unnatural and do not consistently use them. This confirms the view that AE is a code that must be learned even by NESs and that NESs need to adapt their language when switching to the AE lingua franca.

### *Prosody*

Under prosody, we consider intonation and speech rate. Lack of intonation, rhythm and pauses is typical of rapid aviation radio communication and particularly problematic because no visual cues are present. Though ICAO (2001) recommends that for all stations the 'Rate of speech on radiotelephone broadcasts shall not exceed 100 words per minute', McMillan (1998: 46) found that speed of delivery and lack of pauses were a significant cause of readback errors and that 'The rapid speed at which controllers deliver instructions is probably the most common miscommunication complaint received from pilots.' Prinzo (2008) found that readback errors are more common when ATC communications are complex and not clearly broken down by pauses. Barshi (1997) investigated the effects of prosodic elements of speech such as speech rate and pausing on pilot readback accuracy, and Barshi and Healy (1998) extended Barshi's (1997) study to include non-native speakers of English. Interestingly, they concluded that, although length of messages was important, prosodic elements such as speech rate and pausing did not negatively impact pilot comprehension of controller messages, as anecdotal evidence had suggested; nevertheless Barshi and Farris (2013: 71) suggested that speech rate may be 'more of a factor for longer messages than it is for shorter messages'.

Citing Miller (1951: 74) that 'under otherwise optimal conditions, we could double our normal rates of talking without becoming unintelligible', Barshi and Farris (2013: 72) propose that

> it might be the case that rather than pilots not understanding because controllers speak too fast, pilots may misunderstand, and attribute their failure to comprehend to the controller's speech rate when, in fact, the misunderstanding was caused by something else such as message length or reduced distinctiveness of phonetic features.

However, radio communication between ATC and pilots is not 'otherwise optimal'; for one thing, when pilots are communicating they are usually also performing a number of other tasks necessary for safe flight. It is well known that multitasking consumes limited cognitive resources, hence under actual flight conditions the results might be different. Moreover, Barshi (1997) manipulated speech rates by compressing the words for faster rates and by adding pauses for the slow rates, which is not natural fast speech or slow speech, and these negative findings (i.e. no effect for speech rate) may not extend to real ATC communication. Other factors intersecting with speech rate may in fact turn speech rate into a contributing factor. Lack of evidence under these conditions is not evidence for lack of impact and, as suggested by Barshi (Barshi and Farris, 2013: 106), 'It is possible that naturally occurring fast speech rates would cause problems in comprehension because of losses in distinctive phonetic features due to coarticulation, slurring and loss of stress.' The work by Barshi and Farris is further discussed in Chapter 5. The experiments conducted in a flight simulator by Molesworth and Estival (2015) investigate the effect of natural slower and faster ATC speech rate on pilots' communication performance and are discussed in Chapter 7.

## Conclusion

Aviation English (AE) is an instance of a 'vehicular language for transportation', i.e. a lingua franca for a specific sub-domain of international transportation. More specifically, it is one of the aviation languages. In this chapter, we described AE from a linguistic perspective, from the discourse level to the phonological level, giving a number of examples of the phraseology from the AIP, as well as naturally occurring examples of pilot radio communication. The required words and phrases in the regulations (ICAO Manuals and AIP) are part of the phraseology but that is not all that an aviation language is. All aviation languages, including AE, also include specific rules for turn-taking and for pronunciation as well as recourse to plain language in some situations.

Plain English is often defined as language used in problematic situations (Moder, 2013) or when specific phraseology is not available for a situation. For example, where unanticipated circumstances 'result in landing at the destination aerodrome with less than the fixed fuel reserve … [T]here is no specific phraseology in this case as each situation may be different' (AIP, ENR 1.1, 60.4.2), and, in that case, 'plain English must be used' (AIP, GEN 3.5, 4.1.4). We gave examples where plain English is used by ATC to pilots (20.b; 21.b; 23.d; 24; 44), and between pilots (22.a; 22.b). As noted by Moder (2013), plain language used by NES in normal situations may cause problems for EL2 speakers, and we showed a specific example where colloquial use of specific terms would be problematic for an EL2 pilot (51).

We conclude by considering the impact of communication difficulties on aviation safety. As noted by Moder (2013), although problematic transactions occur with relatively low frequency (less than 12 per cent), these occurrences are of great concern and good communication is essential for aviation safety. An ATSB (2010: 13) report on accidents, which gives the impact of various threats to aviation safety, includes communication errors among those threats and shows that 'communicating and coordinating' were contributing errors to 25 per cent of fatal accidents. The same report (ATSB, 2010: 16) found that 'the 3 most commonly perceived threats to GA pilots were adverse weather, traffic (air or ground congestion) and *issues with ATC commands and communications*', while 'the 3 most common errors reported by pilots were procedural checklist errors, *radio errors and communication errors with ATC or other aircraft*' (emphasis added).

Similarly, ATSB (2009: 3) gives as examples of threats to aviation safety: 'ATC/Communication: ATC command/error; ATC language difficulty; ATC non-standard phraseology; radio congestion; similar call-signs; pilot-to-pilot communications; pilot language difficulties.'

Thus, the recommendations to pilots (ATSB, 2009: 11) are as follows:

> To increase the likelihood that your message is accurately transmitted:
> - use correct terminology
> - communicate when there are no cockpit distractions
> - speak slowly and clearly
> - seek feedback if it is not apparent the message has been understood.

However, pilots cannot be considered proficient in AE if they are not able to handle the 'core', i.e. the phraseology and the prescribed turn-taking. Being able to handle Plain English is not sufficient to be able to communicate correctly in the aviation environment.

## Notes

1 Nickerson (2013: 199) makes the point that the term 'Business English' in Japan is used to refer to the field of business communication as if the two terms were synonymous. Here, I wish to make a clear distinction between Aviation English and aviation communication, which are too often also used interchangeably.

2 Most of the examples in this chapter are real examples collected by the author during the course of instructional flights from either Camden or Bankstown, NSW, Australia, as part of a research project funded by the MARCS Institute, UWS. Other examples (as noted in the text) come from the flight simulator experiments described in Chapter 7.

3 Philps (1991) analysed ATC English (not from pilots' communications and not from actual utterances, but from the regulations). Lopez (2013) collected data from several ATC centres in France and compared the data to a corpus of example utterances from training manuals. Hinrich (2008) used a corpus of messages broadcast from Toronto and Dublin, Moder (2013) used the OSU (US-based) corpus, while Barshi (1997) used the Portland recordings (also US-based).

4 We use 'code' as a neutral term, as defined by Crystal (1991: 59): 'a neutral label for any system of communication involving language – and which avoids sociolinguists having to commit themselves to such terms as DIALECT, LANGUAGE or VARIETY, which have a special status in their theories.' In a 'more restricted definition … codes are sometimes defined in terms of mutual intelligibility (e.g. the language of a private or professional group).'

5 See Chapter 6 for a discussion of the impact of noise on the intelligibility of radio transmissions.

6 For instance, the same arguments apply to Aviation French as to Aviation English: my first-time French passengers had exactly the same reactions of incomprehension to the French R/T chatter in France as my first-time English speaking passengers to the English R/T chatter in Australia. On the other hand, an NES who is not a pilot but has enough flying experience with me to

understand radio calls in English and who is fluent in French, had no problem understanding the French radio calls during that same flight.

7 Thanks to Alastair Pennycook for pointing out this similarity.

8 Examples from the prescribed phraseology are given in uppercase, which is the way they are presented in the AIP and the ICAO Manuals.

9 ATC would usually say: ‘LSI. Confirm intentions.’ to ascertain whether an aircraft intends to conduct a full stop landing or a touch and go. In this case, the pilot had called ‘inbound’, which would indicate a full stop, but the instructor had conducted several flights that day with a request for ‘circuits on arrival’ in the same aircraft, so ATC could expect a similar intention on that flight.

10 We follow the linguistic convention of prefixing ungrammatical sentences with an asterisk (‘*’). Here an asterisk indicates that the utterance, although acceptable in natural English, is not accepted as part of the phraseology. Such utterances may be found in Plain English interactions, as shown in this chapter. Real examples cited in the chapter are not marked by an asterisk.

11 See Lopez (2013) for more examples of insertion of modals in plain English.

12 Example (40) forms part of the stimuli for Flight 4B in the flight simulator experiments described in Chapter 7.

13 Note that in (49), the altitude will be pronounced ‘fife tousand fife hundred’.

14 Thanks to Julie Choi for this example, contributed by a student in her class at UTS, Monique Van der Veen (LEUT, RAN).

15 The French and English ‘clock codes’ are exactly equivalent, with the normal time expression used for giving a relative position.

16 See for instance, the well-known example of the ‘Gimli glider’, which is not a type of glider but an incident due in part to mistakes loading fuel using different units of measure (see www.casa.gov.au/fsa/2003/jul/22-27.pdf or en.wikipedia.org/wiki/Gimli_Glider for more details), retrieved 25 June 2015.

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Chapter 3

# ICAO language proficiency requirements

*Candace Farris*

## History and background of the ICAO LPRs

In response to results of analyses of data gleaned from accident report databases such as the International Civil Aviation Organization (ICAO) Accident/Incident Data Reporting System, the US National Transportation and Safety Board reports, and the United Kingdom's Mandatory Occurrence Reporting Scheme, in 2003 ICAO introduced worldwide language proficiency requirements (LPRs) for aviation personnel. The ICAO LPRs had the effect of officializing the role of English as a lingua franca in aviation, as while the ICAO language proficiency requirements actually apply to all languages to be used in radiotelephony, they stipulate that English must be 'made available' in situations where the ground and the crew do not share the same native language. Prior to the introduction of the LPRs, proficiency in English was recommended as opposed to required according to ICAO standards. Nevertheless, English has been widely used as a lingua franca in civil aviation for many decades.

Writing worldwide language proficiency requirements is not a trivial endeavour, and years of work and consultation with stakeholders (e.g. pilots, air traffic controllers, aviation language-teaching professionals) went into the first edition of the *Manual on the Implementation of the ICAO Language Proficiency Requirements*, Doc 9835 (ICAO, 2004). ICAO Document 9835 was produced as guidance material for civil aviation authorities and training and test service providers in relation to compliance with the language proficiency requirements outlined in the relevant Annexes of the ICAO Standards and Recommended Practices (SARPS). In 2010 a second edition was produced (ICAO, 2010) with the objective of addressing and clarifying a number of issues raised by users of the first edition. To provide the reader with a clearer view of the scope and application of the ICAO LPRs, a brief discussion of the history and role of ICAO in civil aviation will be provided here. For those who are interested, a more detailed account can be found on the ICAO website.[1]

ICAO is a specialized agency of the United Nations (UN). As of the time of writing (2015), there are 191 ICAO member states. ICAO became a specialized agency of the UN in 1947 when it replaced the provisional ICAO that was established in 1944, when, on 7 December, 52 nations signed the *Convention on International Civil Aviation*, also known as the *Chicago Convention* (ICAO, 1944). At that time, in the Convention's Preamble, ICAO's purpose was stated as follows:

> WHEREAS the future development of international civil aviation can greatly help to create and preserve friendship and understanding among the nations and peoples of the world, yet its abuse can become a threat to the general security; and
>
> WHEREAS it is desirable to avoid friction and to promote that co-operation between nations and peoples upon which the peace of the world depends;
>
> THEREFORE, the undersigned governments having agreed on certain principles and arrangements in order that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically; Have accordingly concluded this Convention to that end (Convention of International Civil Aviation, 1944, preamble).

One of the primary goals of ICAO is to develop international Standards and Recommended Practices (SARPs), which are then used by national aviation authorities (also called civil aviation authorities) when making their own rules and regulations. The purpose of having such international SARPS is to ensure air safety in civil aviation in both domestic and international contexts through shared or compatible operational systems and regulations.

The SARPs are developed by the ICAO Council and are considered and recommended for approval by the Air Navigation Commission. The Air Navigation Commission is appointed by the Council. The Council is composed of 36 ICAO member states, and is elected for a three-year term by the Assembly. The Assembly is composed of the 191 ICAO member states, and the Council is elected under the following three headings:

1. states of chief importance in air transport;
2. states which make the largest contribution to the provision of facilities for air navigation; and
3. states whose designation will ensure that all major areas of the world are represented.[2]

The following excerpt from the ICAO website describes the intended scope and role for the SARPs in the aviation world:

> SARPs cover all technical and operational aspects of international civil aviation, such as safety, personnel licensing, operation of aircraft, aerodromes, air traffic services, accident investigation and the environment. Without SARPs, our aviation system would be at best chaotic and at worst unsafe.[3]

An aphorism that can be commonly heard in the aviation community is 'For every regulation that exists, someone died when it didn't.' This saying exemplifies the high regard that aviation professionals hold for regulation and rules in relation to safety, and the ICAO SARPS are the vehicle through which a common system of civil aviation is maintained throughout the world.

It was at the 1998 ICAO Assembly that the issue of English language proficiency was brought to the fore. The ICAO LPRs were introduced based on high profile accidents, data gleaned from incident reporting databases, and anecdotal evidence of stakeholders, such as air traffic controllers and pilots who had experienced communication difficulties in contexts where they did not share the native language or dialect of the ground. As discussed in Chapter 1, one of the highest profile accidents occurred in Tenerife in 1977, when two Boeing 747 passenger aircraft collided on the runway: 583 passengers and crewmembers lost their lives, making the Tenerife accident the deadliest in aviation history. But the ICAO LPRs were introduced many years later as the result of a working paper and draft resolution presented by India in 1998 at the 32nd ICAO Assembly.[4] India's paper was inspired by a mid-air collision in Charkhi Dadri, India, between a Saudi Arabian Boeing 747 and a Kazakhstan Airlines Ilyushin II-76. In this accident 349 people lost their lives, making it the third deadliest aviation accident in history. As indicated in India's working paper, accident investigators concluded that English language proficiency played an important role in the accident. As we already pointed out in Chapter 1 in relation to the discussion of the Avianca 052 accident, there is rarely, if ever, a single cause for an aviation accident; aviation accidents almost always involve a number of contributing and interacting factors (e.g. high workload, fatigue, irregular operations, crew interpersonal dynamics, technical problems, miscommunication). Nevertheless, these accidents had the effect of raising awareness and eventually influencing global policy regarding the role of language proficiency in aviation safety.

As a result of Assembly discussions, the Council brought the issue of English language proficiency to the ICAO Air Navigation Commission, for the purpose of strengthening regulations pertaining to language proficiency, which were eventually reflected primarily in Annexes 1 (*Personnel Licensing*) and 10 (*Aeronautical Communications*), but also in Annexes 6 (*Operation of Aircraft*) and 11 (*Air Traffic Services*). The Air Navigation Commission appointed a group of experts, called the Proficiency Requirements in Common English Study Group (PRICESG), whose purpose was threefold:

a) carry out a comprehensive review of existing provisions concerning all aspects of air–ground and ground–ground voice communications in international civil aviation, aimed at the identification of deficiencies and/or shortcomings;
b) develop ICAO provisions concerning standardized English language-testing requirements and procedures; and
c) develop minimum skill level requirements in the common usage of the English language (ICAO, 2004: 1.2).

Clearly this was not a trivial task, and the group was composed of 'operational and linguistic experts with backgrounds in aviation (pilots, air traffic controllers and civil aviation authority representatives) or Aviation English training and applied linguistics, representing member states and international organisations covering most main linguistic areas' (ICAO 2004: 1.2). Importantly, despite the clear relevance of the PRICESG's mandate to language testing – particularly points b) and c) above – language-testing expertise was not mentioned in the group's description, and it appears that no language testing experts were involved in the development of the ICAO LPRs. This omission is not entirely surprising given that the study group was appointed by the Air Navigation Commission, whose members were unlikely to be in a position to clearly distinguish among the disciplines of linguistics, applied linguistics, language testing and language teaching. For the layperson, these disciplines are often regarded as being one and the same.

## The content of Document 9835

Document 9835 (ICAO, 2004, 2010) is meant to serve as guidance material for the implementation of the SARPs related to language proficiency found in Annexes 1, 6, 10 and 11. This differentiation between guidance material and SARPs is an important one since member states are required to adhere to all aspects of the LPRs which are included in the Annexes, whereas all other material contained in 9835 may be considered recommendations or guidance material, as opposed to requirements. Several important elements of 9835, such as the rating scales to be used in all evaluations conducted for the purpose of determining a candidate's level of language proficiency for certification purposes, are included in the SARPs. Other important elements, however, such as recommendations for best practice in language testing and specific recommended practices for native English or expert-level speakers in English as lingua franca (ELF) interactions, are not included in the SARPs and are thus considered guidance material, creating leeway and room for interpretation for stakeholders such as civil aviation authorities, test developers and test service providers. The rating scales and other issues related to aviation language testing will be discussed at greater length in Chapter 4.

### *General content*

Document 9835 is composed of seven chapters and six appendices. The document begins by outlining a safety case for the ICAO LPRs, citing some major accidents involving large loss of life in which insufficient language proficiency was considered to be a contributing factor. In the first chapter of Document 9835, it is stated that 'there can be three ways in which language can be a contributing factor in incidents and accidents:

a) incorrect use of standardized phraseology;
b) lack of plain language proficiency; and
c) the use of more than one language in the same airspace' (ICAO, 2010: 1.1).

Although there is some ambiguity in ICAO's stance regarding the assessment of standard phraseology in relation to the LPRs, it appears that the LPRs are intended, primarily, to address the second contributing factor: lack of 'plain language' proficiency. It is stipulated in Document 9835 that standard phraseology should not be assessed in relation to the ICAO LPRs (ICAO, 2010: 6.3.2.9), and as such, language tests administered for licensure purposes in relation to the ICAO language proficiency requirements are not meant to assess the restricted code of standard phraseology described in Chapter 2 of this book. Furthermore, possibly because the use of more than one language in the same airspace has been identified by ICAO as a source of error, it is commonly misunderstood that the ICAO language proficiency requirements mandate that English-only be used in radiotelephony. This is not the case. Rather,

> [t]he purpose of the ICAO language proficiency requirements is to ensure that the language proficiency of pilots and air traffic controllers is sufficient to reduce miscommunication as much as possible and to allow pilots and controllers to recognize and solve potential miscommunication when it does occur (ICAO 2010, 4.1).

In addition to explaining the need for language proficiency requirements in the global aviation context, Document 9835 provides an introduction to a number of relevant concepts from the fields of applied linguistics and language testing (see below). This introduction is meant to help regulatory and operational stakeholders, such as civil aviation authorities, in the implementation of the ICAO LPRs. While most of the concepts outlined in Chapter 2 of Document 9835 will be familiar to applied linguists and language testers, they serve as a useful introduction for other stakeholders involved in the implementation of the LPRs. Such concepts as native and non-native speaker, second and foreign language speaker, language learning versus language acquisition, English as a lingua franca, and language maintenance and language loss are introduced and briefly discussed.

Similarly, Document 9835 provides a basic introduction to aeronautical radiotelephony communication, intended to assist language-training and -assessment specialists in the design and development of training and assessment in response to the ICAO LPRs, as well as operational managers in raising awareness in pilots and controllers regarding the challenges inherent in radiotelephony voice communications. In short, the whole of Document 9835 is a must-read for anyone involved in developing policies or training and assessment materials in response to the ICAO LPRs. However, there are some contradictions inherent in the document that can give rise to confusion, and some of these will be discussed in the sections below.

### *Standards and Recommended Practices (SARPs)*

As already mentioned, the SARPs relating to language proficiency can be found in Annexes 1, 6, 10 and 11. Chapter 4 of Document 9835 (ICAO, 2010) provides a very readable summary of the SARPs related to language use, and the SARPs are themselves reproduced in Appendix A rendering them more accessible than the Annexes, which are very long documents containing much information that is irrelevant to language and communication. One aspect of the SARPs that has had a tremendous impact on aviation language testing is the rating scales, which are reproduced in both Appendix A and Annex 1. For many, the rating scales have become synonymous with the ICAO language proficiency requirements – a phenomenon that many in the field of language testing consider problematic. The rating scales and criticism of them will be discussed further in Chapter 4. Here, a general description of the rating scales is provided.

### *The ICAO rating scales*

The ICAO rating scales[5] are a set of six analytic scales based on what are considered to be six constructs of language proficiency. The six constructs are: pronunciation, structure, vocabulary, fluency, comprehension and interactions. For each of the scales, there are six levels of performance: (1) Pre-elementary, (2) Elementary, (3) Pre-operational, (4) Operational, (5) Extended and (6) Expert. Operational Level 4 is the minimum performance standard for pilot and controller certification. For each level of each of the constructs, there is a set of descriptors intended to describe the language and/or communication performance at that level. Because the rating scales are included in Annex 1 of the SARPs their use is required in all language proficiency assessments pertaining to licensing.

### *To whom and to which languages the ICAO LPRs apply*

The ICAO LPRs apply to all languages used in radiotelephony. The ICAO LPRs for English apply to all flight crews and controllers operating in air space where the use of English might be required. The LPRs for English apply to both native and non-native speakers of English, and both are required to undergo formal testing, although the testing policy arguably discriminates between native and non-native speakers in terms of formal language testing requirements. This issue was discussed briefly in Chapter 1 and will be discussed more fully in the section below titled *The ICAO LPRs policy for native speakers*.

It is important to clarify that the ICAO SARPs do not imply that English is the only language to be used in radiotelephony. Nor should ICAO's six official languages be construed as being the only languages allowed in radiotelephony. ICAO's official languages, English, French, Spanish, Arabic, Chinese and Russian, do not pertain to radiotelephony; rather, they are the official languages of ICAO business and ICAO strives to provide regulatory documentation in all official languages. The official languages are determined based on common usage and the official languages of the United Nations agencies. Regarding languages to be used in radiotelephony, in Annex 10, the following is stated:

> The air–ground radiotelephony communications shall be conducted in the language normally used by the station on the ground or in the English language. Note 1: The language normally used on the ground may not necessarily be the language of the state in which it is located. A common language may be agreed upon regionally as a requirement for stations on the ground in that region. Note 2: The level of language proficiency required for radiotelephonic communications is specified in the Appendix to Annex 1 (ICAO, 2001: 5.2.1.2.1).

As such, national and regional languages may indeed be used in radiotelephony. Notwithstanding, some would (and do) argue that the use of English-only as a lingua franca would be desirable in radiotelephonic communications, but ICAO has not adopted an English-only policy for reasons both practical and political, and these reasons are stated in Document 9835:

> It should be noted that the establishment, at this stage, of a single language in the radiotelephony environment that would rely only on the English language faces several challenges. It would require all users of airspace to have a sufficient knowledge of the English language (ICAO Operational Level 4). The new ICAO language proficiency requirements will certainly improve levels of language proficiency in aviation, but it is doubtful that the level of English proficiency among pilots and air traffic controllers

> worldwide at the moment the amendments were proposed would have permitted the implementation of such a policy without excluding a large number of currently active pilots. It must also be recognized that there are significant national, cultural, economic and organizational impediments that make such a move impractical. Because language use is so closely tied to a community's sense of national and cultural identity, language policies always require sensitive management. (ICAO, 2010: 4.3.6).

Rather, the policy states that English must be made available by air traffic controllers of airports and routes used by international air services. Pilots flying those routes and into those stations have the option of using either the language of the ground (i.e. the local language being used by the controllers) or English. For example, as we pointed out in Chapter 1, French-speaking pilots flying into Argentina would have the option of communicating with Argentinian air traffic control in either Spanish or English, provided they had both English and Spanish language proficiency at operational Level 4 endorsed on their licences. However, because the policy states that English must be made available internationally, and consequently Aviation English has become the official lingua franca of global aviation, language training and testing in the English language is far more common than training in any other languages. It is therefore most likely that the French pilots mentioned in the example above would have English rather than Spanish language endorsements on their licences. However, it is possible that in the future other languages will become more commonly used as lingua francas. The policy itself does not preclude such developments.

## Impact on professionals and civil aviation authorities

Demonstration of minimum ICAO Level 4 proficiency in English is required of all air traffic controllers and flight crew operating in airspace where the use of English may be required. Clearly this is not a trivial requirement for many of the world's controllers and pilots, particularly those for whom English is not a first language. The policy stipulates that controllers and pilots who have not achieved the highest rating (Expert Level 6) must undergo recurrent testing, the timeframe for which is ultimately determined by the civil aviation authority of the licensing state, although ICAO recommends retesting candidates who were awarded Level 5 every six years, and candidates who were awarded Level 4 every three years. Those who do not achieve a Level 4 cannot obtain the required licence endorsement permitting them to operate in airspace (in the case of pilots) or at a station (in the case of controllers) where the use of English may be required. As such, the potential impact on the careers of professionals to whom the requirements apply is serious.

The implementation of the ICAO LPRs has posed challenges for regulators such as the civil aviation authorities of the ICAO member states. In many ways, language training and assessment as outlined in the ICAO LPRs differs considerably from other aspects of aviation training and assessment. Furthermore, language training and assessment, apart from the specifics of the use of standard phraseology in radiotelephony, is outside the realm of what is offered by many pilot training organisations. As such, many students in need of language instruction are faced with the challenge of choosing an outside organisation that will meet their training needs. This can be a daunting task, since it can be difficult to determine the quality or appropriateness of the programme in relation to the students' needs. Given that, on a global scale, language training and testing industries are often unregulated, in many contexts any training or test service provider can claim to provide training and/or tests that are valid in relation to the ICAO LPRs. It is then up to the student to decide whether or not the quality of the programme is satisfactory. Similarly, in terms of testing, aviation regulators, such as civil aviation authorities, must decide which test results will be accepted for licensing purposes. This decision has been a challenge for many civil aviation authorities, since it is difficult for them to judge the quality of the language tests on the market, as language testing, like language training, is not within the usual realm of their expertise and, even if it were, information about the quality of tests, in the form of validation reports, are often not available. Another option for civil aviation authorities is to develop their own in-house tests, and many have chosen this route. While language training is clearly an important aspect of the LPRs, language testing is the vehicle through which professional and state compliance with the ICAO LPRs is determined; therefore, the importance of the use and recognition of quality aviation language tests by civil aviation authorities is crucial to compliance – an issue that will be discussed in greater depth in Chapter 4.

ICAO demonstrated sensitivity to the implementation challenges faced by its member states. Originally, when the LPRs were introduced in March 2003, with the amendment of Annex 1, states were mandated to demonstrate conformance with the LPRs by March 2008. As that deadline approached it became clear that many member states would be unable to demonstrate conformance, and the deadline was thus extended to March 2011. In an effort to encourage states to comply with the LPRs, states that were non-compliant by March 2011 were required, according to Assembly resolutions, to develop implementation plans that included timelines for adopting the LPRs in their national regulations, and to post these plans on the ICAO website (on a page that has since been removed) along with updates, until compliance was achieved. In turn, states were urged not to restrict their pilots from entering the airspace of states not yet compliant, and likewise they were urged not to restrict pilots of non-compliant states from entering their airspace. It would appear that ICAO had underestimated the challenge that the implementation of the language proficiency requirements would pose for member states, and in the Assembly resolutions the Council was directed to support member states in their implementation of the language proficiency requirements by establishing 'globally harmonized language testing criteria' – a tall order from both an industry and a language testing perspective. These globally harmonized language testing criteria were published in 2009 in Circular 318, which was entitled *Language testing criteria for global harmonization* (ICAO, 2009) and later became Chapter 6 of the second edition of Document 9835 (ICAO, 2010).

Having already given non-compliant member states a three-year extension, in 2013, at the 38th Assembly, a working paper entitled 'Implementation Status of English Language Proficiency Requirements' was presented by the ICAO Council. In this paper the Council proposed the removal of the leniency clause given that 'the aviation community has made substantial progress in implementing these safety critical provisions'.[6] In that paper the council also lists the actions taken by ICAO in support of States' implementation of the LPRs. Such actions include the following:

- Publishing the two editions of Document 9835 (2004, 2010).
- In 2011 the launch of the Aviation English Language Test Service (AELTS), intended to provide a means for the aviation language testing community to standardize and improve their tests. (The AELTS will be discussed in greater detail in Chapter 4.)
- In 2012 the launch of a new edition of the training aid *ICAO Language Proficiency Requirements – Rated Speech Samples*, intended as a means of standardizing the rating process across tests developed in response to the ICAO LPRs. (The rated speech samples are publicly available.)[7]

The Council also indicated in its paper that, although few states had provided implementation plans since 2010, it was confident that the majority of member states had effectively implemented the LPRs based on responses to protocol questions collected through the Universal Safety Oversight Audit Programme Continuous Monitoring Approach in relation to the language provisions. Unfortunately, this information does not appear to be accessible to the public – neither the protocol questions nor the responses – as it is available only through secure ICAO portals. Regardless, based on the assumption that the majority of states are compliant with the LPRs, and based on the belief that ICAO had provided adequate support for states in their implementation efforts, ICAO resolved, in a new resolution that would supersede the previous resolutions, to remove the clauses that urged states to be lenient in allowing pilots of non-conforming states to fly in international airspace and enter other states where the use of English may be required.

## The ICAO LPRs policy for native speakers of English

Despite widespread recognition of the need for a common language in the global aviation context, the ICAO LPRs policy has been the subject of a fair bit of criticism in the applied linguistics and language testing communities, as well as in the aviation community. Much of the criticism has been related to the role of the native English speaker and Expert Level 6, and has been voiced in academic journals (e.g. Kim and Elder, 2009), conference presentations (e.g. Farris, 2010; Farris and Barshi, 2011, 2012, 2013), meetings of professional associations, such as the International Language Testing Association (ILTA), and at ICAO meetings such as the ICAO LPRs Symposia in 2004 and 2007, and the ICAO LPRs Technical Seminar in March 2013. Perhaps due in part to an evolving understanding of the complexity of regulating language proficiency in the global aviation context, as reflected in updates to the guidance material between 2004 and 2010, there are some contradictions inherent in Document 9835 in relation to the role of the native speaker.

### *The 'native speaker' role.*

Document 9835 states: 'The ICAO language proficiency requirements apply to native and non-native speakers alike {...} the burden for improved communications should not be seen as falling solely on non-native speakers' (ICAO, 2010: 5.3.1.1). However, native speakers may be exempt from formal language proficiency testing. Annex 1 states:

> Formal evaluation is not required for applicants who demonstrate expert language proficiency, e.g. native and very proficient non-native speakers with a dialect or accent intelligible to the aeronautical community (ICAO, 2010: Annex 1, 1.2.9.7, Note 1).

The LPRs FAQs on the ICAO website[8] explain ICAO's policy regarding the testing of native English speakers, and there it is explained that although native speakers do need to be evaluated (e.g. by a flight instructor or a representative from the licensing authority) in order to ensure that they do not have a 'speech impediment that would affect their capacity to operate safely', they do not need to be evaluated in the context of a formal language proficiency test. If in the course of such an evaluation the evaluator observes that the candidate has a 'speech impediment or inappropriately strong regional accent', then they are to be referred to an expert for follow-through. Native speakers, therefore, so long as they do not have a speech disorder or an 'inappropriately strong regional accent' – a criterion calling for a highly subjective judgement on the part of the interviewer – may be considered expert speakers in the context of aviation communications.

However, to cite such excerpts without citing the excerpts from Document 9835 which contradict them would be to misrepresent ICAO's intent in relation to the role of the expert/native speaker. Document 9835 also states: 'Native speakers of English, in particular, have an ethical obligation to increase their linguistic awareness and to take special care in the delivery of messages' (ICAO 2010: 5.3.1.3). A following section (5.3.3.2) goes on to advise that native speakers employ such strategies as the following:

- keep intonation neutral and calm
- be explicit, rather than indirect
- train themselves away from the use of jargon, slang and idiomatic expressions
- attend more carefully to readbacks in cross-cultural communication situations, taking greater care to avoid the pitfalls of expectancy
- speak clearly
- state function of communication clearly.

But, despite ICAO's endorsement of what could be considered accommodation strategies in English lingua franca (ELF) interactions, such strategies are not reflected in the assessment criteria outlined in the rating scales for Expert Level 6. In fact, in some cases, the assessment criteria describe quite the opposite behaviour, depicting performance that is in direct contradiction to the recommendations outlined in the guidance material quoted earlier. For example, the Level 6 fluency descriptor states the following: 'Able to speak at length with a natural, effortless flow. Varies speech flow for stylistic effect.' For vocabulary the descriptor is: 'Vocabulary is idiomatic, nuanced, and sensitive to register', despite the recommendation that expert speakers train themselves away from the use of idiomatic expressions. The pronunciation descriptor at Level 6 reads: 'Pronunciation, stress and rhythm, though possibly influenced by the first language or regional variation, almost never interfere with ease of understanding.' One issue with this descriptor relates to 'ease of understanding'. Familiarity with a particular accent facilitates comprehension, so ease of understanding is inevitably subjective and possibly highly dependent on the listeners' familiarity with the accent in question (see e.g. Bradlow and Bent, 2008). Furthermore, even native speakers of English who speak different regional varieties may have difficulty understanding one another. Similarly, all listeners, including native and non-native English speakers, may over time develop improved comprehension of particular accents, be they native or non-native accents, making it difficult to reliably assess a candidate's pronunciation for 'ease of understanding'. This problem is not unique to Level 6, and is relevant to all levels of the ICAO scales.

The rating scales and thus the assessment criteria outlined in the descriptors are included in Annex 1 of the SARPs discussed in the sections above, whereas the recommendations for native speakers are guidance material. Though states must comply with the SARPs, they may choose not to comply with the guidance material. The result is that, contrary to ICAO's intention, native speakers do not truly share the burden of improved communication with non-native speakers as there is no required formal testing of the communication strategies outlined above. Consequently, there is unlikely to be formal training in relation to these strategies unless it is mandated by the civil aviation authority or in the course of professional training and assessment.

Some would view these contradictions as hypocrisy or 'lip service' lacking the teeth of policy to enforce them. Another view is that they are a phase in the evolution of ICAO's conceptualization of the LPRs (Farris & Turner, 2015). Applied linguists and language testers need not look further than the history of their own fields to discover the inspiration for ICAO's native-speaker-as-expert-speaker model. For many years, language learning and testing, in theory, research and practice, held the native speaker as the standard of excellence against which all other speakers were measured. We no longer do so today, in theory, but in research and practice we are still struggling to find practical alternatives to the native speaker model for comparison groups in research and standards in language teaching and testing. We still have a long way to go. For now, the applied linguistics and language testing communities can recognize that ICAO's policy draws inspiration from the history of our disciplines, and that the challenges ICAO faces are similar to the challenges that we ourselves face.

### *Impact of ICAO LPRs on language testing for native speakers*

In an effort to examine the real impact of the policy in relation to the assessment of native-English-speaking pilots and controllers in relation to the ICAO LPRs, below is a summary of the policies and practices of a few randomly selected countries in which English is considered a primary language: Australia, Bahamas, Canada, New Zealand, Nigeria, Singapore, the United Kingdom and the United States of America (see Farris and Turner, 2015 for further discussion of these policies). The information for this section has been gleaned from the websites of the relevant civil aviation authorities.

#### *Australia*

In alignment with ICAO policy, the Civil Aviation Safety Authority of Australia (CASA)

> has trained, assessed and authorized many of its Approved Testing Officers (ATOs) to conduct (only) Level 6 ELP (English Language Proficiency) assessments. The authorized ATOs may only assess applicants who have the potential to be Level 6 ELP speakers, and grade them at either that level or not. They are not permitted to grade candidates at a lower level of ELP, which shall be the role of CASA approved ELP specialist centres.[9]

At the time of writing, the following four testing centres were approved by CASA and listed on the website: Assessment Services Limited, Griffith English Language Institute, RMIT English Worldwide and Aviation Australia. Since all candidates who are not assessed at Level 6 must undergo formal language testing, Australia can be considered to be in conformance with ICAO's requirements. No details regarding the training of ATOs who evaluate Level 6, or the criteria used for those assessments, was readily available online.

### *Bahamas*

The Bahamas Civil Aviation Authority (BCAA) uses an in-house formal test of Aviation English, called the Aviation English Proficiency Test (AEPT), based on the results of which candidates are evaluated as either Operational (corresponding to ICAO Levels 4–5) or Below Operational (corresponding to ICAO Levels 1–3). Candidates who are evaluated at the Operational level receive a 'language proficient' endorsement on their licence and must be retested every three years. The AEPT is a telephone-administered test consisting of role-plays. Candidates are provided with context-relevant maps (i.e. terrain maps) and diagrams (airport and aerodrome maps), which they are required to print off before submitting to the test. There is a fuller description of the BCAA's policy and the AEPT online.[10] Although the AEPT was not designed to assess Level 6 performance, the BCAA does give Level 6 endorsements to licence holders who have been evaluated at Level 6 by 'an internationally recognized language testing organisation', and candidates are advised to contact the BCAA to determine whether or not a test is acceptable before submitting to the test. The policy applies to pilots and air traffic controllers. The BCAA can be regarded as being in conformance with the LPRs, and appears to minimize differential treatment of native versus non-native speakers of English by not administering its own Level 6 assessments.

### *Canada*

In an advisory circular released in 2010 Transport Canada (TC) announced: 'Consistent with ICAO standards, Canada has used an informal process to determine the language proficiency of existing document holders. Most current licence holders have been assessed for language proficiency through this review process.'[11] New applicants have to be assessed using TC's language proficiency test, the Aviation Language Proficiency Test (ALPT). In the circular Transport Canada states that the ALPT was developed to assess language proficiency in English and French. The ALPT test taker guide states that:

> The Aviation-Language Proficiency Test (ALPT) is an English-language or French-language proficiency test, set in an aviation context. It is designed for people with some knowledge of aviation whose native language is not English. However, all applicants including native English or native French speakers are required to complete the test.[12]

Both native and non-native speakers of English and/or French are required to take the test for either French or English. The ALPT distinguishes among three as opposed to six levels of proficiency: Levels 1–3 are collapsed into one level termed 'Below Operational'; Levels 4 and 5 are collapsed into another level termed 'Operational'; and, the 'Expert' level corresponds to Level 6 of the ICAO rating scales. Those assessed at the 'Below Operational' level cannot hold a Canadian flight crew or air traffic controller licence. Those assessed at the Operational level must be retested every five years. Those tested at the expert level do not need to be retested. Canadian licence holders can be endorsed for French, English or English and French. The level of proficiency is not indicated on the licence. TC accepts the language proficiency endorsements of foreign licence holders whose endorsements indicate an ICAO operational level of proficiency (Level 4) or higher in either English or French. Thus, in terms of testing conducted within Canada, the TC does not differentiate between native and non-native speakers in terms of formal language testing requirements, and may be regarded as being in conformance with the ICAO LPRs.

### *New Zealand*

According to advisory circular AC61.1 issued on 3 November 2011 by the Civil Aviation Authority of New Zealand,[13] pilots or air traffic controllers holding licences issued after 2008 are required to demonstrate English language proficiency in one of two ways: Level 6 Proficiency Demonstration or a Formal Evaluation. The Level 6 Proficiency Demonstration:

> is designed to confirm that native or very proficient non-native English speakers can clearly meet ICAO Level 6 language criteria. It is a relatively short semi-direct assessment delivered by telephone that confirms that the speaker can communicate at Level 6 for pronunciation, structure,

> vocabulary, and fluency. This assessment is suitable for pilots who are confident that they are able to communicate at Level 6 in all respects.

It is interesting that at Level 6 candidates are not rated for the constructs of interaction or comprehension. Presumably interaction is not rated for reasons of practicality since the test consists only of semi-direct prompts delivered by telephone, and the reasons why comprehension is not rated are unclear. In contrast, in the Formal Evaluation students are evaluated for all six constructs, and the test consists of two parts: a semi-direct assessment of a format similar the one delivered for the Level 6 Proficiency Demonstration, upon which the scores for vocabulary, fluency, structure and pronunciation are based, and a direct interview, the performance of which is rated for comprehension and interaction. Based on the formal evaluation, candidates may be awarded a Level 6, Level 5, Level 4 or failed. The impact of New Zealand's LPRs policy for native speakers is clear: there is no assessment of the candidate's ability to interact or comprehend – two constructs that may be considered fundamental to effective communication. There is also no mention of language proficiency tests for air traffic controllers. Nevertheless, the policy for pilots may be regarded as being in conformance with the ICAO LPRs.

*Nigeria*

In the advisory circular posted by the Nigerian Civil Aviation Authority on 5 September 2013,[14] the Nigerian CAA indicated that it had given 'grandfather rights' of Level 4 English language proficiency to all holders of pilot, air traffic controller and aeronautical station operator licences due to the fact that English is the official language of Nigeria. These grandfather rights were due to expire on 31 March 2014, after which time all licence holders would need to be re-evaluated in accordance with the criteria of the ICAO rating scales, and those who were not re-evaluated prior to the expiry date would not have their licences renewed for international flight operations. There is no mention, however, of how or by whom the licence holders would be tested, only that

> operators and air navigation service providers are required to ensure compliance of personnel in their employment, i.e. Pilots, ATC (*air traffic controllers*), FE (*flight engineers*), and ASO (*aviation safety officer*) licence holders with the above directives before the expiration of their language proficiency rating by 31 March, 2014 (p. 2).

At the time of writing, there was no further update available on the website, so Nigeria's level of compliance with the ICAO LPRs is unclear.

### *Singapore*

In an advisory circular (AC FCL-2(2))[18] issued on 1 April 2014, the Civil Aviation Authority of Singapore (CAAS) outlined its policy for pilots and flight engineers regarding the ICAO LPRs. The CAAS offers two types of assessment of language proficiency: the language screening and the Aviation English competency test. The purpose of the language screening is to determine whether or not a candidate demonstrates Level 6 proficiency. The purpose of the Aviation English competency test (AETC) is to determine the level of language proficiency (Levels 1–6) for all those who are ineligible for the language screening test. In order to be eligible for the language screening the candidate must:

1 never previously have attempted the Language screening; and
2 must be undergoing private or commercial *ab-initio* pilot training or be seeking to convert their foreign licence to a Singapore licence.

Candidates who are awarded Level 6 based on the language screening may still be required to submit to the AETC for reassessment.

The language screening consists of observation of the candidate's language proficiency in radiotelephony and in 'normal conversation', as well as assessment of the candidate's language background. Candidates are required to fill out a form,[19] in which, as part of the assessment of language background, they are required to indicate their nationality and whether they are from a 'native English speaking country (e.g. Australia, USA, NZ, Ireland)', 'a non-native country with English as a second language (e.g. India, Malaysia, Singapore, Philippines)', or 'a country with English as Foreign Language (e.g. China, Germany, Japan, Paraguay)'. It is not explained in the document how the candidate's nationality affects the assessment of language proficiency, but clearly it is a factor. Candidates are given space in another area of the form to provide further detail regarding their language background, so nationality is potentially not the only source of information about a candidate's language background; nevertheless, the use of nationality and language background as a basis for judging language proficiency, particularly in the context of controller–pilot communications, should be considered problematic. It would seem more appropriate, given the purpose of the assessment, for it to be based entirely on the candidate's performance. However, the CAAS's operationalization of the ICAO LPRs is understandable given that the ICAO rating scales criteria and aspects of the LPRs policy effectively differentiate native and non-native speakers and suggest that native speakers are by definition Expert Level 6 candidates.

The AETC, as described on the CAAS website, is designed to assess ICAO Levels 1–6 and consists of a 20-minute interview (warm-up, role play and closing). The candidate is rated accorded to the criteria of the ICAO rating scales and is placed on one of the six levels for each of the six scales. The final rating is the lowest rating obtained, which is in alignment with ICAO's policy. There is no mention of language background being a factor in the AETC so presumably the assessment is based solely on the candidate's performance.

### *United Kingdom*

The United Kingdom Civil Aviation Authority (UK CAA) policy pertaining to pilots, flight navigators and air traffic controllers is outlined on the UK CAA website,[15] where it states that there are four avenues for language assessment, as follows.

1 The Flight Radiotelephony Operator's Licence (FRTOL) exam, which licences the candidate to operate an aircraft radio station in a UK registered aircraft.
2 A licence proficiency check conducted for licence renewal or revalidation, at which time the candidate may be assessed for language proficiency by an examiner who has been assessed at ICAO Level 6 proficiency.
3 A language school approved by the UK CAA for the purpose of language assessment.
4 An aviation training organisation.

The current list of language testing services recognized by the UK CAA is Anglo-Continental Educational Group Ltd, Flight Training Europe SL, Language Testing and Assessment Services Ltd and Oxford Aviation Academy (Oxford) Limited t/a CAE Oxford Aviation Academy.[16] Although there do not appear to be different assessments for Expert Level 6 versus the other levels in the UK, the UK CAA website states: 'The endorsement is graded in levels. Level 6, which the majority of UK licence holders will obtain, represents complete fluency and is non-expiring.' The assumption that most United Kingdom pilots will obtain a Level 6 rating supports the notion that pilots are being assessed only in relation to the criteria of the Level 6 descriptors of the ICAO rating scales, as opposed to the communication strategies for expert-level speakers recommended in ICAO Document 9835 (ICAO, 2010). This is understandable, given that the rating scales are included as assessment criteria in the SARPs and the recommended communication strategies are not, but it is nevertheless problematic, from the perspective of English as a lingua franca, in that according to the policy candidates need only demonstrate their ability to speak in a native-like fashion (in accordance with the Level 6 descriptors), not demonstrate their ability to interact effectively with a variety of interlocutors of different levels of proficiency in the global aviation context.

*United States of America*

The United States claims that, according to Federal Aviation Administration Regulations, the English language is already required for reading, writing, speaking and listening for licensing purposes, and, as such, formal English language proficiency testing is not required of US pilots and controllers. In the US, all pilots' licences receive an English proficient endorsement that does not indicate the level of proficiency.[17] Given that the FAA does not appear to formally test pilots and controllers in relation to the ICAO LPRs, the US could be considered non-compliant with the ICAO LPRs. The other possible implication of the US policy is that any candidate who does not demonstrate performance in accordance with the Expert Level 6 descriptors cannot obtain a pilot or air traffic controller licence. The issue of language proficiency assessment in the US in relation to the ICAO LPRs is worthy of further research, given that the US air traffic management system is the world's largest.

### *Summary of policy impact on native-speaker training and testing*

The practices described above indicate that in many cases the ICAO LPRs policy has resulted in differential treatment for native and non-native speakers of English in relation to English language proficiency assessment. The policy has resulted in native speakers being assessed in relation to the criteria of Level 6 of the ICAO LPRs, as opposed to being assessed in relation to the communication strategies recommended for native speakers in English as lingua franca interactions outlined in the guidance material of ICAO Document 9835 (ICAO, 2010: 5.3.3.2). As already mentioned, this may be viewed as a discrepancy between the intended role of the native speaker and ICAO's operationalization of that role in the SARPs, as opposed to any malfeasance on ICAO's part. ICAO has taken on an enormous challenge that epitomizes many of the challenges inherent in language for specific purposes and ELF communication, and those challenges are likely to take time and effort to resolve (Farris and Turner, 2015). As such, the ICAO LPRs policy provides an excellent context for LSP and ELF studies, and through the lens of LSP and/or ELF theory and practice the disparity between the intended versus the operationalized role of the native speaker in the ICAO LPRs can perhaps eventually be resolved.

## Notes

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Chapter 4

# Aviation language testing

*Candace Farris*

The introduction of the ICAO language proficiency requirements (LPRs) discussed in Chapter 3 spawned a flurry of activity in the aviation language training and testing markets. Not only did many civil aviation authorities develop their own in-house tests in response to the ICAO LPRs, so did many commercial organisations. As a result, regulators were faced with important decisions as to which test results could be accepted for licensure purposes. It therefore became important for regulators and other stakeholders to be able to determine the quality of the language tests available on the market, and this proved to be a challenge due to:

1 a lack of expertise in language testing on the part of many stakeholders and decision makers; and
2 a lack of information regarding the validity of many of the tests available on the market.

Charles Alderson and other members of the Lancaster Language Testing Research Group played an important role in investigating and bringing to light the state of the art of aviation language testing (see Alderson, 2008, 2009, 2010, 2011). In 2006 the Lancaster group was commissioned to conduct a validation study of a test of English language proficiency for air traffic controllers, called ELPAC (English Language Proficiency for Aeronautical Communication), which had recently been developed by EUROCONTROL – the organisation responsible for co-ordinating air traffic control services in Europe. As part of the validation study, the Lancaster group surveyed the aviation language tests available on the market and discovered that little information could be found about commercial tests that had been developed in response to the ICAO LPRs, nor regarding the tests which ICAO member states were using to assess their pilots and controllers in relation to the LPRs. In an effort to fill this gap and to gain a better understanding of the state of aviation language testing, the Lancaster group launched a survey (Alderson, 2008) based on the Guidelines for Good Practice of the European Association for Language Testing and Assessment

(EALTA) and sent it to test service providers whose tests they believed were being used to evaluate candidates in response to the ICAO LPRs.[1] They also surveyed 190 ICAO member states in an effort to find out which tests they recognized. They received 22 responses from test service providers and only 17 responses from ICAO member states. Based on the information received, they concluded the following:

1 We can have little confidence in the meaningfulness, reliability, and validity of several of the aviation language tests currently available for licensure.
2 Monitoring is required of the quality of language tests used in aviation to ensure they follow accepted professional standards for language tests and assessment procedures. (Alderson, 2008, p. 1)

Although the researchers were unable to conclude with certainty, due to the low response rate, that there was a lack of quality in available Aviation English language tests, they could conclude that there was a lack of public accountability and that this could possibly be an indicator of lack of quality.

Moder and Halleck (2009, p. 25.3) voiced similar concerns regarding the ICAO policy and the quality of language tests available, stating that ‘the aviation language testing situation has been driven more by politics and expediency than by best practices in language test design and validation procedures’. This observation regarding the influence of politics was presumably based on the authors’ personal experience and further details were not provided. In contrast, Alderson (2011) published a commentary dedicated entirely to the politics of aviation language testing in *Language Assessment Quarterly*, in which he provides a detailed account of the politics surrounding aviation language testing based on his own research and interactions gleaned from aviation language-teaching online forums. The article relates a number of criticisms of the ICAO policy, but Alderson also acknowledges some of the actions taken by ICAO to alleviate the challenges faced by stakeholders, such as the rated speech sample project and the second edition of Document 9835 (ICAO, 2010) discussed in Chapter 3, and the Aviation English Language Test Service discussed below.

## The Aviation English Language Test Service (AELTS)

In response to concerns about the quality of language tests being developed, and the difficulties experienced by civil aviation authorities in discerning which language tests to accept or administer for licensing purposes, in 2011 ICAO launched the Aviation English Language Test Service (AELTS). The AELTS is a service to which test service providers can submit their tests of Aviation English for evaluation by a team of experts, composed of some combination of individuals with language testing expertise, expertise in the application of the ICAO rating scales, and subject matter experts (i.e. air traffic controllers and/or pilots). On the website[2] the ICAO AELTS provides a list of tests that have passed this evaluation process, deeming them 'ICAO recognized'. The stated purpose of the AELTS is 'to identify and formally recognize those tests of aviation English designed specifically for aviation and that meet ICAO's Language Proficiency Requirements'[3] and the benefit for civil aviation authorities, potential test users and other stakeholders is that recognition by ICAO may facilitate the process of test selection or recognition for licensure purposes.

Given the high stakes nature of aviation language testing for licensing and air safety, the challenges faced by civil aviation authorities in selecting appropriate tests, and the difficulty in ascertaining the quality of some of the aviation language tests available, was of concern to ICAO. If the quality of the tests developed and used in response to the ICAO LPRs could not be determined, neither could state compliance with the Standards and Recommended Practices (see Chapter 3 for a discussion of the role of the ICAO Standards and Recommended Practices in civil aviation regulation) related to language proficiency. As such, ICAO engaged with the International Language Testing Association (ILTA), as well as subject matter experts and other stakeholders in aviation language testing, and developed the AELTS. Alderson (2011) provides some of the history of ILTA's involvement with ICAO in the development of the AELTS process. Importantly, although ICAO involved a number of stakeholders in the process, the AELTS was developed and is administered by ICAO. Tests recognized on the AELTS website are recognized solely by ICAO. It is a common misconception in the language testing community that ILTA as an organisation is involved in the endorsement of aviation language tests through the AELTS; rather, ILTA has provided expert advice at various points in the AELTS development and administration process but is not, as an organisation, associated with the endorsement or recognition of aviation language tests.

Given the central role of language testing in determining compliance with the ICAO LPRs, AELTS is considered an important aspect of the support ICAO provides for member states' conformance with the policy. In order to be eligible for ICAO recognition, test service providers must demonstrate compliance with the ICAO Standards and Recommended Practices for language proficiency requirements (see Chapter 3) and the guidance material provided in Document 9835 (ICAO, 2010). The AELTS evaluation criteria are based largely on Chapter 6 of Document 9835, the title of which is 'Language testing criteria for global harmonization'. Chapter 6 was originally intended for civil aviation authorities and licensing authorities to use either as a guide in the test development process, or as a checklist to be used when evaluating the quality of externally developed aviation language tests. The list of criteria is provided in checklist format in Appendix C of

Document 9835 (2010 edition). Chapter 6 was new to the 2010 edition, and was first published as ICAO Circular 318 in 2009, in response to the difficulties that civil aviation authorities were experiencing in their efforts to implement the ICAO LPRs and the lack of standardization in the global aviation language testing market. In addition, through the AELTS, ICAO has also made available a document entitled ‘A guide to submitting validity evidence’, whose three-fold purpose, as stated in the document, is:

1 To ensure that concise and appropriate evidence in support of the validity argument are submitted to AELTs.
2 To serve as a screening tool for (test service providers) who are considering submitting their test for evaluation.
3 To serve as an educational tool regarding the general form and purpose of validity evidence required for the AELTS process.[4]

In the document a list of considerations regarding validation in the development, trialing and live phases of the testing process are provided, as well as a list of language testing reference books. The document is a particularly useful resource for test service providers who are either considering submitting their test for AELTS evaluation, or are in the process of preparing their application for submission, but it can also be useful for individuals or organisations who are in the process of developing or administering aviation language tests.

Stakeholders, such as civil aviation authorities and test takers, may consult the AELTS website for a list of tests that are currently recognized by ICAO.[5] In 2015 two tests appeared on the website: The test of English Language Proficiency for Aeronautical Communication (ELPAC) for Air Traffic Controllers and the Royal Melbourne Institute of Technology (RMIT) English Language Test for Aviation (RELTA) for pilots. Tests are recognized for a period of three years, during which time test service providers must submit two annual reports. At the end of the three-year recognition period, test service providers may resubmit their tests for evaluation. There are fees (charged to test service providers by ICAO) associated with the initial full evaluation, the evaluation of annual reports and renewal evaluations. As of 2015, a fee of 7,500 USD was associated with full evaluations, 1,500 USD with the evaluation of an annual report, and 4,000 USD was charged for renewal applications not requiring a full re-evaluation of the test. The purpose of the fees is to help ICAO cover the cost of offering the service.

It is important to note that ICAO does not list tests that did not pass the evaluation process. In other words, tests that are non-conformant are not listed on the website, nor does ICAO currently make available information regarding the number of tests that have been evaluated by the test service. As such, tests that do not appear on the AELTS website may have been evaluated and determined to be non-conformant with the AELTS criteria as outlined in Document 9835, or they may simply not have been submitted for review. On the one hand, this aspect of the AELTS policy may seem like a disservice to stakeholders in that they do not have access to a list of tests that have been determined to be non-conformant with ICAO standards. On the other hand, the policy ensures that the AELTS evaluation process is non-punitive in that test service providers who submit their tests and are determined to be non-conformant will not be revealed as such. This suggests that there is potentially a formative element to AELTS, in that test service providers can submit their tests for evaluation without negative consequence, and in the process obtain useful feedback as to how their test might be improved. Indeed, the FAQs of the AELTS website state that, although ICAO does not provide consultative services for test service providers, strengths and weaknesses of the test, as well as specific areas for improvement, are identified in the test evaluation process.[6] It is also important to keep in mind that the AELTS evaluates tests according to the criteria outlined in Document 9835, and the fact that a test does not meet these criteria does not necessarily mean that the test is of poor quality from a more general language testing perspective. In other words, it is quite possible for a systematically designed and validated test to be non-conformant according to the AELTS criteria because it does not meet the specific criteria outlined in the ICAO SARPs or Document 9835.

## Tests of Aviation English

In an effort to give readers an idea of what current tests of Aviation English might consist of, descriptions of four tests are provided here: ELPAC for Air Traffic Controllers, RELTA for Pilots Heavy, the Versant Aviation English Test (VAET) and the ELPAC Level 6 test. These specific tests have been chosen for one or both of the following reasons:

1 the test is recognized by the AELTS; and/or
2 there is sufficient (non-marketing) information provided about the test to provide an informed description.

As already mentioned, both ELPAC and RELTA have been recognized by the AELTS. The VAET has been written about in academic journal articles. The one exception to the inclusion criteria described earlier is the ELPAC Level 6 test, which has been included in this discussion for its innovative approach to assessing candidates at ICAO Level 6, a controversial level of the ICAO rating scales that was discussed in Chapter 3. The sample that follows is not meant to be comprehensive, nor does exclusion from this list imply that a test is of poor quality. The purpose of these descriptions is simply to provide the reader with a general idea of the content and diversity of aviation English tests available at the time of writing.

### ELPAC for air traffic controllers

ELPAC has developed a number of tests in response to the ICAO LPRs (ELPAC for Air Traffic Controllers, ELPAC for ATC students, ELPAC for Pilots and ELPAC Level 6). ELPAC for Air Traffic Controllers is the only ELPAC test that is (as of 2015) recognized on the AELTS website. It was developed by EUROCONTROL in partnership with the Zurich University of Applied Sciences and ENOVATE (a training software development company). It consists of two papers and is designed to assess candidates at Levels 3, 4 or 5 of the ICAO rating scales (discussed in Chapter 3).[7] The first paper tests listening comprehension and the second paper tests oral interaction. Future candidates can practice Paper One by clicking on the appropriate link on the EUROCONTROL website.[8] On the website, candidates are advised to do the sample test at least once before taking the ELPAC test, as a test familiarization exercise. Instructions and information about Paper One are simultaneously displayed on the screen and presented orally. Because it involves examiner–candidate interaction, candidates cannot actually practice Paper Two prior to taking the test, but they can watch videos of examiner–candidate interactions in the three different air traffic control test scenarios (tower, approach and en route) available for Paper Two. Paper One is computer-based and involves listening to routine and non-routine aviation communications and typing responses. A notable feature of Paper Two is that it involves tasks in which there is non-visual communication, i.e. tasks in which the examiner and the candidate cannot see each other due to the presence of a screen between them. This is presumably an effort to replicate the non-visual condition present in controller–pilot communications, adding not only to the face validity (i.e. the subjective appearance of validity) of the tasks, but also, importantly, assessing candidates' ability to communicate in the absence of the visual cues present in face-to-face communication, as is the case with radiotelephonic communications. In most if not all tasks of the ELPAC test for air traffic controllers there is a high prevalence of standard phraseology in the test prompts. A search on the test website for a validation report yielded no results; however, Alderson (2008) refers to the Lancaster group having conducted a validation study for ELPAC, and in the past an executive summary of that validation report was publicly available. It is therefore unclear why the report is not currently available on the test website.

### RELTA for Pilots Heavy

There are actually three types of RELTA tests: RELTA for Pilots Heavy (instrument flight rules), RELTA for Light Aircraft (visual flight rules) and RELTA for Air Traffic Controllers. In this section RELTA for Pilots is discussed, as it is the only RELTA test that was recognized by the AELTS as of 2015. RELTA for Pilots is a speaking and listening test designed to assess candidates at Levels 1–6 of the ICAO rating scales. It is divided into two sections: speaking and listening, each consisting of three tasks. The speaking test is administered by an examiner and lasts approximately 25 minutes. The listening test is computer-delivered and lasts about 40 minutes, and consists of multiple choice and short answer questions. The first part of both the listening and speaking tests involves the use of prompts related to routine situations and the use of standard phraseology. The second part of both the speaking and listening tests involves the use of prompts pertaining to non-routine aviation situations and the use of plain language, and the third part of both the speaking and listening tests involves conversation and the use of complex plain English. Prospective candidates (and interested readers) may take the RELTA practice test for both listening and speaking on the RELTA website.[9] There are also a number of other test preparation materials available on the test website, such as test transcripts, rated speech samples and detailed rater sheets for test performances at Levels 3, 4 and 5, together with detailed instructions for test preparation and clear descriptions of each of the test tasks available. In short, RELTA has made a number of test preparation resources available free of charge to potential candidates. A search for a validation report on the test website yielded no results.

### *Versant Aviation English test (VAET)*

The Versant Aviation English test is developed by Pearson and is an innovative although potentially controversial test in that it involves no human interaction and is delivered by phone or computer using semi-direct prompts. It is intended for both pilots and air traffic controllers, is comprised of eight sections, and takes 25–30 minutes to complete.[10] It involves prompts using both standard phraseology and plain language. The first six tasks require candidates to read, repeat, provide short answers, readbacks, corrections and confirmations. The final two tasks involve story retelling and responding to open questions. Recordings of the candidate's responses are automatically scored. Potential candidates can request a demo test, in which they can try a couple of test items from each of the tasks.[11] In the actual test, candidate responses would be recorded and automatically scored and the final test score would be available within minutes; however, for the demo test responses are not recorded or scored. Nevertheless, although it is much shorter than the test itself, the demo test provides candidates with the opportunity to become familiarized with the test format, and to gain a degree of practice.

The VAET is a well-documented test of Aviation English in terms of development and validation. A full test description and validation summary are available on the Versant website.[12] In addition, at least two articles describing the test development and validation process have been published

(Downey et al., 2010; Van Moere et al., 2009). A detailed discussion of the theoretical foundation and development process of the VAET is outside the scope of this chapter; however, ample information is available through the references provided earlier and they make for an interesting read from the perspective of language testing theory and practice. The objective of the VAET was to develop a highly practical and reliable assessment instrument, and indeed it does have certain strengths compared to other tests. For example, the automated rating system is calibrated and validated using large numbers of expert raters, which greatly limits the subjectivity inherent in any test involving two or three human raters. Scoring of the VAET is automated and thus highly reliable in that it is consistent in how it assigns scores to a candidate speech sample. In addition, because scores for each of the constructs (pronunciation, fluency, vocabulary, structure, comprehension and interactions) are derived separately using independent observations (i.e. different data from the candidate's speech sample are used to derive scores for each of the constructs), the scores for each of the constructs are truly independent of each other. This could be considered important since candidates are awarded the lowest score obtained on any of the six categories of the scale. However, the VAET does have a weakness in that it does not involve multiple-turn interactions. Interactional competence is inferred based on multiple single-turn 'interactions'. While Downey et al. and Van Moere et al. present convincing arguments to support this interpretation of interaction, it is nevertheless a leap to infer interactional competence using this automated method of evaluation. Regardless, this test is very interesting in terms of its innovative approach, its underlying psycholinguistic framework, and its reliability and practicality. In addition to reading the validation report and journal articles associated with the test, doing the demo test helps to clarify the rationale behind the VAET.

### *ELPAC Level 6*

ELPAC Level 6 was developed by the Zurich University of Applied Sciences. As already mentioned, ELPAC Level 6 is not currently recognized on the AELTS website, nor is much information about the test development process or the test structure currently publicly available, either on the ELPAC website or in academic journals (according to searches conducted in 2015). Nevertheless, it has been included in this list of test descriptions because of its innovative approach to assessing candidates at ICAO Level 6, and hopefully further information about its development and validation processes will be made available in the future.[13] ELPAC Level 6 is a test for both controllers and pilots, and is considered the third paper of ELPAC for Air Traffic Controllers or ELPAC for Pilots. In other words, in order to take the ELPAC Level 6 test (Paper Three) candidates must have first passed Papers One and Two of either the ELPAC for Pilots or ELPAC for Air

Traffic Controllers tests. The ELPAC Level 6 test is innovative in that it incorporates the assessment of the interactional skills recommended for native or expert-level speakers, making it unusual in that it assesses according to ICAO's intentions for native or expert-level speakers, as outlined in the guidance material of Document 9835 (ICAO, 2010). (See Chapter 3 for the discussion of the discrepancy between ICAO's intended role for native speakers versus the role for native speakers operationalized in the policy and the ICAO rating scales.) According to the test description provided on the website, rather than merely following the descriptors of the ICAO Level 6 scales, in the ELPAC Level 6 test the following interactional skills are assessed: understand and avoid idiomatic English; recognize and avoid ambiguity; use clear and concise English; negotiate meaning; and clarify potential misunderstandings.[14] For this reason, it is a noteworthy innovation and the ELPAC Level 6 test has therefore been included in this list, despite the apparent lack of information currently publicly available regarding its development process and validation.

## Language testing theory and practice in the aviation context

As can be seen from the brief descriptions of a few tests provided earlier, tests of Aviation English come in all shapes and sizes. Some tests are designed specifically for either air traffic controllers or pilots, while others use the same test for both. Tests differ in the extent to which they employ standard phraseology in test prompts, or the extent to which standard phraseology is elicited in test taker responses. They also differ in the extent to which they attempt to simulate the real-life communicative environment of controllers and pilots. Another way in which tests differ is the number of levels of the ICAO scales they have been designed to evaluate. Some tests assess candidates at all six levels, while others assess candidates only at Levels 3–5. At least one (ELPAC for Level 6) views Level 6 not only as a separate level of the same scales, but as representing a different test construct altogether, and thus has a separate test for evaluating Level 6 candidates. These differences demonstrate diversity, but they also suggest a certain ambiguity and uncertainty in the definition of the construct about which evidence is to be gathered in tests designed in response to the ICAO LPRs.

Test development in response to the ICAO LPRs is a challenging endeavour. Recall that the ultimate goal of the ICAO LPRs is to ensure that controllers and pilots have the language proficiency required to communicate effectively in non-routine aviation situations, based on the assumption that such situations call for the use of plain language, i.e. language that is outside the realm of standard phraseology. Nevertheless, despite this quite specific goal in a quite specific context, the construct of communicative effectiveness in relation to the ICAO LPRs remains elusive (Farris and Turner, 2015). As

Emery (2014: 206) quite nicely put it, 'Unfortunately, although the ICAO guidance material is very useful in laying out the context of and purpose for aviation language testing, it is of little practical use in the definition of the construct and the development of test specifications.' As an aviation language test developer, he is presumably speaking from personal experience. Moder and Halleck (2009) voiced similar concerns related to construct definition, with reference to the difficulties inherent in determining test characteristics for aviation language tests.

Before going much farther, it may be helpful to provide a brief definition of the word 'construct', since readers who are not involved in language testing or measurement and evaluation in general may not be familiar with the term. It can be a difficult concept to grasp or explain, but fortunately, Fulcher and Davidson (2007: 370) provide a tidy definition based on Kerlinger and Lee (2000):

> [A] construct is a concept that is defined so that it can be scientifically investigated. This means that it can be *operationalized* so that it can be measured. Constructs are usually identified by abstract nouns, such as fluency, that cannot be directly observed in themselves but about which we need to make inferences and observations.

To give an example, in the ICAO rating scales six constructs have been identified as underlying the overall construct of language proficiency for communicative effectiveness in aviation. They are: pronunciation, structure, vocabulary, fluency, comprehension and interactions. These constructs appear to be derived from a theory of language proficiency, although, as discussed below, the theoretical and empirical basis for the constructs and criteria of the ICAO rating scales has not, to our knowledge, been published. Following this example, in order to determine whether or not a candidate has the language proficiency necessary to communicate effectively in the aviation context, evidence is gathered in relation to these six constructs from the candidate's performance in test tasks and, based on that evidence, a judgement is made regarding the candidate's level of language proficiency. However, despite the provision of the rating scales, construct definition and determining test characteristics for test design have proved to be quite challenging for test developers. Douglas (2000) states that, in language for specific purposes testing, there should be alignment among the purpose of the test, the test tasks and the assessment criteria. In the case of the ICAO LPRs, there is possibly some misalignment among these elements, rendering the test development process in this context particularly challenging. Some of the specific challenges of aviation language test development will be discussed here.

### *Standard phraseology versus plain language*

As mentioned in Chapter 3, Document 9835 states that tests of Aviation English designed in response to the ICAO LPRs and used for licensing purposes should not be used to assess standard phraseology (ICAO, 2010). However, there is some ambiguity surrounding the type of language and communication to be assessed in relation to the ICAO LPRs. A note in the Appendix to Section 1.2.9 of Annex 1 of the ICAO Standards and Recommended Practices states: 'The language proficiency requirements are applicable to the use of both phraseologies and plain language.' The separation of standard phraseology from plain language has been of concern to test developers. Pilots and air traffic controllers tend to argue that standard phraseology is a technical aspect of their job, closely linked to procedures, that is evaluated in the course of training and should not be evaluated in a language test, particularly not by a language expert who is very possibly not familiar enough with standard phraseology and the operational context to determine whether or not it has been used correctly. This is certainly a valid concern. The difficulty, however, in separating standard phraseology from plain language lies in the fact that the two are intertwined in the real life context. As such, in Document 9835 (ICAO, 2010) it is stated that standard phraseology may be used in test prompts, but the accuracy of its use in test-taker responses should not be evaluated. Given the earlier discussion regarding the difficulty in separating plain language, technical knowledge and standard phraseology in the assessment of communicative effectiveness in the real life context, the feasibility of such separation is questionable. In other words, it is unclear whether or not the assessment of standard phraseology can or should be disregarded in the assessment of language proficiency in relation to the goal of the ICAO LPRs, which is to ensure that pilots and controllers have the language proficiency required to communicate effectively in an unexpected turn of events. Furthermore, this association of routine situations with standard phraseology and non-routine situations with plain language may be to some extent artificial, in that plain language is present in routine communications as well as non-routine communications. Thus, one of the difficulties in developing tests in response to the ICAO LPRs is that tests are to be developed in response to policy and to largely theoretical notions of language use in the aviation context, as opposed to being developed in response to empirical studies of the way language is actually used in this context. As such, test developers inevitably run into difficulties when they try to develop tests that are both context-specific and in alignment with the ICAO LPRs policy and rating scales. One such example is standard phraseology, as already discussed. While ICAO's reason for not including the assessment of standard phraseology in assessments designed in relation to the LPRs is understandable, it also creates a tension between policy and reality that is difficult for test developers to reconcile.

### *Native English speaker versus English as a lingua franca (ELF) standards*

As discussed in Chapter 3, the standard against which expert performance is to be measured in relation to the aviation context is currently problematic in the ICAO rating scales. Although it was not ICAO's intention (as evidenced in the guidance material of Document 9835), the native speaker is the standard according to which expert performance is measured in the current assessment criteria. This problem is not unique to ICAO. It is one that the language testing community is also grappling with. In an attempt to establish standards for language training and testing that are not based on a description of native-like speech, some researchers are attempting to create linguistic descriptions of ELF (e.g. Jenkins, 2000; Seidlhofer, 2001). These early works by Jenkins and Seidlhofer are mentioned because they can be considered seminal works in ELF in the field of applied linguistics, but there have been many developments in ELF studies since that time (see Jenkins, 2011, for a review). While, according to some definitions, ELF is defined as communication in English between non-native speakers of English, according to other definitions native speakers of English are included as potential ELF speakers, sometimes based on the assumption that ELF is a code in and of itself that must be acquired, even by native speakers (Jenkins, 2011). Whether or not one subscribes to the notion that ELF is a separate code that has to be acquired by native speakers of English, it is quite certain that ELF is not a single code. Given that English is spoken in a wide variety of contexts by a wide variety of people, there are likely to be many varieties of ELF. Therefore, attempting to create a unified description of ELF is surely a tremendous task. As such, ELF researchers face challenges similar to those faced by ICAO. In the absence of a native speaker standard for testing purposes, what should the standard for expert performance be? Another approach is the one taken by Harding (2014), which is to focus on interlocutor adaptability as opposed to acquisition of particular linguistic features of ELF. Whatever the approach taken, ICAO's challenge of finding a viable alternative to the native speaker standard is one that is shared by the language testing research community. ICAO's intentions for native/expert-level speakers outlined in the guidance material of Document 9835 (and described in Chapter 3) reflect an ELF perspective, even if the operationalized role of the native/expert speaker in the policy and the descriptors in Level 6 of the rating scales reflect a native speaker standard at the expert level.

### *Context specificity versus generalizability*

Another challenge in the development of aviation language tests, or any language test for that matter, is the tension between context specificity and generalizability. One of the objectives of a language for specific purposes test is to test language in accordance with the communicative needs of that specific context. However, even in a highly constrained environment such as controller–pilot radiotelephonic communications, there are an endless number of potential situations and interactions such that it is impossible to include all of them in training let alone in a single test. For that reason, the constructs that underlie the ability to communicate effectively in the aviation context must be identified and described for assessment purposes. Another question, then, is to what extent or which elements of the context are relevant to performance such that they should be included in the testing context (Farris and Turner, 2015). Related to this question is the impact of contextual factors on performance in the aviation context – a topic that we discuss in greater detail in the following three chapters.

## The ICAO rating scales

The empirical basis of the ICAO rating scales is unclear, as the process of their development and validation has never been published. As such, the extent to which a systematic development process took place cannot be ascertained. The current rating scales[15] reflect very little of the highly specific context in which radiotelephonic communications take place. In fact, in some cases, the scale descriptors may be considered to be in contradiction to the communicative needs of controllers and pilots in radiotelephony. Clear examples of such contradictions can be found in the descriptors for Expert Level 6. Examples of these contradictions were given in Chapter 3 (e.g. the fluency descriptor that calls for the ability to speak at length with an effortless flow, or the vocabulary descriptor that calls for the use of idiomatic language). However, although the Level 6 descriptors of the rating scales have been the focus of much of the recent criticism of the scales, the descriptors of the other five levels are also open to criticism.

Moder and Halleck (2009: 25.5) point out that the descriptors of the ICAO rating scales 'primarily reference general concepts of oral proficiency, making little or no specific mention of the Aviation English domain'. Nevertheless, ICAO takes the following theoretical stance regarding language proficiency: 'language proficiency is necessarily linked to particular uses of the language' (ICAO, 2010: 3–1), although, for the most part, the scales themselves describe language use that is rather non-specific to the context of controller–pilot communications. This discrepancy between the rating scale descriptors and the guidance material highlights another discrepancy between the theoretical orientation of the LPRs policy, as described in the guidance material, and the operationalization of the policy in the assessment criteria.

In an innovative study that explores the use of stakeholder feedback in post-hoc validation research, Knoch (2009) elicited stakeholder feedback on the ICAO scales. The stakeholders in Knoch's study were either users of the

ICAO rating scales or pilots. Nearly half of the respondents indicated that they felt that the scale descriptors were not very suitable for use by raters who were operational (e.g. pilots, controllers, trainers) as opposed to language experts. Furthermore, over half of the respondents in the study indicated that they did not believe that Level 4 represented an adequate level of language proficiency in relation to the goal of the ICAO LPRs (i.e. the ability to communicate effectively in non-routine aviation situations). Of course it is important to note that 48 per cent did believe that Level 4 was an adequate level of language proficiency, so there is clearly disagreement among stakeholders in the aviation language testing community regarding the appropriateness of both the scale's descriptors and the level of language proficiency adequate to meet air safety objectives. Interestingly, in response to a question asking whether or not respondents were satisfied with the categories (pronunciation, fluency, structure, vocabulary, comprehension and interactions) the quantitative data suggested that respondents were satisfied, with the majority indicating satisfaction with each of the categories and descriptors, but the qualitative data obtained in open-ended questions indicated that there was indeed dissatisfaction with the rating scales among stakeholders, to an extent that Knoch interpreted as possibly being indicative of the need for revisions. Some of the themes that emerged in the criticisms Knoch reported were that some of the descriptors were not relevant to the work context of controllers or pilots (particularly at Level 6), that the descriptors were too vague, and that there was a lack of congruence in the terms of the skills and abilities described across levels of the scales.

Interestingly, there were some cases in Knoch's data where the language raters and pilot raters differed, and in these cases the pilot participants tended to confound candidates' language ability and technical knowledge in their judgements of the candidates' ability to communicate effectively. This is not surprising given that pilots are most likely concerned with whether or not a candidate can do the job at hand, and technical knowledge plays an important role in the outcome of the real-life performance, highlighting the difficulty of separating language proficiency from other aspects of performance in the assessment of communicative effectiveness in a real life context. In addition to technical knowledge, Knoch found that pilots also attended to overall evaluation of speech level, transition from standard phraseology to plain language, visual cues and appropriateness of answer. Given that ICAO recommends the use of a double rating system, ideally including one rater with operational expertise and another with language expertise, it is important to consider the factors that operational experts in particular might attend to in the rating process, and to consider whether or not the separation of technical and language skills is realistic for operational raters when assessing communicative effectiveness in the aviation context. Knoch's study is important as it provides an empirical basis upon which to consider the ICAO rating scales, but, as Knoch herself concedes, it is but one piece of a complex puzzle. Much more empirical research is needed in order to validate the scales, or to justify the need to revise them.

Although Knoch (2009) is the only known ICAO rating scale validation study (a rather surprising observation given the high stakes and ubiquitous nature of the LPRs), other authors have expressed dissatisfaction with the scales. For example, Emery (2014: 207) states, '[A]lthough the second edition of Document 9835 (ICAO, 2010) provides some accompanying notes on the rating scale, not all of these abilities are clearly defined, and they require interpretation. In addition, the operationalisation of some of the abilities would appear to be problematic.' As already mentioned, alignment among the goal of the ICAO LPRs, the test tasks and the assessment criteria is paramount to development and validation according to language for specific purposes testing theory. It would appear, based on the limited empirical evidence available and stakeholder feedback, that there is reason to consider revisions to the ICAO LPRs, and the validity and usefulness of the rating scales in particular. However, in order to ascertain which criteria should be used in the assessment of test performance, further research is required in order to better define the construct of communicative effectiveness in the aviation context (Farris and Turner, 2015).

## Notes

1 EALTA guidelines for Good Practice are available in 35 different languages at the EALTA website, http://www.ealta.eu.org/guidelines.htm, retrieved 9 May 2015.
2 https://www4.icao.int/aelts, retrieved 9 May 2015.
3 https://www4.icao.int/aelts/Home/About, retrieved 9 May 2015.
4 https://www4.icao.int/aelts/Uploads/A%20Guide%20to%20Submitting%20Validity%20Evidence.pdf, retrieved 24 June 2015.
5 https://www4.icao.int/aelts/home/recognizedtests, retrieved 9 May 2015.
6 https://www4.icao.int/aelts/Home/About?Tab=FAQ, retrieved 9 May 2015.
7 Descriptions of the tasks can be found at the following link to the ELPAC website: https://www.eurocontrol.int/articles/elpac-tests, retrieved 9 May 2015.
8 https://www.eurocontrol.int/articles/tests-preparation, retrieved 9 May 2015.
9 https://practicetest.relta.org/, retrieved 9 May 2015.
10 A sample paper is available at the following link: http://www.versanttest.com/samples/Versant-Aviation-English-Certification/Sample-Test-Paper-VAET-Certification-all-watermark.pdf, retrieved 9 May 2015.
11 The test website can be found at https://www.versanttest.com/samples/aviationEnglish.jsp, retrieved 9 May 2015.
12 A full test description and validation summary are available at the following link to the Versant website: https://www.versanttest.com/technology/VersantAviationEnglishTestValidation.pdf, retrieved 9 May 2015.
13 A brief description of the test can be found at the following link: https://www.eurocontrol.int/articles/elpac-tests, retrieved 9 May 2015.
14 http://www.eurocontrol.int/articles/elpac-tests, retrieved 20 September 2015.
15 The ICAO rating scales are found in Attachment A to Annex 1 and are reproduced in Appendix A of ICAO Document 9835 (2004, 2010).

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Chapter 5

# Communications between air traffic control and pilots

*Candace Farris and Brett Molesworth*

## Introduction

Air traffic controller–pilot communications take place in a constrained but dynamic environment. They are usually highly scripted, brief, routine and, in most cases, unfold as expected. Sometimes miscommunications occur, and most of the time these miscommunications are easily resolved. Occasionally a miscommunication is not immediately resolved, or important information is not accurately conveyed in a timely manner. Even more rarely, a miscommunication results in an incident or accident. Because air traffic controller–pilot communications are high-stakes interactions, such miscommunications, however rare, must be avoided insofar as possible so as to minimize the probability of an incident or accident occurring. For this reason, we believe it is important to take a proactive approach in examining the context in which these communications take place, for the purpose of understanding the conditions under which these interactions are most likely to be successful.

Both pilots and air traffic controllers interact with a number of interlocutors in the course of doing their jobs, and there are several loops of communication in the air traffic controller–pilot communicative environment. Although the focus of this book is on the loop between ATC and pilots, in this chapter the broader environment of air traffic controller–pilot communications will be described. Having an understanding of this environment is important as it facilitates an understanding of the nature of these interactions, for language and communication training, assessment and research purposes. We therefore provide further detail regarding the jobs of air traffic controllers and pilots. It is important to note that controller–pilot communications are a global phenomenon, and there is likely a high degree of regional differences in terms of the language used in communication, despite the efforts discussed in Chapters 2 and 3 to standardize aviation operations and procedures for the purpose of ensuring global harmony in civil aviation. Similarly, controller–pilot communications take place in a variety of contexts, from commercial flights carrying hundreds of passengers to general aviation flights carrying only the pilot, and, as mentioned in Chapter 2, there are also many other general aviation contexts such as rescue operations, fire-spotting, fire-fighting, aerial beach patrol (shark spotting), aerial fish spotting, aerial photography and flight training. Although these contexts may differ in terms of the frequency of interaction between pilots and air traffic controllers, they have much in common and share many of the same challenges in relation to communication. Recognizing that it is not possible to give a detailed description of the wide variety of aviation contexts in which controllers and pilots communicate with each other, we nevertheless provide an overview of the contexts in which aviation communications take place, with a particular focus on commercial operations, since this context accounts for a large volume of civil air traffic in the world's air traffic management systems.

In addition to providing this overview, we also focus on particular factors present in the communicative environment of pilots, some of which we have investigated in our research programmes. Interestingly, although we have worked independently as researchers, we have converged on a common understanding that the context in which communication takes place is paramount to understanding what it means to communicative effectively. We will therefore, in this chapter, discuss some of the research investigating relationships among factors inherent in the communicative environment of controllers and pilots.

## The context and interlocutors

Controllers and pilots are, naturally, seated in different environments and, in the case of voice communication,[1] they communicate with one another over the radio through headsets. Whereas pilots are seated in the cockpit of the aircraft, talking to the controller through a headset and listening to communications between the controller and all other pilots on the selected frequency, air traffic controllers are in most circumstances seated at a control centre, looking at a radar screen, using a headset to talk to all pilots on the selected frequency and possibly communicating with other controllers within the same control centre and/or at other control centres. A challenging but highly organised communicative environment is the result.

### *Airspace classification*

According to the International Civil Aviation Organization (ICAO), there are different classes of airspace (classes A–G) representing different flight rules – instrument and visual[2] – and different requirements for controller–pilot interactions, most notably, whether a pilot is in controlled or uncontrolled airspace. As mentioned in Chapter 2, it is primarily in controlled airspace that pilots communicate with air traffic control, although a pilot flying in uncontrolled airspace may contact air traffic control for information, and would broadcast his or her intentions when arriving at an uncontrolled aerodrome. It is important to note, however, that not all member states adopt the various classes of airspace, for diverse reasons such as traffic volume and geographic expanse, and, if adopted, they are free to apply changes to the airspace classification as deemed appropriate. The following is therefore a brief overview of the different airspace classes based on ICAO's airspace classification system.

Class A airspace is the most restricted airspace. To gain entry into this airspace, ATC clearance is required, along with a two-way radio, and the aircraft must be operated under instrument flight rules (IFR). The service provided by ATC in this class of airspace is the highest possible (full separation provided). Hence, ATC will ensure aircraft remain separated from each other to prevent a collision, as well as provide additional information such as weather and traffic. Class B airspace can be used by all aircraft operated under both IFR and visual flight rules (VFR), with ATC again providing separation. Of course, a two-way radio is required. In Class C airspace, aircraft operated under IFR will receive separation from all other aircraft, but, in the case of aircraft operated under VFR, separation will only be provided from IFR aircraft (i.e. not between VFR aircraft). In Class D airspace, separation between IFR-operated aircraft is provided, but traffic information only is provided to those using VFR. No separation is provided between VFR- and IFR-operated aircraft. What is consistent between Class C and D, however, is the need to have a two-way radio.

Class E and F airspace are similar, in the sense that both IFR- and VFR-operated aircraft are permitted in the airspace, and that aircraft separation is only provided to IFR-operated aircraft; however, this separation service is not guaranteed in Class F airspace, and is only available where practicable. Class G airspace is uncontrolled airspace and therefore no such service is offered for either VFR or IFR. As expected, a two-way radio is required for all aircraft operating under IFR in Class E–F airspace, whereas VFR-operated aircraft are not required to carry a two-way radio. It is important to note that pilots in controlled airspace are in continual communication with ATC, and the extent of this communication is dictated by the phase of flight, which will be discussed in greater detail below.

Controller–pilot communication, as discussed in Chapter 2, is highly prescriptive. As a result, a positive relationship between communication accuracy and exposure is expected. This means that commercial pilots flying on both domestic and international flights who remain solely in controlled airspace can be expected to be more proficient in aviation communication than a general aviation pilot who may only occasionally enter controlled airspace, such as landing at a controlled aerodrome (with the remainder of the flight being outside controlled airspace). Pilots who fly in remote areas may rarely come into contact with ATC. When they do, their adherence to the prescribed language and phraseology is likely to be less polished than their commercial counterparts, because they have fewer opportunities to practice, though the level of experience may, of course, vary. The same implications are, possibly to a lesser extent, to be expected for pilots employed in industries such as aerial fire fighting or search and rescue, where their exposure to controlled airspace is, at times, limited. This may be compounded by the environment they work within, where, due to factors such as noise and lack of mobile telephone coverage, their primary means of communication with personnel on the ground and/or in command posts/ stations is via the same radio as they would use to communicate with ATC. However, given the nature of the communication and the background of the people they are communicating with, it is unlikely that they would adhere to the same strict communication protocols and phraseology as employed in controlled airspace. This relationship between pilot experience and communication accuracy will be discussed further in Chapter 7.

### *The air traffic controller*

The standard phraseology discussed in Chapter 2 is representative of the disciplined and highly regulated system of air traffic control. Air traffic control is a highly researched area, and, ideally, all systems and conditions present in the environment are carefully designed to ensure optimal job performance and reduce the possibility of human error. The job of an air traffic controller can be very demanding, particularly when handling large volumes of traffic or irregular operations, and high task demands can result in high workload for the controller. Conversely, the job can be quite boring during times of low traffic. Both situations, with low or high workload, can result in performance decrements, a phenomenon that will be discussed in greater detail in Chapter 6.

In terms of communication, the primary job of an air traffic controller is to ensure aircraft separation by issuing navigation instructions to pilots in order to ensure that aircraft in a given area maintain a minimum vertical and horizontal distance from each other or from the terrain. Another important aspect of an air traffic controller's job is coordination with other controllers. Throughout the flight, as the aircraft moves through airspace, it is handed off to a sequence of controllers, each responsible for a sector (although in some cases, multiple controllers look after one sector, which is further subdivided according to altitude). These hand-offs occur through the use of flight strips, which were originally actual physical strips of paper on which controllers wrote pertinent information such as aircraft call-sign, aircraft type, altitude, and departure and destination locations, then physically handed off the piece of paper to the next controller. In cases where the controllers were not in the same facility, pilots were responsible for initiating contact with the next controller using the frequency given to them by the previous controller. While pilots still do initiate contact with air traffic control when changing sectors, nowadays electronic systems based on the principles of the flight strip system (and sometimes even made to look like flight strips) have replaced paper flight strips in many air traffic control centres (although paper flight strips are still used in some towers where it is physically possible), and hand-offs occur electronically so that controllers usually know that aircraft are on their way before they arrive in their sector. Such systems changes have been necessary to support dramatic increases in air traffic volume and complexity in many parts of the world.

Just as there are many aviation contexts for pilots, there are many aviation contexts for controllers. Controllers handle military, regular public transport (RPT) and general aviation (GA) aircraft, and in each of these categories there is a wide range of aircraft types. Fixed wing versus rotor is just one such distinction. In addition to dealing with a number of different types of aircraft, from light to heavy, with different speed restrictions and separation requirements, controllers need to be apprised of changing conditions at their facility, such as which runways are in use, and meteorological conditions such as wind, fog and lightning, which may affect pilot navigation. In short, the job of an air traffic controller involves much more than issuing instructions to pilots and listening to their readbacks, although clearly this is a central aspect of their role in the air traffic management system.

Air traffic controllers are positioned on the ground and they direct traffic based on information gleaned from their monitoring of radar screens, on visual information (in the case of aerodrome controllers) and on information obtained from their interactions with pilots and other air traffic controllers. When we think of air traffic controllers, we often think of those seated in a tower, controlling traffic in the immediate vicinity of the airport; however, there are several types of air traffic controller, most of whom cannot directly observe the air traffic under their control from their position. The general manner in which air traffic control is organised and the various types of air traffic controller are described below, though this may differ from place to place.

### *En route or area controllers*

En route (also called area) controllers work in area control centres which can cover thousands of square miles of airspace. That airspace is divided into clearly defined three-dimensional sectors, and at least one controller is responsible for each sector. As an aircraft passes out of one sector into another, it is handed off to another controller, either another en route controller, or, if the aircraft is approaching an airport, an approach controller.

### *Approach controllers*

Approach controllers are responsible for sectors approximately 50–100 km radius from the airport. Approach control handles departures, arrivals and fly-overs. Once aircraft are within closer range of the airport, they are handed off to aerodrome control.

### *Aerodrome controllers*

Aerodrome controllers are responsible for aircraft within the immediate vicinity of the airport. Aerodrome control may be further subdivided into tower and ground control.

Tower controllers are responsible for runways (the airport area where aircraft take off and land), and ground controllers are responsible for taxiways (a paved strip that runs parallel to the runway and is used by aircraft to access the runway from the terminal without disturbing active runway traffic).

### *Communication with pilots*

As already mentioned, because a single air traffic controller may be responsible for a number of aircraft at a time, and because in radiotelephonic communications only one individual can speak at a time, air traffic controllers communicate with pilots sequentially. As we also mentioned earlier in the discussion, controllers have other duties apart from communicating with pilots, such as monitoring weather (as changes in the weather may necessitate changes to the navigation instructions they issue to pilots or a change of runway for take-off and landing), coordinating with or assisting controllers in other sectors, and other duties within their own air traffic control centre. As such, controllers are often very busy, and, as a result, particularly during periods when task demands are high, they may issue a number of instructions at a time to a pilot, in the interest of efficiency. This can be a source of frustration for pilots, who often complain that controllers either speak too quickly or provide too much information in a single message (Barshi and Farris, 2013).

## ***The pilot***

The aviation adage ‘aviate – navigate – communicate’ summarizes the primary tasks performed by pilots, supposedly in order of importance, but of course these three tasks are interdependent and the overall success of the flight is dependent on the prioritization and coordination of all three (Dismukes et al., 2001; Loukopoulos et al., 2009). Just as the air traffic controller’s primary job is to ensure aircraft separation, the pilot’s primary job is to ensure that the aircraft remains safely in the air, on the runway, taxiway, etc., as the case may be. However, just as the air traffic controller’s job involves the coordination of a complex network of aircraft within a sector, the pilot’s job involves not only monitoring and maintaining an understanding of the dynamic state of his or her own aircraft, but also maintaining some degree of understanding of the position and state of other aircraft in the vicinity. This understanding is often referred to as situation awareness, and listening to and understanding communications between pilots and air traffic controllers on the appropriate radio frequency is considered to be an important factor in developing and maintaining situation awareness. In fact, communication is considered to be so important for situation awareness that situation awareness has been the primary argument used in support of single language policy for air traffic control.

As discussed in Chapter 3, the single-language argument goes that, if pilots cannot understand communications between air traffic control and other pilots in the sector, then the pilot cannot maintain a clear understanding of the position and state of other aircraft in the sector. At least intuitively, this is a convincing argument; however, it does not take into account other aspects of performance that might be impacted by a single-language (in most arguments, English-only) policy. Clearly the role of communication in situation awareness is an important consideration in relation to language use, but it is not the only consideration. Another consideration is the facility with which pilots can express themselves, particularly in situations that call for the use of language outside the realm of the highly practiced standard phraseology.

Along the same lines as the single-language argument for air traffic control follows the argument that pilots should speak the same language in the cockpit (to each other) as they do with air traffic control, in order to avoid any confusion or additional cognitive load imposed by code switching. Indeed, some major airlines have a policy stating that only English should be used in the cockpit, although the success and impact of such policies is largely unknown. The International Civil Aviation Organization has not mandated the use of a single language in air traffic control, and, given the current lack of evidence in terms of safety outcomes to support such an extreme measure on a worldwide scale, this seems to be a sensible decision.

Just as the volume of traffic in the sector might affect an air traffic controller's workload in terms of communication, so might the phase of flight affect a pilot's workload in terms of the need to communicate with the controller. Flights are commonly described as consisting of the following five phases:

- preflight, taxi, take-off;
- departure and climb;
- en route (cruising);
- descent and approach; and
- taxi and arrival.

However, these five phases do not take into account non-routine situations. Therefore, in recognition of both the complexity and variability of flight operations, as well as the need for international standards when describing flight operations, definitions taken directly from *Phase of Flight: Definitions and usage notes* (April, 2013) developed by the joint Commercial Aviation Safety Team and ICAO Common Taxonomy Team will be used here.[3] These definitions were developed for the purpose of creating a common taxonomy for use in aviation incident reporting systems, but they can be useful in any context in which it is necessary or helpful to refer to flight phases. They are particularly useful because they acknowledge the circularity of flight phases, in that the end of one flight may represent the beginning of another (e.g. for commercial pilots flying more than one segment). In such cases, the first phase, standing (see Table 5.1), may be either the end or the beginning of a

*Table 5.1* Summary of flight phases

| *Phase of flight* | *Description* |
|---|---|
| Standing | Prior to pushback or taxi, or after arrival, at the gate, ramp or parking area, while the aircraft is stationary. |
| Pushback or taxiing | Aircraft is moving in the gate, ramp or parking area, under own power or assisted by a tow vehicle (tug). |
| Taxi | The aircraft is moving on the aerodrome surface under its own power prior to take-off or after landing. |
| Take-off | From the application of take-off power, through rotation and to an altitude of 35 feet above runway elevation. |
| Initial Climb | From the end of the take-off sub-phase to the first prescribed power reduction, or until reaching 1,000 feet above runway elevation or the VFR pattern, whichever comes first. |
| En route | Instrument Flight Rules (IFR): From completion of Initial Climb through cruise altitude and completion of controlled descent to the Initial Approach Fix (IAF). Visual Flight Rules (VFR): From completion of Initial Climb through cruise and controlled descent to the VFR pattern altitude or 1,000 feet above runway elevation, whichever comes first. |
| Manoeuvring | Low altitude or aerobatic flight operations (apart from take-off and landing). |
| Approach | Instrument Flight Rules (IFR): From the Initial Approach Fix (IAF) to the beginning of the landing flare. Visual Flight Rules: From the point of VFR pattern entry, or 1,000 feet above the runway elevation, to the beginning of the landing flare. |
| Landing | From the beginning of the landing flare until aircraft exits the landing runway, comes to a stop on the runway, or when power is applied for take-off in the case of a touch-and-go landing. |
| Emergency descent | A controlled descent during any airborne phase in response to a perceived emergency situation. |
| Uncontrolled descent | A descent during any airborne phase in which the aircraft does not sustain controlled flight. |
| Post-impact | Any of that portion of the flight which occurs after impact with a person, object, obstacle or terrain. |
| Unknown | Phase of flight cannot be determined based on the available information. |

flight. Many of the details of each of these phases of flight have been omitted from this description in the interest of brevity, but the titles and brief description provided should be sufficient to provide an idea of the complexity and potential variability of flight operations.

The flight phases described in Table 5.1 provide a skeletal overview of the process of flying experienced by a pilot. From the perspective of the pilot, a number of the phases represent periods of high workload in terms of both cockpit task demands and ATC communication demands. For example, standing, pushback/towing, taxi and take-off are very high workload phases for the pilot, and, at large and busy airports, the pilot may communicate with as many as three controllers (ground, tower, approach) during these phases, while doing such things as preparing the aircraft for take-off, conducting a pre-flight briefing with the crew, checking the weather, reviewing the route, etc. Add to all of these tasks communications with the controller, as well as listening to the communications between the controller and all other aircraft on the frequency, and the result is an environment in which the operator is performing multiple 'concurrent' tasks. At least in theory pilots are rested at this take-off phase of flight (which is not always the case as pilots may be flying multiple segments or flights in a single day, sometimes changing aircraft), but, in cases of lengthy delays where the aircraft remains in one phase for a long period, fatigue can result.

The approach and landing phases are also high workload phases, the effects of which, after a long-haul flight, or a long day of search and rescue, or multiple short-haul flights, can be compounded by fatigue. During these phases of flight, pilots are expected to receive instructions from ATC regarding desired altitude, direction and even approach speeds, as well as weather and applicable traffic information. In some commercial operations, and presumably in acknowledgment of the high workload and the multitude of tasks required by pilots, restrictions on communication between the cabin and the flight crew are imposed, in addition to non-essential communication between flight crews (i.e. only operational matters are to be discussed). Referred to as a 'sterile cockpit', cabin crew are also strongly discouraged from contacting the flight crew, unless an emergency presents. Similarly, and in accordance with the United States Federal Aviation Regulations (FAR) pertaining to flight crew member duties (FAR 121.542 and FAR 135.100), flight crew members are to refrain from engaging in non-essential activities (i.e. activities that have no relationship with safely operating the aircraft) below 10,000 feet, such as ordering supplies from the galley, pointing out places of interest to passengers, discussing personal matters, etc. For flight operations other than RPT (i.e. airlines), similar restrictions may apply, but the altitude in which they apply would be dependent on the operation and company policy. Again, ATC communication demands are high and the pilot may have to communicate with up to three controllers in a brief period. In addition to the many other duties associated with landing the aircraft, the pilot must ensure that each controller is apprised of his or her aircraft's particular situation.

Both emergency descent and uncontrolled descent are clearly high workload phases stressful events for the pilot, and in some cases it is extremely important that the pilot maintain communications with the controller in order to ensure separation from other aircraft in the area, or to ensure emergency services are properly directed. These phases are characterized not only by high workload, but also high emotional stress. The pilot needs to be able to maintain accurate and efficient communications with the controller under these conditions.

## Challenges in controller–pilot communications

At the beginning of this chapter we stated that controller–pilot communications take place in a constrained but dynamic environment. The descriptions given provide an indication of the complexity of the environment in which controllers and pilots interact with each other, and a number of factors inherent in the communicative environment create challenges for controller–pilot communications. Some of these factors (message length, speech rate and workload) will be discussed in this chapter in relation to pilot performance.

One important challenge in controller–pilot communications is that during busy times, controllers want to convey as much information as possible in one message to the pilot, so that they can move on to the next aircraft as quickly as possible; however, at such busy times (usually the phases associated with take-off and landing) the pilot is also performing many tasks concurrently and may have difficulty retaining all of the information the controller wishes to convey in one long message. Further exacerbating this challenge of high workload and conflicting interests, in most contexts controllers and pilots rarely if ever train together (though many ATC also fly and as a result hold some type of pilot licence), and so, often, have little knowledge of each other's work environment or task demands (see Barshi and Chute, 2001, for a more complete discussion of this issue). In addition, pilots and controllers may not only be strangers, but are often from different sociolinguistic backgrounds, and cannot see each other, making it even more challenging to achieve mutual understanding and shared situation awareness. Because the primary means of communication is the radio, which is not always clear and necessitates rigid turn-taking protocol, many of the usual tools of conversation development and maintenance (e.g. back channelling[4], overlapping talk) are eliminated. This is further compounded by the fact that air traffic management systems often handle high volumes of traffic, resulting in the need for controllers to balance the competing constraints of accuracy and efficiency. In practical terms, this can result in controllers trying to convey a lot of information in a single message, and possibly not taking the time and attention required to listen carefully to pilots' readbacks, failing to ensure that there are no errors contained therein. Clearly air traffic controller–pilot communications present some contextual factors that make these high-stakes communications potentially challenging and in relation to language teaching and testing, a degree of understanding of the contextual factors that impact communication may be useful in the development of training and assessment materials. Aviation English is an example of language used for a specific purpose and, as such, the environmental and contextual factors that impact communication would be useful considerations for language teachers and testers.

Conversely, air traffic controller–pilot communications take place in a constrained environment, and are goal-oriented, which makes them relatively simple and often predictable. It is important to remember that most often these communications are successful, despite the challenges described earlier and despite the fact that many of the interlocutors in the global context do not share the same native language and one or both are communicating in a second language. Even in cases where the interlocutors share the same native language, there can be significant dialectical differences that render the communications challenging. The success of these communications may be attributed to the underlying knowledge of the aviation context, prescribed phraseology and procedures which controllers and pilots share. There are standards and procedures that guide communication in most situations, but the success of these communications can also be attributed to the flexibility and resilience that pilots (human operators) bring to the system (Barshi and Farris, 2013). As such, despite the challenges imposed by the context in which they communicate, controller–pilot communications are remarkably resilient to problems arising from miscommunication. Nevertheless, given that aviation is a high-stakes environment, there is a low tolerance for error and every effort must be made to eliminate the miscommunications that do occur. For this reason, research into factors impacting controller–pilot communications is important for air safety, as it is through such research that a better understanding of how controllers and pilots communicate effectively will be achieved. Some of this research will be discussed below and in the following two chapters.

## Empirical investigations

Our interest in the impact of contextual factors on controller–pilot communications drew us to experimental research, since under experimental conditions specific factors can be controlled and thus predictions can be made regarding the relationship between these factors and performance. In this section, some of the work of Candace Farris and her mentor, Immanuel Barshi, will be discussed.

Barshi (1997) reports a study in which he investigated the effects of linguistic properties and message length on pilot comprehension and retention of controller messages. This study has recently been published, in Barshi and Farris (2013), along with an extension of that work (Farris, 2007). The purpose of the original study was twofold:

- whether the omission of linguistic elements (determiners, linking verbs, prepositions, and sequence markers) typical in controller messages impacted pilot comprehension of those messages; and
- whether controller message length (messages varying in length between one and six controller commands, or in linguistics terms, propositions) and prosody (speech rate, pauses) impacted pilot comprehension of controller messages.

Barshi used both naturally occurring controller–pilot discourse and laboratory speech data in his study.

The first part of the study investigated the effects of the omission of linguistic elements generally absent in standard phraseology (determiners, linking verbs, prepositions and sequence markers), as well as the effect of prosody (speech rate, pauses), on errors in pilot readbacks. Barshi found that neither the omissions nor prosody consistently corresponded with error rates in the pilot readbacks. He did, however, conclude that it was possible:

> that the absence of linguistic elements such as prepositions and sequence markers, as well as the extensive use of numerical information and the inconsistent structure of prosodic units, all have a cumulative effect that is confounded with the effect of message length' (Barshi and Farris, 2013: 23).

In order to tease apart the prosodic variables from message length, Barshi (1997) created an experimental paradigm designed to be cognitively analogous to the communication and navigation tasks performed by pilots (see Barshi, 1998, and Barshi and Farris, 2013, for a full explanation and discussion). Participants (university students with no aviation experience) played the role of pilots. They listened to analogue 'controller' messages and were instructed to 'navigate' by clicking a visual representation of a three-dimensional navigational space presented on a computer screen. An example of a three-command navigational instruction would be: 'Turn left one square. Climb up one level. Move forward one step.'

As with real-life controller instructions, which generally maintain the same presentation order for heading, speed and altitude, so the instructions in the analogue task maintained the same order of presentation for turn, climb and move. Barshi conducted four experiments. In experiments 1–3 he manipulated speech rate and message length and examined their effects on participant performance, and in experiment 4 he manipulated natural intonation patterns marking clausal boundaries. In all four experiments the dependent variables were the accuracy of the participants' 'readbacks' of the 'controller' messages, and participants' accuracy on the navigation task. The results of these experiments corroborated the findings obtained in his analysis of the natural speech data, in that no consistent effects of speech rate or pauses were obtained. However, strong and consistent effects of message length were obtained: participant accuracy rates in terms of readback and navigation accuracy decreased as a function of increased message length. Participants responded to messages containing between one and six commands or informational units, and showed important drops in performance between lengths three and four.

Another important result of Barshi's experiments was the effect of practice on performance accuracy on the readback and navigation measures. In his analysis of natural data (i.e. his analysis of recorded controller–pilot messages), pilots exhibited reduced readback accuracy (i.e. made more errors) when responding to controller messages that contained more than four units of information. Because such long messages occurred relatively rarely in the natural data set, it was unclear whether this tendency was due to pilots' lack of practice with longer messages or message length effects. Barshi's experimental studies revealed that participants' performance (as measured in blocks from one to six commands) improved across blocks only for messages containing up to three commands, for which participants tended to achieve nearly perfect levels of accuracy. In contrast, in messages between lengths three and four, even at the final block, performance accuracy dropped by nearly 50 per cent, indicating that pilots' difficulty in retaining and comprehending messages containing four or more commands was not due to a lack of practice, but rather due to basic cognitive processes (i.e. working memory constraints), given that the practice that allowed participants to improve in response to messages containing up to three commands did not support improvement in response to messages containing four commands. Based on these results, and considering the results of previous studies in which message length effects were investigated (e.g. Cardosi et al., 1996; Morrow and Rodvold, 1993), Barshi concluded that controllers should limit the length of their messages to three commands or information units, in order to ensure accurate pilot comprehension and retention of controller messages.

Regarding his experimental investigation of the effect of speech rate and pauses on navigation and readback accuracy, Barshi obtained no reliable effects of prosody in his experiments. It is important to note, however, that Barshi used words spliced from the speech stream and digitally manipulated speech rate and pauses. He did so in order to isolate the particular prosodic elements under investigation, so that they would not be confounded with co-articulation effects, which can result in reduced intelligibility, particularly in speech that is delivered at a faster rate. As Barshi himself points out, it is important to keep this in mind when considering practical recommendations for speech rate in controller messages. In addition to co-articulation factors that may affect intelligibility, there are also sociolinguistic factors to take into account when making speech rate recommendations, in terms of the effect of fast, impatient-sounding controller speech on pilot perception (Barshi and Farris, 2013). From a psycholinguistic perspective, Barshi's speech rate findings are very interesting in that they suggest that speech rate in and of itself, teased apart from other potentially confounding variables present in natural speech, does not reliably affect comprehension. From an applied perspective, the limitations of Barshi's findings must be acknowledged, but, nevertheless, they have implications for language training and assessment in that, in relation to comprehensibility, instructors should focus not on simply slowing down, but rather on clear articulation. The effects of speech rate on comprehension merit further investigation in the aviation context, and one such investigation will be discussed in Chapter 7.

Barshi and Healy (1998) extended Barshi's study to investigate the effects of speech rate and message length on the performance (readback and navigation accuracy) of native and non-native English-speaking participants, using the same analogue pilot communication and navigation task described earlier. This is important work in that it was the first known experimental study to investigate the effects of language proficiency on performance in the aviation context. Barshi and Healy divided participants (university students) into three groups: native English speakers, high proficiency non-native speakers, and low proficiency non-native English speakers. Language proficiency groups were determined based on two factors: language background and performance on a TOEFL listening comprehension test. Similar to Barshi's previous study, messages of lengths one to six were presented to participants. As with the earlier experiments conducted by Barshi, one of the objectives was to isolate the effects of speech rate, so that they were not confounded by extraneous variables present in connected or co-articulated speech. For that reason, speech rate was digitally manipulated by splicing individual words from the speech stream and either lengthening or shortening pauses between the words. For the first experiment, the pause duration between words was manipulated to create two speech rate conditions: normal and slow. For the second experiment, word duration was manipulated in order to create two speech rate conditions: normal and fast. For the third experiment, the number of words per command was manipulated to create a condition comparing less redundant commands with the usual redundant experimental commands (e.g. 'Left one' versus 'Turn left one square'). The university students in this study had no aviation experience. As in the experiment described earlier, participants heard analogue 'controller' messages and were instructed to 'navigate' by clicking a visual representation of a navigational space presented on a computer screen.

Overall, results obtained by Barshi and Healy supported their hypothesis that the robust message length effects obtained in this and previous experiments could be attributed to basic cognitive processes (i.e. working memory constraints) as opposed to processes that are associated specifically with language or with a specific language. Native and non-native speakers demonstrated the same pattern of results in that they each displayed performance decrements when responding to long messages. As in Barshi's previous studies they found that performance improved across blocks. Generally, all groups displayed the largest drop in performance between message lengths three and four, with the exception of experiment 2, in which the low proficiency group displayed the largest drop in performance between lengths two and three. Nevertheless, despite the fact that experiment 2 had a fast speech rate condition, no reliable effects of speech rate were obtained. Nor were any reliable effects of redundancy obtained in experiment 3, in other words no participant group, even the low-proficiency group, differed significantly in terms of readback or navigation accuracy as a function of message redundancy.

The results of these experiments supported the recommendations regarding controller message length (maximum of three commands) based on Barshi (1997) with one caveat: Barshi and Healy recommended that, when communicating with pilots of low EL2 proficiency, controllers should limit the length of their messages to two commands, in the interest of facilitating accurate comprehension. The results for speech rate effects did not support Barshi and Healy's hypothesis that a slower rate of speech would result in improved comprehension for the low-proficiency non-native speaker group. Based on those results, Barshi and Healy concluded, once again, that speech rate in and of itself does not appear to negatively impact comprehension, provided intelligibility is maintained. They do highlight, however, that speech rate effects may differ between native and non-native speakers when listening and responding to natural speech, uncontrolled for connected or co-articulation effects.

Farris (2007) extended the work of Barshi and Healy by investigating the effects of language proficiency, message length and cognitive workload on readback and navigation accuracy, and speech production, using the same analogue task developed by Barshi. Farris modified Barshi's paradigm to add a condition in which additional cognitive workload was imposed by the performance of a concurrent arithmetic task. Part of this study was published in Farris et al. (2008) and the full study was later published in Barshi and Farris (2013). Here a brief summary is provided.

As with Barshi and Healy's study, the participants used in Farris's study were university students with no aviation experience. There was a total of 60 participants, divided into three groups of 20 each: native English speakers (NES), high proficiency non-native English speakers (high EL2), and low-proficiency non-native English speakers (low EL2). The speaker groups were determined by using two factors: language background and overall English language proficiency scores, which were based on a number of measures (listening test, rated participant speech samples, proportion of errors in a speaking task). The two EL2 groups were determined by performing a median split of overall proficiency scores of the 40 EL2 participants, and differed significantly on all proficiency measures (i.e. the high group received better scores than the low group). The native speaker participants received the highest scores on all proficiency measures. All EL2 participants were native speakers of Mandarin or Cantonese.

As already mentioned, there were two experimental conditions: low workload and high workload. In the low workload condition, participants listened to messages containing between one and three 'controller' commands, read back the messages, and then carried them out by clicking on the appropriate squares on the navigational space represented on the computer screen. In the high workload condition, the participants performed the same task, but a two-digit number appeared briefly and randomly in one of four quadrants on the computer screen immediately following the controller message. Participants were required to reverse the number and add it and the original number together mentally while repeating the controller message, and then provide the answer to the arithmetic problem immediately following the readback, thus inducing an additional cognitive workload concurrent with speaking. There were two sets of dependent variables in the study: performance (navigation accuracy and readback accuracy) and speech production (comprehensibility, fluency, accentedness and confidence). The speech production measures were determined based on the ratings of speech samples of each of the participants, by 10 NES raters.

For the performance variables, as expected, results of the study indicated that all participant groups (NES, low EL2, high EL2,) performed less accurately (in terms of readback and navigation accuracy) in response to longer messages. In other words, there was a negative relationship between message length and performance accuracy. Also as expected, all groups performed less accurately in the high workload condition than in the low workload condition, indicating that participants were unable to maintain the same levels of readback and navigation accuracy when communicating under high workload conditions. As with Barshi and Healy's experiments, all groups displayed a similar pattern of results, suggesting that workload effects were due to basic cognitive processes related to working memory as opposed to language-specific processes. Contrary to expectations was the lack of reliable difference in terms of workload effect between the native speaker and EL2 participants; however, pairwise comparisons revealed a complex relationship between proficiency and workload in terms of effects on performance, and in terms of the proportion of correct responses; EL2 groups did display greater differences than the NES group between the low and high workload conditions, particularly in response to shorter messages.

The EL2 groups displayed meaningful drops in performance between the low and high workload condition in response to messages containing two commands, whereas for the native speaker group a meaningful drop in terms of the proportion of correct responses between the low and high workload conditions occurred in response to messages containing three commands. At message length three, all participants had difficulty performing accurately in the high workload condition.

For the speech production variables, the results were more complex, but will be briefly outlined here (see Barshi and Farris, 2013, for a full report and discussion of the results). In the low workload condition native speakers did not display perceptible changes to the speech signal in response to longer messages, whereas the EL2 groups did, for all measures. There were, however, no reliable differences in ratings between the low and high EL2 groups in the low workload condition. In the high workload condition, the NES group did display perceptible changes to the speech signal, but only for the fluency and confidence measures and only at length three. In contrast, both the low and high EL2 groups received significantly lower ratings due to increased message length for *all* measures in *both* conditions when responding to messages containing two or three commands. These results suggest that the additional cognitive load imposed by longer messages and a concurrent task have a greater effect on the speech production of EL2 speakers (at least intermediate-level EL2 speakers) than on native speakers (and possibly advanced-level EL2 speakers, but there were no such participants in this study), to an extent that is perceptible to listeners.

Based on the message length results of this experiment, Barshi and Farris (2013) recommended that, in situations where pilots are experiencing high workload due to concurrent task performance, controllers should limit their commands containing new information to two propositions (or commands) for native or near-native speaking pilots, and to one proposition (or command) for pilots of low EL2 proficiency. Clearly these recommendations pertaining to message length should be regarded with some caution. In a real-life context, controllers and pilots need to maintain a balance between accuracy and efficiency, and it may not always be practical or necessary to issue such short messages when communicating with a pilot perceived to have a low level of language proficiency and who is likely to be experiencing high workload conditions. In addition to the need to balance the accuracy and efficiency constraints of the air traffic management system, there is also the challenge, for the controller, of recognizing that a pilot is experiencing high workload or that a pilot is of a relatively low level proficiency in the language of communications. Neither will necessarily be obvious. However, the results of studies such as those already discussed can be considered not only in light of regulatory procedures, but also in light of training. They can be useful in creating awareness of potential difficulties in controller–pilot communications, and can be discussed and practiced in the context of communication strategies in training scenarios. For example, if a controller notices in the hearback phase that the pilot is having difficulty retaining the content of a message, the controller could recognize that the problem is due to a legitimate cognitive constraint and deliver the message in manageable parts, rather than becoming frustrated with the pilot and merely repeating the long message over and over, creating stress for both parties. In other words, adjust to the situational context. Likewise the pilot could recognize that the controller may be under high workload and make sure he or she has a pencil handy to copy down instructions that may be too numerous to remember. Better mutual understanding could lead to improved cooperation between controllers and pilots in a busy global air traffic management system. Furthermore, another practical consideration to take away from the study of language proficiency, message length and workload effects is that unless training programmes and assessments are carefully designed, levels of performance may not be consistent between the classroom or the testing context and the real-life context in which pilots and controllers operate. Furthermore, both NES and EL2 participants' ability to perform accurately was affected by contextual factors, suggesting that the high workload conditions typical of certain phases of flight may impact on all aviation professionals' ability to communicate effectively, regardless of native language or language proficiency level. That is not to say that NES and EL2 learners will require identical language and communication training, or that assessments pertaining to language proficiency must be conducted in a high-fidelity simulator. Rather, awareness and consideration of the context in which these potentially high-stakes communications take place may be useful in informing the development of training syllabi and assessment criteria in controller–pilot communications. In the following chapter, contextual factors that impact on communication will be discussed in greater detail, and in Chapter 7, a discussion of a study that extends the research reported will be provided.

## Notes

1 This is in contrast to controller–pilot data link communications, where digital information is transmitted and received in text format.

2 Visual flight rules (VFR) and instrument flight rules (IFR) differ primarily in terms of the instruments, or lack thereof, used to ensure aircraft orientation and navigation. With VFR, visual cues outside the aircraft (e.g. landmarks, the horizon) are used for navigation purposes, whereas with IFR , instruments are used. Aircraft flying under VFR may indeed be IFR equipped (i.e. have the required instruments on board), but visual cues are still the primary means of navigation for the pilot. In addition, a pilot must be trained to read the navigation instruments, and hence must hold a current instrument rating to operate in IFR.

3 http://www.intlaviationstandards.org/Documents/PhaseofFlightDefinitions.pdf, retrieved 2 February 2015.

4 *Longman's Dictionary of Teaching and Applied Linguistics* now includes 'back channelling' under 'feedback': 'In discourse analysis, feedback given while someone is speaking is sometimes called back channelling, for example comments such as *uh, yeah, really,* smiles, handshakes, and grunts that indicate success or failure of communication' (Richards and Schmidt, 2010: 217).

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Chapter 6

# Contextual factors impacting on aviation communication

*Brett Molesworth*

This chapter provides a synopsis of the contextual factors that have the potential to adversely affect aviation communication. Referred to as stressors, these can be either physical or psychological and all have the potential to modify communication performance. One particular stressor that is discussed at length in this chapter is 'noise'. Noise, while not unique to aviation, is prevalent. Its interaction with the language background of the speaker is of particular interest to aviation and effective communication, as its effect is more pronounced for non-native speakers.

Prior to discussing noise and its effect on performance in the aviation setting, it is important to ensure the reader has a clear understanding about the classification of noise and for that matter, other performance moderating factors such as temperature (i.e. thermal) and light, and their relationship with cognition from a behavioural perspective. Noise, as discussed at length later, is one example of a physical stressor. Other examples include thermal and light. However, not all stressors are derived from the physical (external) environment. Stressors can also be psychological in origin or social (interaction with another person). Not surprisingly, definitions of stress are diverse and reflect the many decades of research in this area. McGrath (1976) attempts to define stress not by what it is, but by the condition (or sets of conditions) which are required before treating a situation as being stressful. Accordingly, he notes that for a situation to be considered to be stressful, three elements must be present:

1 perceived by the stressee as demanding;
2 perceived inability of the stressee to cope/meet the demands; and
3 the perception of the importance of being able to cope with the demand.

Stokes and Kite (2001: 109) define stress at a more finite level: 'an agent, circumstance, situation, or variable that disturbs the normal functioning of the individual'. Irrespective of the definition one aligns with, the fact remains that the impact of a stressor, either physical or psychological, has the real potential to alter behaviour, including communication, and, in a safety critical domain such as aviation, has important safety implications.

From a behavioural perspective, the relationship between stress and performance is founded on the premise that cognition underpins all human actions. Models such as the ‘Structure of Information Processing’ model by Wickens (1992), which highlights the cognitive architecture and its subcomponents (i.e. sensory processing, perception, decision and response selection, response execution, attention resources and memory) provides a neat framework to illustrate where stressors can impact cognition.

Importantly, not all stress is bad. In some circumstances, stress can be challenging and energizing (Matthews et al., 2000). This is possibly best illustrated with reference to the Yerkes and Dodson (1908) famous curvilinear relationship (inverted U) between arousal (often interchanged with stress) and performance (the original research was conducted with mice involving a simple learning task with electric shocks used to shape their behaviour; neither was arousal or stress measured). In other words, too little arousal or too much arousal will degrade performance. Importantly, and as the reader will soon discover from the discussion that follows, the presence of a stressor (i.e. noise or thermal condition) does not guarantee changes in behaviour. In contrast, stressors are best described as having *potential* to alter behaviour. In other words, stressors create an environment where changes in behaviour are more likely. The challenge for everyone involved in a complex system reliant on humans, such as aviation, is to understand the potential of these stressors, the environment in which change is more likely to occur, the potential consequences of the change, and, importantly, to design systems and implement defences to protect against these changes if deemed undesirable.

With this in mind, and since aircraft are renowned for producing high levels of noise, and the negative effects of a stressor such as noise on cognitive performance are widely known, the following sections will investigate the research in this area.

## Noise and performance

‘Repeat’, ‘confirm’, ‘say again’ are all standard phrases that both pilots and air traffic control operators are very familiar with. The existence of these phrases reflects the complexity and difficulty of communicating effectively in aviation, despite the presence of specific and clearly defined phraseology. For pilots in particular, there are many factors that make communicating effectively in aviation particularly challenging. Take their work environment, for example. In comparison to a typical office, noise levels inside the cockpit of a common general aviation aircraft such as a Cessna 172 during cruise are 50 decibels louder (Jang et al., 2014). Inside the cabin of a commercial aircraft such as an Airbus A321, noise levels are at least 30 decibels louder than a typical office. For an office environment, target noise levels should be 40–45 decibels (Standards Australia, 2000). Even with hearing protection (passive and/or active) that is incorporated into all modern aviation headsets, in-ear noise levels exceed recommended levels for an office environment. Excessive noise is known to affect individuals' performance, including although not limited to communication. Stress, temperature and fatigue are also known to have an adverse effect on individuals' performance. However, the variability to which these factors influence individuals' performance is only equal to the variability in vulnerability of individuals to these factors.

All sound, irrespective of its origin, is said to be processed cognitively. In most cases, this process is highly automated and hence little thought is given to the mental effort afforded to such a task. Consider the following situation:

> Declan is preparing his children's lunch in the kitchen. In their open plan house the kitchen adjoins the lounge room where the television is on at low, but auditable volume; the morning news is being broadcast. He is engaged in a conversation with one of his children about the presentation she will be making today in her science class. While engaged in this discussion he hears a news bulletin concerning a wild storm en route to the town he grew up in. He asks his daughter if they could continue the conversation in a minute and then proceeds to ask his second daughter, who happens to be close to the television, to increase its volume. Occurring simultaneously, he stops preparing the lunches and focuses on the news bulletin.

This example highlights the effort required to process auditory information. For example, in an attempt to clearly hear and process the information provided in the news bulletin, Declan temporarily ceased one conversation, thereby eliminating any competing audio signal (could be considered noise as it distracts from the target signal); at the same time he improved the target audio signal by having the volume increased on the television (improved signal-to-noise ratio). In an attempt to further increase the cognitive resources available to process the information from the news bulletin, he ceased preparing the children's lunch (psychomotor task).

While Declan had the luxury of asking one of his daughters to suspend their conversation, thereby reducing competing audio so he could focus on the target signal, pilots are not afforded the same luxury when it comes to aircraft noise. As all pilots can attest, in-cabin aircraft noise is present from start-up to shut-down. Aircraft noise is both phonologically and semantically different from speech, but, in contrast to the effects of speech on performance, little is known about the effects of aircraft noise (such as the continuous noise present in the cabin of an aircraft) on performance. What is known is summarized in the text that follows.

For the purpose of this chapter, noise is defined as unwanted sound. Importantly, this classification may vary between people: one person may consider a particular sound or collection of sounds as noise, whereas another may not. Research investigating the effects of noise on performance can be divided according to whether the noise is presented as continuous or intermittent and how personally significant or meaningful the noise is to the listener. Since aircraft noise contains no distinguishable phonemes that could be interpreted as speech, it is considered non-meaningful noise. It is at this point that the author hopes readers with an aviation background (e.g. pilots) will object to or at least question the appropriateness of this term for use in an aviation setting. For pilots, engineers and even lay people (i.e. ear witnesses), noise generated from engines such as aircraft can provide valuable information, for example its proximity and functionality. It is the latter that is most important to pilots as changes in aircraft engine noise provide pilots with clues that there may be a problem with an engine. To avoid the confusion of introducing a new term specific to aviation, I will keep the term 'non-meaningful noise' to refer to aircraft engine noise that has no distinguishable phonemes that could be interpreted as speech, but with the understanding that this noise contributes to the pilots' interpretation of the environment.

Depending on the location of the listener, aircraft noise can either be continuous noise as experienced in the cabin of an aircraft or intermittent noise as experienced when an aircraft flies overhead. Research investigating the effects of aircraft flyover noise (i.e. intermittent noise) on performance is plentiful. In contrast, there is limited research examining the effect of in-cabin aircraft noise on the occupants' (pilots, cabin crew or passengers) performance. Nonetheless, the aircraft flyover noise research is informative regarding the potential effect of in-cabin aircraft noise on aircrew and cabin crew performance, as well as their passengers, who may be engaging in work during their journey.

Chronic aircraft flyover noise exposure has been repeatedly linked to impaired cognitive performance in school children (Haines et al., 2001; Hygge et al., 2002). Complex tasks (often referred to as a higher order cognitive tasks) such as problem solving and decision-making, as well as tasks that involve language, such as reading, appear most vulnerable to its effects. Aircraft flyover noise has also been found to have adverse physiological effects, most notably resulting in elevated blood pressure and increased risk for ischemic heart disease in both adults and children (Cohen et al., 1986; Knipschild, 1977; Stansfeld and Matheson, 2003). In contrast, research examining the effect of noise, including aircraft noise, on tasks described as forming the basis of human information processing, such as perception, attention, reaction and, to some extent, memory (i.e. low-order cognitive processing tasks), reveals mixed results.

The variability in the results appears to stem not necessarily from the distinction between low- and high-order cognitive tasks, but from the cognitive load imposed by the task itself; however, it is rare that researchers in this field discuss the effect of noise on performance from this perspective. For example, a basic simple memory-based exercise is unlikely to be affected by noise, either soft or loud. In contrast, a complex memory-based task that imposes high-cognitive load is likely to be affected by noise, even noise that is deemed to be soft. Hellbrück and Liebl (2007) remind us that the basic cognitive functions such as perception, attention, reaction and memory form the elements of complex cognitive tasks such as comprehension and decision-making. The implications for high consequence industries such as aviation, where pilots are expected to perform a variety of tasks from the simple readback of air traffic control instructions to the complex diagnosis of a system failure/malfunction are significant. Hence, reducing noise levels within aviation can decrease the moderating (i.e. intensity) effect noise has on performance. With this backdrop, and recall that it is rare for researchers to discuss the cognitive load imposed by the task itself on performance, the following provides a summary of the research in this area, focusing on the relationship between noise (mainly aircraft flyover and in-cabin noise) and its effect on key skills required for aviating, including effective communication.

### *Effects of aircraft noise on cognition*

The effect of aircraft noise, most notably aircraft flyover noise on cognitive performance, is widely reported. Tasks involving central processing and language comprehension are the most vulnerable to both intermittent as well as continuous aircraft noise. Even though the noise itself is the same for all speakers, its effect on understanding speech is different and is greater for non-native speakers. The significance of this is most profound in aviation, where noise is prevalent, and where many pilots who use Aviation English are not native speakers of English.

The effect of noise on non-native speakers will be discussed later, but first it is important for the reader to appreciate what is meant by sound, and the typical and/or expected sound (i.e. noise) levels in a variety of settings.

The sound pressure level measured in decibel (dB) is a logarithmic unit used to quantify the loudness of sounds. This unit has been developed following studies on the perception of sounds. So a change of 1 dB is a just noticeable change in loudness under perfect listening conditions, such as a special test room. A change of 2 or 3 dB is just noticeable under normal conditions when there is sound around. The normal frequency range for humans is between 20 Hz and 20,000 Hz. As human hearing is not even across this frequency range a filter that has a response similar to human hearing, called an A weighting, is used in noise assessments and the levels expressed as dB(A).

It is important to note that exposure to excessive noise can cause hearing damage. As a result, there are regulations in most countries that limit the noise exposure in the workplace to an average level 85 dB(A) over 8 hours. As the sound level increases, the permissible exposure time decreases. For example, the limit for a constant noise at 88 dB(A) is 4 hours and for 91 dB(A) is 2 hours (Safework Australia, 2011).

Below the workplace noise exposure limits there are recommended design sound levels for various uses within buildings. The basis for these levels is that that intrusion of noise from outside the space should not affect the work being done within the space. So, for example, the recommended maximum design sound level for a general office should not exceed 45 dB(A). For a court room, where it is vital to hear what is being said, the maximum design sound level is 35 dB(A) and for cafeteria and food courts 55 dB(A) (Standards Australia, 2000). This document does not include guidance on recommended noise levels inside aircraft. Given the safety critical role of pilots and the complex tasks commonly conducted, it would be reasonable to consider the flight deck environment to be comparable to an office.

The noise levels within aircraft, however, are considerably higher. It is not uncommon for noise levels in some military aircraft to exceed 100 dB(A) (Pääkkönen et al., 2001). In commercial aircraft such as a Boeing 747, noise levels during cruise range from 74 to 80 dB(A) and for a McDonnell Douglas MD-80 can reach as high as 85 dB(A) (Burgess et al., 2014). Even during taxi, the noise level can be 65 dB(A).

In one study the academic performance and health of young children at four schools in a high aircraft noise-impact (16-h outdoor Leq > 66 dB(A)) urban area was compared with the performance and health of young children from four matched controlled schools in a low aircraft noise-impact (16-h outdoor Leq > 57 dB(A)) urban area, all around Heathrow Airport in West London in England (Haines et al., 2001).[1] After controlling for factors such as age, sex, ethnicity and socio-economic status, students in the high-noise exposed schools had poorer reading comprehension and poorer sustained attention than students from the low-noise school. Higher levels of self-reported stress as well as annoyance were also evident in the high-noise schools compared to the low-noise schools.

A similar study in Munich in Germany revealed similar trends in performance as a result of aircraft flyover noise. However, rather than testing student performance at schools around an existing airport, the researchers capitalized on the opening of the new Munich International Airport and the termination of the old airport (Hygge et al., 2002). In total 326 students participated in the study in two experimental groups: one from a school located at the old airport (noise level with aircraft noise 68 dB(A), without aircraft noise 54 dB(A)); and another from a school near the new airport (noise level without aircraft noise 53 dB(A), with aircraft noise 62 dB(A)). In addition, two control groups featured from an area that had little exposure to aircraft noise (before changeover 59 dB(A) and 53 dB(A), and after changeover 55 dB(A) and 55 dB(A); 24-hr dB(A) Leq). Children in the control group were matched to children from the two experimental groups based on socio-demographic characteristics. Performance data, such as memory for information, reading ability, speech perception and focused attention, was collected at three distinct points: six months prior to the changeover of airports; one year post changeover; and two years post changeover. The results revealed that long-term memory and reading was impaired in the new noise-exposure group while the reverse was found in the old noise-exposure group. Children in the new noise-exposure group also experienced speech perception problems. In terms of the effects of noise on attention, results revealed that attention relating to a visual search task was not vulnerable to the effects of noise.

Survey data from teachers about their students' attention or concentration levels concur with the findings that aircraft flyover noise affects student performance. In fact, the results of a survey of 2,100 Hong Kong teachers in both primary and secondary schools identify a correlation between noise levels within the classroom from aircraft flyovers and student concentration problems (Ko, 1979).

### *Effects of noise on perception (speech or auditory discrimination)*

Research examining the effect of noise on perception reveals mixed results. Remember perception could be described as a basic element required for complex cognitive tasks such as text comprehension and decision-making. In an auditory discrimination task (Wepman auditory discrimination test) with grade three children, aircraft flyover noise with peaks at 95 dB(A) failed to have any effect (Cohen et al., 1986). However, in a similar study with children between the grades of two and five, street traffic noise between 55 and 66 dB(A) was found to adversely affect auditory discrimination performance on the same test (Cohen et al., 1973). Laraway (1985) found that intermittent white noise at 80 dB adversely affected the performance of children with cerebral palsy on a digit discrimination task but had little effect with the healthy control group.

Tabri et al. (2011) found that the number of languages a person speaks also affects their ability to perceive speech in a noisy environment. Specifically, in a study with 34 adults who were either monolingual English speakers, bilingual speakers (fluent in Arabic with English as their second language) or trilingual speakers (fluent in Arabic, with French and English as additional languages), performance on the speech perception in noise test (SPIN) was notably different as the noise (multi-talker noise) level increased (50, 55, 60, 65 and 70 dB). Moreover, when noise levels were considered soft (i.e. 55 and 60 dB), performance on the SPIN test was similar between the three groups. However, as the noise levels increased beyond the soft level, bilingual and trilingual listeners' performance decreased more rapidly on the SPIN test compared to monolingual listeners. These results reflect those identified by Weiss and Dempsey (2008), who found that, as bilinguals obtain greater experience in their second language, their ability to perceive speech in their first language in the presence of noise deteriorates to a point that is noticeably worse than their monolingual counterparts. This result, suggesting that in some way bilingualism affects language processing, is an important finding which warrants further attention, given that English is not the native language of many aviation personnel (discussed further below).

### *Effects of noise on attention*

Similar to the research findings regarding the effect of noise on perception, research examining the effect of noise on attention also reveals mixed results. Recall attention could be described as another one of the basic elements of information processing and variations in the cognitive demands of the test employed may contribute to these mixed results, as well as the native language background of the participants under examination and the type of noise (frequency and duration). In the two aforementioned studies at airports in Europe, Hygge et al. (2002) found that aircraft noise (flyover) did not affect students' attention on a visual search task. However, Haines et al. (2001) found in their study with students near Heathrow Airport in England that attention was adversely affected by aircraft flyover noise. Other types of industrial noise, such as road traffic noise, have also been found to adversely affect school children's ability to remain vigilant. Moreover, in a study with school children between the grades of seven and ten, road traffic noise in the range of 40–85 dB was said to account for students' longer response and increased errors on a concentration test (Bourdon Test: Karsdort and Klappach, 1968).[2] Teachers' subjective evaluation of students' concentration levels concur with these findings, where teachers in noisy schools report more concentration problems with students than teachers from quieter schools (Kryter, 1985).

With adults there appear to be limited studies examining the effect of aircraft noise on vigilance level. The only study that could be found was conducted by Molesworth et al. (2014b), who examined the effect of 80 dB(A) of continuous simulated aircraft noise (i.e. wideband noise) for a period of 83 minutes on university students' vigilance (low cognitive demand task) using a Mackworth Clock task. In this task, participants were exposed to a clock and had to detect when the clock jumped one second ahead. Since the aim of this study was to examine the prolonged effect of simulated aircraft noise on performance, they tested students (half NES and half EL2 speakers) both prior to and post the noise exposure condition. In total 84 students participated in the study, equally divided into three groups: no noise; noise exposure without hearing protection; and noise exposure with hearing protection (active noise attenuation headphones). The results revealed no differences in performance on the vigilance task between the three groups or between NES and EL2 speakers. This result suggests that 80 dB(A) of simulated aircraft noise over a period of 83 minutes has no noticeable effect on individuals' ability to complete a low cognitive demanding task such as a Mackworth clock task.

Research outside aviation, examining the effect of background noise such as music or noise reflective of a coffee shop atmosphere on vigilance, is more plentiful. The results can be summarized as follows. When individuals are completing tasks requiring minimal cognitive resources (i.e. simple repetitive and often boring tasks), music at low volume often improves performance (Beh and Hirst, 1999; Fox and Embrey, 1972). When noise levels are considered loud, in the vicinity of 80 dB, vigilance performance is often degraded (Beh and Hirst, 1999). As the reader would come to expect, there are some circumstances where the converse occurs. For example, extroverts often perform better in the presence of loud noise such as noise at 80 dB compared to a quieter condition of noise at 65 dB (Furnham and Strbac, 2002). Conversely, introverts have been found to perform better in the quieter condition of 65 dB of noise than in the noisy condition of 85dB of noise (Geen et al., 1985).

### *Effects of noise on auditory discrimination*

It would be no surprise to the reader that, in an auditory discrimination task, noise in excess of the target signal degrades performance. In such a case, the noise masks the target audio signal, thereby preventing the listener from discriminating between the noise and the target stimuli. Conversely, as the signal-to-noise ratio increases (i.e. noise levels decrease relative to the target stimuli), auditory discrimination improves. This is why in noisy environments where auditory communication is essential, such as in aviation, pilots wear hearing protection with an incorporated communication unit. What might be a surprise is that noise is more detrimental to non-native than native speakers (discussed in this section), when the target signal is in the native language of the speaker (Jang et al., 2014; Molesworth et al., 2014a; Shimizu et al., 2002). Noise also affects children more than adults in terms of speech intelligibility. According to Nelson (2003), the ability to understand in a noisy environment is learnt rather than innate. It is only in adolescence that individuals' ability to understand in noise matures.

Stelmachowicz et al. (2000) showed that, in quiet conditions, children with no hearing deficit could repeat fully audible and predictable words at a level equal to adults (also without any hearing deficit). However, when the audibility of the words reduced by 50 per cent, 5-year-old children could understand accurately approximately 70 per cent of the words. As the children's age increased (i.e. 6, 8, 10 years) so did their understanding, with

10-year-olds understanding close to 95 per cent. If word audibility reduced to 25 per cent, children between the ages of 5 and 6 could understand virtually nothing while adults could understand considerably more, close to 70 per cent. If the words were unfamiliar to the children or the adults, performance notably reduced. In such a condition, and with word audibility at 25 per cent, adults could barely understand 50 per cent of the words while 5- and 6-year-olds were unable to understand a word, and 8- and 10-year-olds could understand approximately 40 per cent of words. It was only when word audibility reached close to 80 per cent that adults could recall all unfamiliar words; for children it varied between 90 and 100 per cent of word audibility.

For children and adults alike, understanding speech that is not in their native language in the presence of noise is difficult. This appears to occur even when the non-native speakers demonstrate native-like speech recognition in quiet settings. Irrespective of age, 10 dB of noise below the target audio signal is enough to adversely affect non-native speakers ability to understand speech (Nelson et al., 2005). For adult Japanese medical students, reproduced aircraft noise with a signal-to-noise ratio of +6 dB was found to degrade performance by approximately 10 per cent on a simple (phonologically balanced monosyllabic English words) word recognition task (Shimizu et al., 2002). When the signal-to-noise ratio decreased to +1 dB, word recognition decreased by a further 10 per cent. Recall performance fell to approximately 50 per cent when the signal-to-noise ratio was –4 dB. According to Shimizu and colleagues, there was large variability in subjects' scores, which was attributed to variations in English proficiency levels. It was also recognized that, despite the variations in English language proficiency, non-native speakers never reach the level of native speakers. This claim is supported by Mayo et al. (1997), who found that monolinguals and early bilinguals (who learnt English before the age of 6) outperformed late bilinguals (who learnt English after the age of 14) Mexican-Spanish speaking listeners on a word recall task in the presence of noise with and without contextual information to assist.

Importantly, Shimizu et al. (2002) found that not all words are equally affected by noise. Specifically they found that, for English, consonants are more likely than vowels to be mistaken in the presence of aircraft noise. This is particularly the case when the sibilant /s/ occurs between the vowel /i/ and the consonant /t/ (e.g. 'eat' vs 'east'); when the consonant following the vowel /ei/ is a voiced stop /d/ or a voiceless stop /t/ (e.g. 'aid' vs 'ate'); or when the nasal stop /m/ is followed by a vowel or a consonant (e.g. 'me' vs 'them'). This result is attributed to the fact that consonants produce a less intense and more transient sound than vowels (Nábělek and Nábělek, 1994).

The reason why noise is more detrimental to EL2 than to NES remains unknown, but there are a number of theories that attempt to explain this fact. These theories are discussed in the later section entitled *Noise and* *language background*. The implication that noise affects EL2 more than NES is of importance in aviation since English is not the native language of many aviation personnel.

### *Effects of noise on memory*

The effect of aircraft noise, both flyover noise as well as in-cabin noise has repeatedly been shown to adversely affect memory. With children, Hygge and colleagues found that as little as 62 dB(A) of aircraft flyover noise adversely affected students' long-term memory (Hygge et al., 2002). Similarly, Clark and colleagues found that the same type of noise, and at similar levels, also affects students' working memory as well as episodic memory (Clark et al., 2005). In adults, Molesworth and colleagues have found that as little as 65 dB(A) of simulated in-cabin aircraft noise (continuous noise) is enough to adversely affect adults' long-term memory as well as recognition memory (Molesworth and Burgess, 2013; Molesworth, Burgess and Chung, 2013a; Molesworth, Burgess and Gunnell, 2013b). Sixty-five decibels of continuous aircraft noise is typically what is present during the taxi phase of flight in a commercial aircraft such as an Airbus A321 (Burgess et al., 2014; Ozcan and Nemlioglu, 2006). During cruise in a commercial aircraft however, noise levels are typically much higher and can reach 80–85 decibels (Molesworth et al., 2014a). For general aviation pilots, noise levels in a Cessna 172 during cruise average 95 dB(A). Such noise has been found to affect pilots' short-term memory and as expected, adversely affect speech discrimination (Jang et al., 2014).

In one study designed to investigate the negative effect of in-cabin aircraft noise on memory, Molesworth and colleagues compared recall performance on a single task in the presence of 65 dB(A) of in-cabin aircraft noise with recall performance on a dual task which involved completing a computation task while listening to the target audio, but with the aid of active noise attenuation headphones (Molesworth et al., 2013c). Active noise attenuation headphones are known to reduce in-ear noise levels, hence improving the signal-to-noise ratio. They also had a number of other experimental conditions, including testing two high-price point (i.e. expensive) commercially available active noise attenuation headphones. In terms of recall performance, there were no notable differences between the two active noise attenuation headphones tested. In contrast, recall using the noise attenuation headphones was significantly better than in the baseline condition without the headphones. Surprisingly, no differences were evident in recall performance between the no headphones condition and the dual task with noise attenuation headphones condition. In order to ensure that participants in the dual task condition did not neglect completing the computation questions, which could account for the results, they compared participants' performance on this task to a baseline condition without noise and another task. They found that while in the dual-task condition participants completed slightly fewer questions, there was no difference in the number of errors committed between the two conditions. Considering the instructions to the participants in the dual-task condition emphasized accuracy over speed, these results were interpreted as illustrating the detrimental effect of in-cabin aircraft noise on performance.

In an attempt to eliminate the possibility that it was the masking effect of the in-cabin aircraft noise (i.e. continuous noise) that was adversely affecting recall performance rather than the effect of noise itself, Molesworth and colleagues designed a study where they had participants listen to the target audio unaided (through external speaker) in the presence of 65 dB(A) of simulated in-cabin aircraft noise and compared this to a condition where they listened to the target audio (through external speaker), along with music at low volume (50 dB(A)) played through active noise attenuation headphones, also in the presence of simulated in-cabin aircraft noise (Molesworth et al., 2013a). There were a number of other experimental groups, including one group that used passive noise attenuation headphones as well as listening to music of their choice at high volume (70 dB(A)) in both headphone conditions, and testing performance with just with active noise attenuation headphones. As expected, music at 70 dB(A) masked the target audio irrespective of the headphones employed, and performance under this condition was inferior to any other group. In contrast, performance using active noise attenuation headphones without any competing audio was superior to without headphones. The detrimental effect of low-level masking noise (with the aid of active noise attenuation headphones) on performance was found to be similar to the effect of in-cabin aircraft noise on performance.

In order to provide industry professionals a user-friendly index concerning the effect in-cabin aircraft noise has on individuals' memory, Molesworth and colleagues sought to compare the effect of this type of noise on performance to a widely used and accepted marker, namely alcohol (Molesworth et al., 2013b). Employing four different experiment groups: blood alcohol concentration (BAC) level of 0.05, BAC level 0.10, 65 dB(A) of simulated in-cabin aircraft noise without hearing protection (baseline condition), and 65 dB(A) of simulated in-cabin aircraft noise with active noise attenuation headphones, they compared recall performance between all four experimental groups. In terms of the beneficial effects of active noise attenuation headphones, the results were consistent with their other research, where performance improved with the use of these headphones (the baseline condition of no headphones presently occurs on commercial airlines for passenger and cabin crew). The results revealed that aircraft noise at 65 dB(A) adversely affected performance to a level comparable to being intoxicated with a BAC of 0.10.

### *Effects of noise on motivation*

The relationship between noise and motivation is of particular interest to aviation. None more so than how noise affects individuals' motivation to find a solution to a pressing problem that affects the safety of the aircraft. In the phenomenon known as 'learned helplessness', after repeated exposure to uncontrollable events, individuals no longer persist or continue with a challenge. Quite simply, individuals learn that the outcome is independent of their response and hence stop trying. Research examining the effect of uncontrollable noise on both adult and children performance has shown that it can induce 'learned helplessness'. Alarmingly, a study using college students investigating the effect of noise (intermittent noise) on learned helplessness found that exposure to 50 trials of loud noise (110 dB at 5 sec intervals) during a training session, with no means of terminating the noise resulted in students giving up on attempting to escape from the same noise under tests conditions, compared to students who were able to control the noise signal during training or students who were not exposed to noise during training (Hiroto, 1974).

Cohen and colleagues found a similar effect with school children from noisy schools (external generated noise such as road or aircraft noise – peak sound levels 95 dB(A)), who, when compared to school children from quiet schools were less likely to solve a moderately difficult puzzle (Cohen, Evans, Krantz and Stokolos, 1980; Cohen et al., 1986). These same students were also more likely to give up before the allocated time to complete the task had elapsed. The experimental procedure involved exposing students to a demonstrator puzzle followed by a trial puzzle, and then two test puzzles. Performance on the first test puzzle revealed a strong trend (although not statistically significant) where 41 per cent of students from the noisy school failed to solve the puzzle, compared to 23 per cent of students from the quiet school. Performance on the second test puzzle indicated a clear difference (statistically significant) between the two groups, where 53 per cent of the children in the noise condition failed to complete the second test puzzle compared to 36 per cent of the students in the quiet condition. The results are even more striking in view of the number of students who just gave up with the puzzle-solving task; 31 per cent of the students who failed the second puzzle in the noise condition just gave up, while only 7 per cent of the students who failed in the quiet condition gave up on the same task.

### *Noise, fatigue and performance*

Noise has also been known to induce fatigue. Fatigue is defined as the detriments in performance beyond what is normally expected as part of completing work tasks. Evidence that noise, in particular continuous aircraft noise induces fatigue can be found from a laboratory study which involved dividing 84 students into three different groups and exposing two of the groups to 80 dB of simulated aircraft noise (continuous) for 83 minutes. One group was spared the burden of noise (quiet laboratory conditions – A weighted Leq, 1min, 44 dB(A)), while another group was exposed to the noise without any hearing protection, and the third group was afforded some protection in the form of active noise attenuation headphones. During the 83 minutes of noise exposure, all participants watched an animated movie without the audio, but with subtitles. Prior to the movie, they completed a recognition memory task consistent with the recognition memory tasks employed by Molesworth and colleagues in their other studies. At the conclusion of the movie, all participants completed a second word recognition task (two different tasks were employed and presented in a counterbalanced order). The results revealed that participants in the no noise condition improved in performance between the two tests (statistically significant increase of 16 per cent in performance). Participants in the noise group did not improve in performance (deceased by 5 per cent), while participants in the noise with hearing protection group improved marginally (9 per cent); neither of these results was statistically significant. Molesworth and colleagues interpreted this as evidence that noise does indeed induce fatigue, beyond what would be normally expected as part of the natural consequences of work over time (Molesworth et al., 2014b).

Kjellberg and colleagues found similar results regarding the effect of noise on fatigue in a series of studies – one epidemiological survey and a number of quasi-experimental field studies (Kjellberg et al., 1998). Their first study involved surveying 50,000 state employees about work noise exposure and health conditions such as frequency of headaches, tiredness, ability to concentrate, irritability, anxiousness, and depression. After controlling for possible confounding factors such as age, gender, and work schedule, they found that both fatigue and headaches were more common in the group with the highest noise exposure (> 80 dB(A)). They also found in the group who were commonly exposed to noise levels between 60 and 80 dB(A), headaches were common. They interpreted these findings that noise may contribute to the development of fatigue.

Kjellberg and colleagues' second study focused on the relationship between fatigue and reaction time with twenty-four male aeroplane mechanics over a two-week period. During the first week, working close to the runway, the mechanics were routinely exposed to noise levels between 95–100 dB(A), and in some cases with peaks up to 138 dB(A). During the second week, the mechanics worked back at their base where noise levels were said to be 20 dB(A) lower. While hearing protection was worn in both weeks, and despite noise levels being different in both weeks, the tasks the mechanics performed also varied. The mechanics completed a self-reported stress level questionnaire daily to investigate potential differences in stress level based on the work task. The results on a simple reaction time test revealed shorter reaction time when workers were at their base, compared to when they were at the runway. In terms of stress level, there were no differences noted between the two work conditions. These results were interpreted as evidence that noise levels adversely affect fatigue.

Melamed and Shelly (1996) conducted a similar study with 35 healthy industrial workers who were commonly exposed to ambient noise close to 85 dB(A). For two whole weeks workers were asked to report fatigue and irritability levels three times a day (at 0630, 1030 and 1330). In the first week workers performed their tasks without any hearing protection. In the second week, they all wore hearing protection that attenuated the noise at the eardrum by 30 to 33 dB. Comparing across the two work weeks, one without hearing protection and the other with hearing protection, self-reported fatigue levels and irritability levels were less (statistically) at the end of the end of each work shift when hearing protection was worn.

The processes by which noise induces fatigue remain unknown. Remember noise is processed both consciously as well as unconsciously. One explanation relates to the conscious blocking of unwanted sounds (i.e. noise) which directly increases the cognitive demands in the short term, leading to increased level of fatigue in the long-term. Similarly, noise can mask the target signal, causing individuals to concentrate more on the target signal, resulting in increases in cognitive demand, hence leading to increased level of fatigue. In terms of the unconscious processing of noise, individuals are thought to process all sounds in order to determine which sounds they should attend to. The larger an individual's vocabulary or database of sounds, the longer it takes to determine if the sound heard has any meaning and hence importance, and is thought to be more cognitively taxing, resulting in fatigue. Likewise, the more similar the noise is to a sound in their database, the more cognitive resources are expended in order to continually compare the two sounds or, if the sound is familiar, to monitor the sound for any change; all of which are thought to increase cognitive demands, leading to increased level of fatigue.

### *Noise and individual differences*

#### *Age and sex*

The effects of aging on hearing function are well documented (Pichora-Fuller and Souza, 2003). For individuals over the age of 60, hearing loss is common (Kras and Anderson, 2013). However there is evidence that for men (with no ontological disorders i.e. congenital hearing loss, otosclerosis, cholesteatoma, etc.) in particular, hearing sensitivity declines are detectable as early as 20 years of age (Pearson et al., 1995). Specifically, Pearson and colleagues found that for men aged 20 and beyond, hearing sensitivity declines for sounds of 500 hz. As males pass the age of 30, hearing sensitivities to all other frequencies decline. Not surprisingly, the rate of decline increases with age, with higher frequencies being most vulnerable. For women, hearing sensitivity appears to decline for all frequency ranges from the age of 30. Hearing thresholds also vary between genders, with men showing a better hearing threshold than women at 500 hz. At 1,000 hz, no differences exist. Whereas with all frequencies above 1,000 hz, women display superior hearing thresholds.

Often accompanying age-related declines in hearing loss, and in some cases with substantial variation, are declines in cognitive abilities (Tun et al., 2012). For example, age-related declines have been found in basic cognitive functions such as attention (McDowd and Shaw, 2000), memory (Meguro et al., 2000), and processing speed (Salthouse, 1996). While in many situations the effects of these age-related declines may be negligible, in others they may hinder an individual's ability to understand speech. For example, a person experiencing a decline in processing speed would find it difficult to understand a person who spoke quickly. Similarly a person experiencing a decline in memory function may find it difficult storing and retrieving key information they just heard. It is the interaction between the two that can in some cases amplify the symptoms of hearing loss, or conversely mitigate their effects.

Further compounding the effects of hearing loss and declines in cognitive functions as a result of aging, is noise. Noise makes it more difficult to hear and understand spoken language. Hence, everyday situations such as conversations in the presence of noise are more difficult.

### *Introversion–extroversion*

Pilots are often described as 'Type A' personalities: confident, ambitious and impatient. Some of these traits are associated with extroverts, one of which involves seeking gratification from others (i.e. likes the company of others; Costa and McCrae, 1992). By extension of Broadbent's (1971) Arousal theory, an extrovert is someone who is generally thought of as being under aroused. Given that noise is often described as a stimulant, noise should impact extroverts and introverts differently. This is precisely what was found when Belojevic, Slepcevic, and Jakovljevic (2001) exposed 77 extroverts and 46 introverts (as identified with the Eysench Personality Inventory/Questionnaire) to 88 dB(A) of noise (urban street noise) while completing a mental arithmetic task. In the presence of noise, extroverts were found to complete the mental arithmetic task more quickly than introverts, with no difference in the quiet condition (42 dB(A)) where both groups performed equally in terms of speed and accuracy. Belojevic et al. also found that the noise adversely affected introverts ability to concentrate, and they reported higher levels of fatigue as a result of the noise.

Geen and colleagues (1985) found similar results with 40 undergraduate students, half of whom were introverts and the other half extroverts (as identified with the Eysench Personality Inventory/Questionnaire) when asked to complete a vigilance task in two different noise conditions (65 dB or 85 dB of white noise). Introverts in the presence of 65 dB of noise improved across trials, whereas when exposed to 85 dB of noise, they showed a decline in detection. The reverse was found for the extroverts, where 85 dB of noise was associated with improved performance across trials. These results are consistent with those of Davies and Hockey (1966) who exposed 24 extroverts and 24 introverts to white noise at slightly higher noise levels, either 95 dB (high noise) or 70 dB (low noise). Moreover, introverts outperformed extroverts in the low noise condition when they were tasked to identify digits that may have been incorrectly transcribed from the screen to a typescript.

When the tasks employed to distinguish differences between personality types such as introverts/extroverts, are more cognitively demanding, differences in performance are less noticeable. For example, Furnham, Trew, and Sneade (1999) divided 144 sixth form students into two personality groups, namely introverts and extroverts (as identified with the Eysench Personality Inventory/Questionnaire) and exposed them to three different noise conditions: no noise, instrumental and vocal. In each noise condition, students were asked to complete a reading comprehension task, logic problem solving task and a coding task. The reading comprehension task test was taken from the Graduate Admission Test (GMAT) and was designed to examine skills associated with academic performance. The logic problem solving task test was taken from the Law School Admission Test (LSAT) and required deductive, clear thinking and good analytical skills. The coding task test comprised 370 hand/eye coordination problems spanning three pages where students had to match a random set of musical notes to numbers on each page and then write the symbol corresponding to the 370 numbers in the boxes provided. The researchers were expecting to find an interaction between noise and personality type (introvert/extrovert), however none were found. In fact, the only significant result was a main effect for personality, where introverts outperformed extroverts irrespective of noise conditions.

### *Noise and language background*

By now, the reader would acknowledge that, based on the evidence presented in this chapter, not all noises affect people equally and that not all people are affected equally by the same noise. This was most evident in the results of a meta-analysis (review of 242 separate studies) regarding noise effects on human performance, where Szalma and Hancock (2011) found continuous non-speech noise more debilitating than intermittent non-speech noise. However, when noise was presented as speech, there was clear evidence that intermediate schedules of speech were more debilitating than continuous speech. The most telling result was that noise, whether presented as speech or non-speech, adversely affected accuracy in cognitive and communication tasks. This effect has been shown to be more detrimental for non-native listeners than for native speakers (Broersma and Scharenborg, 2010; Náběelek and Donahue, 1984).

In aviation, Molesworth et al. (2014a) and Jang et al. (2014) also found that noise affects native English speakers differently to non-native English speakers. Moreover, in a study with 32 participants, half EL2 (native German speakers) and half NES, reproduced aircraft noise (continuous noise) at 65 dB(A) was played to participants who were tasked to complete a series of cued recall memory exercises in the presence of this noise. Four experimental conditions were presented:

1 no hearing protection and target audio played through external speaker;
2 hearing protection in the form of active noise cancelling headphones and the target audio signal played through the headphones;
3 hearing protection in the form of active noise cancelling headphones and target audio played through an external speaker; and
4 hearing protection in the form of active noise cancelling headphones but with the noise cancelling feature switched off and target audio played through an external speaker.

The results revealed that, without any hearing protection (condition 1), noise significantly degraded cued recall performance for EL2 participants by approximately 75 per cent. Noise cancelling headphones alleviated some of the noise effects, but only when the target audio was played through the headphones (Condition 2; NES recalled 22 per cent more than EL2 speaker). When the target audio was not played through the active noise cancelling headphones (condition 3) or the active feature of the headphones was turned off (condition 4), performance was similar to when no headphones were used (condition 1). These results highlight the detrimental effect of aircraft noise reflective of that during the taxi phase of flight for non-native speakers.

Research investigating the effect of noise on NES and EL2 pilots produced similar results. Replicating noise levels typically present in a Cessna 172 during cruise (95 dB(A)), Jang and colleagues asked pilots and non-pilots of both native and non-native English backgrounds to complete two communication tasks, namely a short-term memory task (recalling aviation phrases) and a speech discrimination task (recalling monosyllabic phonologically balanced non-aviation specific words; Jang et al., 2014). Since the level of noise exceeded that known to cause hearing damage, they provided participants hearing protection in the form of active noise cancelling headphones as well as passive noise cancelling headphones. They found that, overall, performance improved on both tasks with the aid of active noise cancelling headphones, irrespective of native language background. They also found that the native speakers were able to recall and repeat more words correctly than the non-native English speakers, irrespective of headphone condition. Experience with the aviation language did prove beneficial in the presence of noise for non-native English speakers only in the passive noise cancelling headphone condition, but not for native English speakers. This result has important implications, as it indicates that, for non-native English speakers, proficiency with Aviation English can offset some of the noise effect.

In an attempt to create a user-friendly metric illustrating the extent to which noise affects EL2 speakers, Molesworth et al. (2014a) compared the effects of noise on memory recall (recognition memory task) with the effects of alcohol. They found that, for non-native English (EL2) speakers, a blood alcohol concentration (BAC) of 0.05 affected the memory and recall of information similarly to a noise level (wideband non-speech noise) of 65 dB(A). For native English speakers, the same noise level affected performance equivalent to a BAC of 0.10. Hence, noise effects are more pronounced for non-native English speakers as opposed to native English speakers. These results are consistent with their other research examining the effects of noise on performance (recognition memory) between native English speakers (NES) and non-native English speakers (EL2).

The precise reason why noise affects bilingual speakers more than monolingual speakers remains unknown. However, there are a number of theories that attempt to account for these differences. For example, Von Hapsburg and Peña (2002) posit that it is the larger lexicons that are at the root of the problem, where bilingual speakers need to search both their lexicons to match appropriate phonemes or target words, ultimately slowing information processing and/or response time. Noise is thought to decrease the clarity of these phonemes and/or draw on the limited cognitive resources available, which as a result are then being used both to process the noise and to search the larger lexicons. The differences may also be explained by the difficulties in maintaining attention in the presence of noise, where the distracting properties of noise are potentially greater for bilingual speakers due to the added challenge of the language, including the clarity of phonemes and meaning/definition of words. Alternatively, noise is seen as a masker, where contrasts in speech phonemes are more difficult to distinguish due to the masking properties of the noise. The masking of speech phonemes are particularly problematic for non-native speakers, who, due to their level of experience with the language (e.g. size of the lexicon, understanding of word meanings and of word usage in different contexts), may not be able to guess (i.e. fill in the blanks) as accurately as native English speakers.

Hull and Vaid (2007) claim that speech perception may be affected by the lateralization of language, where bilingualism built on only one hemisphere is most susceptible to interference from noise. Moreover, based on the results of two meta-analyses, Hull and Vaid found that early bilinguals, defined as having acquired two languages by the age of 6, showed bilateral hemisphere involvement for both languages. In contrast, late bilinguals, defined as having acquired a second language after the age of 6, showed left hemisphere dominance for both languages, as do monolinguals for their one language (for multilinguals, a similar pattern is thought to occur where late multi-language acquisition builds on one hemisphere – left, i.e. anchor organisation of language – and early multi-language acquisition builds on both hemispheres). Presumably, bilingualism built on one hemisphere increases the chance of phoneme and word confusion, and adding noise further compounds the problem in terms of perception. Similarly it could be an information-processing problem, where bilingualism built on one hemisphere requires parallel processing, and bilingualism (as well as multilingualism) built on two hemispheres requires serial processing; the latter being less susceptible to interference and increases in cognitive load as a result of noise.

### *Noise and noise attenuation headphones*

One method that has proved beneficial in reducing the effect of noise on performance is to increase the signal-to-noise ratio. According to Kobayashi et al. (2007), optimum speech level when the background noise level is more than 40 dB(A) is achieved when there is a 15 decibels of A-weighted sound (dB(A)) difference between speech level and background noise (steady state noise). For pilots in general aviation, where noise levels commonly exceed 90 decibels during normal operations (Jang et al., 2014), increasing the signal-to-noise ratio has the real potential to reduce communication errors. Using active noise attenuation headphones, otherwise known as noise cancelling headphones, is one method that has proven effective in increasing the signal-to-noise ratio (Molesworth and Burgess, 2013). As their name suggests, these headphones, through a process of reproducing a signal that is 180 degrees out of phase with the original noise, attempt to eliminate noise prior to its entering the ear canal. In application, however, they reduce rather than totally eliminate the noise. Nonetheless, this technology is effective in improving the listening conditions pilots are exposed to.

### *Summary: noise and performance*

In summary, noise, including aircraft noise, is a known stressor that has repeatedly been demonstrated to adversely affect cognitive performance. However, not all skills are vulnerable to the effects of noise. Complex cognitive skills appear most vulnerable to noise effects. Less surprising is the masking effect of noise: as the signal-to-noise ratio decreases, performance in terms of speech detection, perception and intelligibility decrease. What is surprising, however, is that the effect is more pronounced if the target signal (i.e. speech) is in a language other than the native language of the listener. Considering that aviation spans the whole globe and as a result a number of different countries, nationalities and therefore language groups, the potential implication of these noise effects on effective communication, and by extension safety, is significant. As discussed in Chapters 1–3, communication has been cited as a contributing factor in many commercial as well as general aviation incidents and accidents. What remains unknown is the contribution of noise to miscommunication in such circumstances. What is clear, however, is that noise levels in the quietest phase of flight, namely during the taxi, is known to adversely affect recognition memory performance to a level similar to being intoxicated with a blood alcohol concentration (BAC) level of 0.05 for non-native English (EL2) speakers and 0.10 for native English speakers. Considering Aviation English is founded on the English language, and for many aviation personnel (i.e. pilots, ATC and cabin crew) English is not their native language, the implications of these findings are significant. Hence it could be concluded that noise at best makes it more challenging for pilots and crew to perform optimally under normal flight conditions; at worst, it could be concluded that noise significantly degrades performance making optimal performance near impossible. Based on these findings, it would appear that the message is clear: noise levels in aircraft are excessive and may adversely affect many of the key skills required to safety operate an aircraft, most notable the skills required to communicate effectively.

## Temperature, performance and communication

The thermal conditions to which a person is exposed as part of completing his or her work are known to affect their performance. Temperature in excess of 24°C (degrees Celsius) is known to reduce work productivity (Lan et al., 2010; Lan et al., 2011; Seppänen et al., 2006). Similarly temperatures below 21°C are also known to affect work productivity. Hence an ideal temperature range exists where performance is said to be unaffected. The thermal range is, however, highly dependent on the task being performed. For office-based professions, where physical work is at a bare minimum, the ideal thermal condition is 22°C. As all commercial pilots and many general aviation pilots can attest to, the thermal conditions on the flight deck fluctuate in and out of this ideal range.

One known effect of operating in a thermal condition in excess of 27°C on communication performance is auditory fatigue, otherwise referred to as the temporary threshold shift (TTS). Auditory fatigue is defined as a measurable but temporary loss in auditory sensitivity. In most cases, auditory capacity is restored in a matter of hours, though in some extreme cases (apart from when permanent hearing loss occurs) it can take as long as several days. Auditory fatigue is commonly experienced following exposure to excessive noise such as industrial noise or leisure noise (i.e. music). A reduction in auditory sensitivity has been reported following exposure to continuous noise at levels as low as 80 dB(A) and for as little as 60 minutes (Nasser, 2001). Increasing the level of noise, the frequency in which the noise is presented (i.e. noise bursts), or the duration of exposure all affect the time it takes to recover from the effects of auditory fatigue. In some cases, if the level of noise or the duration of exposure is excessive, permanent hearing loss is a likely outcome (Ward, 1970).

Chen et al. (2007) found they could simply induce auditory fatigue by altering the climate in which individuals were asked to perform tasks varying from low to high workload, with noise during tasks in the range 75–95 dB. Quite simply, Chen et al. increased the temperature within the thermal exposure chamber where the research was conducted and found that, when temperatures exceeded 27°C (up to 32°C), TTS (audio fatigue) increased. In the worst case, the TTS measured two minutes after the end of exposure resulted in a 15 dB threshold shift in the frequency range 3,000–5,000 Hz. Less than ideal thermal working conditions have also been found to affect performance on tasks not dependent on hearing such as basic arithmetic. In fact, Witterseh et al. (2004) found that participants exposed to work conditions where temperatures averaged 30°C (described as too warm by participants) committed 56 per cent more errors on a simple arithmetic task.

Tham (2004) also found that the thermal work environment can affect communication. Moreover, using a blind intervention approach at a call centre handling billing inquiries, he found that, by varying the office temperature by as little as 2°C, from 24.5°C to 22.5°C, he was able to improve the timeliness in which call centre staff delivered relevant information to the customer.

## Fatigue and communication

Fatigue, like noise, is a performance-moderating factor. However, unlike noise which is clearly observable (i.e. measurable), fatigue is a hypothetical construct: only its effect can be measured with the correct scientific instrument or method (Williamson et al., 2011). Nonetheless, there are countless accidents and incidents where fatigue has been cited as a contributing or leading cause; some of the more recent in aviation include: Loganair B-N2B-26 Islander Air Ambulance flight at Argyll, Scotland in 2005 (Department of Transport, 2006); MK Airlines 747-200 at Halifax Airport Nova Scotia Canada in 2004 (Transport Safety Board of Canada, 2006); and Asiana Flight 214 at San Francisco, California USA in 2013 (NTSB, 2014). Interestingly, there is much debate about which performance functions are susceptible to the effects of fatigue. Bonnet (2011) claims that complex cognitive tasks are most susceptible to fatigue effects. However, there appears to be limited evidence in support of this. In fact, Williamson and colleagues found the complete opposite, namely simple tasks are most susceptible to fatigue effects. These findings were derived from a study where they compared the performance effects of alcohol to that of fatigue (28 hours of sleep deprivation) on a wide variety of cognitive and psychomotor tasks (Williamson et al., 2001; Williamson et al., 2011). Gillberg and Åkerstedt (1998) contend that the duration of the task makes it more or less susceptible to fatigue effects, where tasks requiring sustained attention are most susceptible.

What seems less ambiguous is the effect of fatigue on communication, specifically in terms of speech. According to Whitmore and Fisher (1996), alterations in the acoustical characteristics of voice can provide valuable information about the level of fatigue a person is experiencing. Moreover, in a study where 20 healthy male participants were forced to stay awake for 36 hours, Dhupati et al. (2010) found that the duration of voiced to unvoiced speech (i.e. silence) increased as a result of fatigue. Zhang et al. (2010) found that articulation of vowels decreased with as result of fatigue. Similarly, Whitmore and Fisher (1996) found that both the duration of time taken to pronounce a word and the fundamental frequency in which the word was spoken varied with fatigue levels. In addition, Greeley et al. (2007) found that speech sounds requiring a large average airflow, such as with the plosive /p/ in 'pea' for example, altered with fatigue. Interestingly, only one of these studies examined speech in the presence of noise (Whitmore and Fisher, 1996). As already shown, noise, such as aircraft noise, makes attending to the target stimuli more difficult, and even more so for non-native English speakers. Therefore it can be assumed that the effects of fatigue on speech, combined with other factors such as noise, would only increase the likelihood of miscommunication for a non-native English listener.

## Conclusion

Stressors such as noise and thermal conditions have the potential to alter performance, as does fatigue. Although the presence of one or all of these conditions does not guarantee an adverse outcome, what is certain is that their presence creates conditions that increase the likelihood of an adverse outcome if left unmanaged. With fatigue and, to a lesser extent, the thermal environment, the threat to safety is widely known. In contrast, for the aviation industry in particular, the impact of noise (in-cabin continuous aircraft noise) on pilot performance is an area that has received little attention. Noise inside the cabin of commercial as well as general aviation aircraft can only be described as excessive. In-cabin aircraft noise is particularly problematic for non-native speakers, when the tasks involve recognition memory in a language other than their native tongue. Considering pilots are expected to perform at consistently high standards in a noisy and stressful environment and many of the tasks they are expected to perform require the use of recognition memory, which is impaired under such conditions, these results have important implications for aviation safety. Since Aviation English is based on English, and English is not the native language for many aviation personnel, these effects will be significant in many instances of aviation communication.

## Notes

1 Due to a procedural error at one of the low-noise schools regarding the baseline sample, only data from seven schools featured in this analysis.

2 Karsdort and Klappach (1968) used Phon as opposed to decibels in their study. Phon is used as a form of noise measurement. Hence, to facilitate in comparisons between studies, Phon was converted to decibels. While noise levels were taken at three different schools, the authors did not state the noise level (Phon) at the quiet school. Since Standards Australia note 40 dB as an acceptable noise level for an office, this level was extrapolated to this paper and in particular to the noise levels for the school described as quiet.

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Chapter 7

# Native English speakers and EL2 pilots

## An experimental study

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As described in Chapter 2, Aviation English comprises a variety of phrases which are used to convey specific information between pilots and air traffic control (ATC) officers. For all pilots, the challenge is to learn what information needs to be communicated and at what point. They also need to ensure they place the required information in a predefined order, that all required information is included, and equally that unnecessary or redundant information is not transmitted. Further challenges include learning specific phraseology unique to aviation, as well as sentence structures that would be grammatically incorrect if employed in everyday conversation. These challenges are greater for pilots for whom English is a second language, who are at the same time learning or improving their English language skills. In this chapter, we discuss the challenges faced by native (NES) and non-native (EL2) speakers of English when they communicate over the radio using Aviation English in an operational environment. We draw on our studies of pilots in the Australian general aviation environment and we discuss the implications of the results of the research for the training of pilots and air traffic controllers, who are all required to pass English language proficiency tests. For pilots these tests examine their ability to communicate in conversational English and in situations requiring Aviation English. In contrast to conversational English, which commonly employs pauses and intonations, Aviation English is monotone, and most often presented in one short block without any pauses or breaks (Estival and Molesworth, 2009). Furthermore, all verbal communication between pilots in two different aircraft or between pilots and ATC are conducted using the radio, and, under such conditions, the use of information from facial expression, hand gestures and/or body position (i.e. body language), which have long been known to be crucial in effective communication (Mehrabian, 1972), are not available. In addition, as described in Chapter 6, environmental factors, such as workload (i.e. multitasking: flying plus communicating), work pressure (i.e. maintaining flight schedule) and the physical environment (i.e. temperature, hot or cold, and noise) are all known to adversely affect communication accuracy, especially for EL2 speakers.

The question of who counts as a NES and how to reliably categorize speakers as native or non-natives is notoriously a fraught one (see e.g. Pennycook 2012). As explained in Chapter 3, in testing for English language proficiency (ELP) in aviation, such decisions are made somewhat arbitrarily and the categories do not coincide with the notions of NES and EL2 which linguists and applied linguists may be familiar with. In many cases, someone considered a NES will automatically be assigned an ICAO Level 6, the highest possible level, and will therefore never be tested or assessed for ELP again. This decision is extremely important for pilots and aviation professionals throughout the world, as it determines whether the individual is to be tested again every two years (Level 4) or every four years (Level 5), with serious consequences for employment. Although in theory someone assessed as Level 6 is not required to be tested again, in practice pilots from the 'outer circle' (i.e. countries where a variety of English is one of the official languages, such as Singapore or India: Kachru, 1992) may find themselves required to be reassessed when moving to a different country.[1] Nevertheless, the intent of ICAO is that a Level 6 is equivalent to a 'Functional Native Speaker' (FNS). Importantly, an FNS is not someone who can 'pass' as a Native Speaker, but someone who can function at the same level as a Native Speaker. Of course the notion of FNS is itself fuzzy and the boundaries are not clearly defined. An FNS may or may not be able to understand all the cultural references shared, or assumed to be shared, by Native Speakers, for example television shows, nursery rhymes or children's stories, but then neither do all English NSs share such references around the world.[2]

This chapter presents the results of the analysis of a set of flight simulator experiments designed to study the complex relations between language background (NES or EL2), flying experience and four conditions under which communication is expected to be more difficult. Following two preliminary studies completed via questionnaires distributed to pilots in the Sydney and Australian Capital Territory (ACT) regions (Estival and Molesworth 2009, 2012), in which we investigated the impact of English as second language on radio communication between native English speaker pilots (NES pilots) and pilots with English as a second language (EL2 pilots) and Air Traffic Controllers (ATCs), these flight simulator experiments are part of a larger research programme whose overall goal is to better understand miscommunication in aviation as well as the conditions under which miscommunications and misunderstandings occur in the aviation environment. While the first aim is to investigate the determinants of communication problems specifically with respect to EL2 pilots, the second aim is to research solutions to mitigate the impact of such problems on air safety in order to obviate potentially dangerous situations, e.g. pilots misunderstanding a clearance given to another aircraft as being given to them. This is not a far-fetched scenario, as illustrated by an incident on 18 November 2011, when a China Eastern Airlines Airbus A330-200, with 245 people on board, took off without clearance from Osaka Kansai (Japan) for a flight to Shanghai (China). Following that incident, China Eastern Airlines announced they would improve the English language training of their pilots, prompting speculations about the causes of the misunderstanding.[3]

## The study

### *Background*

In our two questionnaire-based studies (Estival and Molesworth, 2009, 2012), we first found that, although EL2 and NES pilots differ in terms of the number of miscommunication incidents reported, native language was not an influencing factor in what pilots found difficult with radio communication, and flight qualification had no impact on which radio communication task pilots found most difficult. An even more unexpected result came from the question asking pilots to rank five communication tasks in order of difficulty: communicating with ATC was judged the least difficult task and communicating with other pilots the most challenging (Estival and Molesworth, 2009). In the second study, the emphasis was not on *whether* miscommunication incidents occur, but on *when* they occur and on their frequency. The results showed that EL2 pilots, regardless of their level of experience with English, communicate less effectively with ATC than NES pilots and find ATC messages harder to understand. An important result, however, was that, contrary to what might have been expected, the actual number of years of speaking English had no impact on the EL2 pilots' ability to understand ATC and that the actual number of years of speaking English had no impact on the number of miscommunications with ATC (Estival and Molesworth, 2012).[4]

In the follow-on experimental project, we investigated the extent to which pilots' language background impacts on their radio communication and how linguistic factors already identified as contributing to misunderstandings in aviation communication are affected by workload and stress. Specifically, we posed the following four research questions.

1 Does the number of items in a transmission, such as four or more items per radio transmission, increase pilot communication errors?
2 Do the prosodic features of a message, such as a radio transmission without pauses, increase pilot communication errors?
3 Is there a relationship between pilot workload and pilot communication errors?
4 Does airspace (radio frequency) congestion adversely affect pilots' ability to communicate?

Expanding on the experimental model of the study by Farris and colleagues (Farris et al., 2008), we ran experiments with pilots in a flight simulator. Importantly, in contrast to Farris et al. (2008), who used analogue tasks and naïve participants, our participants were actual pilots performing in a medium-fidelity flight simulator. For each of the four research questions, we designed a pair of flight scenarios and sets of audio stimuli to probe the particular corresponding variable. The experimental flights were conducted by pilots of various language backgrounds and levels of flying qualifications as described below, and the stimuli were pre-recorded transmissions from ATCs and other pilots under varying conditions (described in the section *Audio stimuli recording*). On the basis of the existing literature, we had posited the following three hypotheses.

- H1 A negative relationship would exist between each of the four independent variables, namely, faster speech rate in ATC transmissions (no pauses between items), information density (number of items) in ATC transmission, workload and frequency congestion, and communication accuracy from the pilots.
- H2 A greater decrease in communication accuracy would be more evident for EL2 pilots than for NES pilots.
- H3 A greater decrease in communication accuracy would be evident for low hours or less experienced pilots than for pilots with high hours or higher levels of flight qualification.

Consequently, we hypothesized that EL2 pilots would perform at a lower level in the more challenging situations of faster ATC speech rate, higher amount of information, high workload and greater radio frequency congestion than NES pilots. This is indeed what we found, but the results are much more nuanced and reveal a complex relationship between the variables. We describe the analysis of the audio data recorded during the experiments below in the Results section and we present the results of the experiments and our interpretation of these results in Implications of the findings. First, however, we turn to the design of the experiments themselves.

### *Experiment design*

The experimental flights were conducted in a flight simulator consisting of a PC-based aviation training device (PCATD) with realistic flight controls and cockpit environment. The PCATD displays the flight instruments on a 21 inch flat screen monitor while surrounding projection panels provide a 120-degree view of the outside environment, in this case featuring terrain and airports in the Sydney Basin. X-Plane 6.21 software was used and set to simulate a Cessna 172, a single-engine aircraft widely used in general aviation training, with call-sign ‘ABC’ (pronounced ‘Alpha Bravo Charlie’, a call-sign typical of an Australian-registered aircraft). To further replicate a realistic flight environment, reproduced aircraft noise of a Cessna 172 at 65 dB(A) was played during the flights.

Following a short familiarization flight in the flight simulator, each pilot conducted eight different flights, each flight in essence being a separate experiment. For each flight, the pilots were given new instructions consisting of a weather forecast for that flight and a flight plan containing the information a pilot would prepare for such a flight: waypoint, heading, altitude, airspeed and time interval for each flight segment; radio frequencies; and fuel on board. During the flight, pre-recorded air traffic control (ATC) transmissions were played at regular intervals through an aviation headset worn by the pilot. The pilot's voice responses were recorded with Audacity software on one computer, while the pilot's actions were recorded through the X-Plane software on another computer. The X-Plane output files provide a record of the pilot's flight responses: altitude, heading and position at each point in flight, thus allowing an automatic comparison with the expected behaviour for that stage of the flight.

As described in Chapter 2, a pilot transmission consists of a number of items, e.g. heading, altitude, call-sign, which must be read back accurately by the pilot, or reported at certain points in a flight. Example (1) shows the expected call by a pilot who has been asked to contact Sydney Centre:

(1) *Expected*: Sydney Centre. ABC at 5500, tracking 190.

The results of the experiment (dependent variables) were evaluated by counting: the number of correct pilot calls per flight, the number of correct items, the nature of any error committed (whether the error was an omission or a mistake), whether the error occurred in words or numerals, and the types of items in which errors were committed. While the complete analysis of the experimental data will eventually cover both the audio recordings of the pilots' verbal responses and the pilots' flight actions as recorded by the flight simulator software, this chapter is primarily concerned with the analysis of the audio data and the implications for teaching and testing Aviation English.

### *The four flight scenarios*

Four different flight scenarios were designed, with two flights per scenario to set up different experimental conditions. One flight in each pair (the A flight) served as the baseline normal condition and the other (the B flight) provided the more challenging condition. Flight scenarios 1, 2 and 3 involved navigation flights in the Sydney Basin area which would have been familiar to the pilot subjects, while flight scenario 4 involved an approach and landing at Bankstown airport, Sydney, which would also be a familiar exercise to all the pilots in the study. All the flight scenario details and the specific audio stimuli, i.e. the ATC transmissions for the eight flights and the additional aircraft transmissions for Flight 4B, were designed by the two authors, both pilots familiar with that environment. Table 7.1 shows the details of the four flight pairings.

*Table 7.1* Flight conditions

*Flight pairing 1*: *Rate of speech of ATC*
- Flight 1A – Slow, with pauses between items in ATC transmissions.
- Flight 1B – Fast, no pauses between items in ATC transmissions.

*Flight pairing 2*: *Amount of information in ATC transmission*
- Flight 2A – Low, with fewer than 3 items per ATC transmission.
- Flight 2B – High, with 4 or more items per ATC transmission.

*Flight pairing 3*: *Pilot workload*
- Flight 3A – Low workload: normal navigation flight.
- Flight 3B – High workload: navigation flight with in-flight fuel recalculation.

*Flight pairing 4*: *Radio frequency congestion*
- Flight 4A – Non-congested environment: only 1 (one) other aircraft on the same frequency during approach and circuit to land at a training airport.
- Flight 4B – Congested environment: more than 5 aircraft on the same frequency during approach and circuit to land at a training airport.

To ensure the validity of the comparison within each flight pair, although the pilots were given a fresh set of instructions for each flight, the flight plans and weather forecasts prepared for the pilots were in fact the same for the A and B flights in each pair. However, to minimize any possible learning effect within the flight pairs, the eight flights were presented to the pilots in a counterbalanced order determined by a 4 x 4 Latin Square design.[5]

### *Audio stimuli recording*

The ATC transmissions were recorded by a male Chief Flying Instructor with over 40 years of professional aviation experience, in a role-playing session of the scenarios, with the first author playing the pilot's role. The second author reviewed a sample of the recordings for content accuracy. Example (2) shows the ATC transmission and the expected pilot's readback at the beginning of Flight 3:

(2) *ATC*: ABC. Climb to 2500. Maintain runway heading until advised.
*Pilot*: Climb to 2500. Maintain runway heading. ABC.

Since flight pairing 1 was intended to study the impact of speech rate on pilots' communication difficulty, the instructions for recording the stimuli were to speak at a normal ATC speech rate with pauses between each item for the recording of the stimuli for Flight 1A. The instructions for the Flight 1B stimuli were to speak without pauses between items, as an ATC speaking fast would. As a result, there were no abnormal pauses between words within items nor long pauses between items for Flight 1A; at the same time, this method avoided any unwanted consequences of removing pauses in the stimuli for Flight 1B, such as also removing the co-articulation effects from the original recordings and not reproducing the possible slurring due to natural faster speech (cf. Barshi's experiments). To verify that the instructions to speak without pauses did result in a faster speech rate, as measured in words per minute, the words/minute rates were calculated for all the ATC stimuli in Flight 1A and Flight 1B, with the results shown in Table 7.2.

*Table 7.2* ATC speech rate in Flight 1A and Flight 1B

| | *Words/minute* |
|---|---|
| Flight 1A<br>Speech rate: slow | average 89.5 (range 65.95 – 165.00, SD: 25.05) |
| Flight 1B<br>Speech rate: fast | average: 159.76 (range 111.43 – 223.26, SD: 32.94) |

ICAO (2001) recommends that for all stations the 'Rate of speech on radiotelephone broadcasts shall not exceed 100 words per minute' and that, even in distress or emergency situations, pilots 'maintain an even rate of speech not exceeding 100 words per minute' (ICAO, 2001). For the recording of all the other stimuli, the instructions were to speak at a normal ATC speech rate which did not exceed 100 words per minute. The additional aircraft transmissions for Flight 4B were recorded by several staff members in the School of Aviation at the University of New South Wales (UNSW) in a separate session. Example (3) shows one of the transmissions from another aircraft, with call-sign 'ABD' (pronounced 'Alpha Bravo Delta') and the ATC response, intended as a possible source of distraction or confusion for the pilot subject, whose own call-sign was 'ABC' (pronounced 'Alpha Bravo Charlie').

(3) *Aircraft*: ABD request runway Centre.
*ATC*: Negative, ABD. Runway centre not available.

The recorded stimuli were concatenated into a single audio file for each flight, with enough time inserted between the ATC transmissions for the pilot to respond verbally and to react to the instructions. Each flight lasted for about 8 minutes and gave at least 15 opportunities for a pilot to transmit (every 30 seconds) per flight.

### *Participants*

The participants were recruited through two methods. First, flyers advertising the research were placed at a number of different flight training schools at the Bankstown and Camden aerodromes in the Sydney Basin. Second, students within the Bachelor of Aviation programme at the University of New South Wales were informed of the research during class and invited to participate. With all pilots, a mutually suitable time was arranged to conduct the experiments and a total of 18 pilots from the Sydney Basin participated between November 2012 and March 2013. Some of the pilots found the experiments challenging, with one pilot expressing frustration during Flight 3B when asked to perform fuel calculation, but nevertheless completing all the flights, and another pilot abandoning the task when he realized he did not have enough recent flying experience to perform adequately. All the other pilots completed all the flights without any issue. In total 17 pilots, 8 of whom were native English speakers, completed the task. The average time to complete the task was two hours for each pilot.

On the day of the experiment, the participants completed a consent form, a demographics questionnaire (age, gender, language background, number of years speaking English, flight training, pilot licence) and flying history (number of flying hours). There was only one female pilot and the average age of the participants was 30.82 years, ranging from 20 to 62 (SD = 13.97). The EL2 speakers declared the following native languages: Cantonese (4), Chinese (1), Malayalam (1), Italian (1), Danish (1) and Russian (1); on average, the EL2 speakers had been speaking English for 17.11 years, ranging from 2 to 35 (SD = 11.96).

In terms of pilot qualifications, 7 pilots held a Private Pilot Licence (PPL) or lower type of licence (e.g. student pilot licence or general flying progression test) and 10 pilots held a Commercial Pilot Licence (CPL) or advanced type of qualification (e.g. instrument rating or flight instructor rating). The average number of flight hours was 394.31 (SD = 810.87) and the range of flying experience varied from 42 to 3,500 hours. Table 7.3 shows the distribution of the pilots with respect to their flying qualification and language background.

The person who conducted the experiments was also a qualified pilot. Before the flights, the pilots were told they could ask questions of the experimenter, e.g. in case of equipment malfunction or to modify the sound level, but that they would not be able to request a repetition or clarification from ATC, as the transmissions were pre-recorded.

*Table 7.3* Distribution of pilots by qualification and language

| *Qualification* | *Language* | |
|---|---|---|
| | *NES* | *EL2* |
| Private Pilot Licence (PPL) or lower | 2 | 5 |
| Commercial Pilot Licence (CPL) or higher | 6 | 4 |
| *Total* | 8 | 9 |

## Data analysis

### *Transcription and coding*

With 17 pilots conducting 8 flights each, we have a total of 136 flights to investigate the questions posed in the section above *The study*. The pilot recordings were transcribed by an independent researcher who also evaluated each pilot call as either *correct* or *incorrect* by checking against the set of transmissions expected for the particular flight scenario. The transcription was then thoroughly checked by one of the authors for complete agreement before being further analysed at the levels of items by another researcher.

Due to technical issues, the audio recordings for 6 flights (out of 136) were either lost or incomplete, resulting in 85 possible pilot transmissions missing, from a total of 2,142 transmission opportunities.[6] The entire data set was reviewed and we followed the 'Prior Knowledge Process' recommend by Tabachnick and Fidell (2013), which in this case involved the comparison of pilots' performance with their performance on the other flights and with other pilots' performance across all flights, to insert the number of *correct* and *incorrect* calls for the missing data. The same process was repeated at the level of items, with the number of *correct* and *incorrect* items inserted for the missing data, but not for the lower levels of analysis (i.e. nature, category and locus of errors, see later) where it would not have been appropriate.

### *Levels of analysis and variables under study*

For the statistical analyses presented in the next sections, the independent variables were:

1 language background (NES/EL2) – 8 NES, 9 EL2 (see Table 7.2);
2 flying experience (number of hours) – range 42 to 3,500 hours;
3 pilot qualification (PPL or lower; CPL or higher) – 7 PPL, 10 CPL (see Table 7.2); and
4 flight condition (4 × 2) – F1A/B, F2A/B, F3A/B, F4A/B (see Table 7.1).

The data was analysed based on the following five dependent variables:[7]

1 number of incorrect transmissions;
2 number of incorrect items;
3 nature of error (omissions/mistakes);
4 category of error (words or numerals); and
5 locus of error (item type).

The analysis for the first three dependent variables (incorrect transmissions, incorrect items and nature of error) followed the same procedure, namely, a

2 × 2 × 2 mixed repeated measures analysis. The sole repeated measures factor was Flight Condition, which contained two levels: easy (A) vs hard (B). The first between-group factor was Native Language, containing two levels: native English speaker (NES) vs non-native English speaker (EL2). The second between-groups factor was Licence Qualification, also containing two levels: PPL or lower vs CPL or higher. For all post hoc tests, a Mann–Whitney non-parametric post hoc test was employed because of the small and sometimes unequal sample sizes. The final analysis employed Pearson's product–moment correlational analysis to examine relationships between the Flying Experience of pilots (total number of flight hours) and the dependent variable under examination, such as number of incorrect transmissions, number of incorrect items or nature of error.

For the fourth dependent variable, category of error (omissions or mistakes), a series of dependent samples *t* tests were employed. As a result, performance in terms of percentage of total omissions and total mistakes was compared based on flight condition (easy vs hard). Additional analyses included a comparison between flights regarding the omissions of numerals, the omissions of words, the mistakes with numerals, and the mistakes with words.

For the fifth dependent variable, locus of error, no statistical procedures were employed, as the objective was not to compare differences between conditions, but to better understand where the errors occurred. All the communication errors were categorized for the type of item in which they occurred and we provide descriptive data to illustrate the prevalence of errors with different item types.

### *Correct and incorrect calls*

At the call level, each pilot transmission was assessed as either *correct* or *incorrect*. In our data, a call was considered incorrect if there was no readback or report as expected at that point in the flight, as prescribed by the *Aeronautical Information Publication* (AIP, 2005), or if any of the items to be read back or reported was erroneous or omitted by the pilot. Example (4) shows an expected readback to an ATC call during Flight 3A, with optional elements within parentheses, and the actual readback from Pilot 1, which was classified as *incorrect*.

| | | |
|---|---|---|
| (4) | *ATC*: | ABC. Wilton. Continue climb to 5500 and maintain 180. Traffic is a Cessna at your 11 o'clock at 5000. Report sighted. Contact Sydney Centre 124.55 |
| | *Expected*: | (Continue climb to) 5500. (Maintain) 180. Looking for traffic. (Contact) Sydney Centre 124.55. ABC. |
| | *Actual* (P1): | Maintain 5500. Track 180, and contact Sydney Centre 124.55. ABC. |

In (4), the first instruction is read back incorrectly, showing confusion between the instruction ‘continue climb’ and ‘maintain’. The pilot also omitted acknowledging the presence of traffic. Since there were no other aircraft in the environmental display, the pilots could not report ‘Traffic sighted’ as they would if they could see the other aircraft, and they were expected to reply to such advice with the standard ‘Looking for traffic’, advising ATC they had heard the warning and were alert to the presence of another aircraft.[8]

As per AIP (2005), some variants are acceptable. For instance, although not required and usually omitted by professional pilots, the verbs in the instructions (e.g. ‘maintain’, ‘climb’, ‘descend’, ‘contact’) are frequently repeated by general aviation pilots in their readbacks, as shown in (1) and (4) earlier. We also accepted variations in the ordering and extra words added by the pilot, even if they did not conform to the precise phraseology. Example (5) shows an instance in Flight 1A where the pilot reversed the order of the items and used extra words:

| | | |
|---|---|---|
| (5) | *ATC*: | ABC. Climb 3500. Track 160. Traffic is now a Cherokee at your 2 o’clock at 3500. What altitude do you intend to fly to Wollongong? |
| | *Expected*: | (Climb) 3500. (Track) 160. Looking for traffic. 4500 to Wollongong. ABC |
| | *Actual* (P11): | Altitude intend to Wollongong is 4500 and your altitude climb to was 3500 and tracking 160. ABC. |

In (6) from Flight 3B, the pilot reversed the order of the instructions so he could request ATC to repeat the item (Heading) which he was not sure about.

| | | |
|---|---|---|
| (6) | *Expected*: | Looking for traffic. (Climb to) 3500 when clear of traffic. (Track) 210. ABC. |
| | *Actual* (P17): | Climb and maintain 3500, looking for traffic, say again track. ABC. |

In some cases, the variation was warranted, being due to the actual flight conditions. For instance (7) below was transmitted by Pilot 15 in Flight 2A instead of the expected readback shown in example (1). In this case, the aircraft had not yet climbed to 5500 feet as expected, but since the pilot correctly transmitted their actual position and intentions, this call was considered *correct*.

| | | |
|---|---|---|
| (7) | *Expected*: | Sydney Centre. ABC at 5500, tracking 190. |
| | *Actual* (P15): | Sydney Centre ABC is passing 4600 for 5500 tracking 190. |

### *Correct and incorrect items*

At the item level, each item in a call was assessed as being *correct* or *incorrect*. The number of incorrect calls (see earlier) and the number of incorrect items in a flight measure different effects. The number of incorrect calls per flight is a measure of the potential impact on frequency congestion, with ATC needing to ask the pilots to repeat incorrect calls. The number of incorrect items is a finer-grained measure of communication accuracy, reflecting comprehension and correct readback by the pilots. It is possible to have a high percentage of calls being incorrect in a given flight, but a lower percentage of incorrect items for that flight. For example, if a call contains just one incorrect item, which might be the omission of the call-sign, at a call level this would be deemed incorrect. However, if this same call contained three items, only one item from three would be deemed to be erroneous. In example (4) earlier, the pilot's transmission contains three incorrect items: two mistakes (i.e. Altitude and Heading) and one omission (i.e. Traffic).

### *Nature of error: omissions versus mistakes*

We wanted to study in more detail the types of communication error. Of particular interest is the difference between omitting an item, for instance omitting the assigned altitude, and transmitting the wrong information, for instance saying '3500' instead of '4500'. Therefore, each *incorrect* item was categorized as either *missing* or *erroneous*. In example (4), the pilot's transmission contains two erroneous items (i.e. Altitude and Heading) and one missing item (i.e. Traffic).

### *Category of error: words or numbers*

Many items which must be read back or reported by pilots involve a numeral. In our data, these were: Altitude, Heading, Radio Frequency and Transponder Code (Tx Code). Such items also involve a specific instruction associated with the action to be performed by the pilot (e.g. 'climb' or 'maintain'). Other items only involve words or phrases, e.g. 'Looking for traffic' or 'Clear to land'. For items containing a numeral, we want to know whether the error concerns the instruction itself or the numerical value (e.g. '4500' instead of '3500'). Thus we coded all errors as either *words* (or phrases) or *numbers*. The hypothesis is that mistakes would be more likely to occur with numerals than with words, but it is also possible for pilots to make a mistake with the instruction itself.

In example (4), the two erroneous items in the pilot's transmission concern the words used for the instruction rather than the numerals: for Altitude 'maintain' rather than 'continue climb', and for Heading 'track' instead of 'maintain'. The omission also concerned a phrase, because we would expect 'Looking for traffic'.

In example (8) below, from Flight 1B, the error is on both the instruction ('descend' instead of 'climb') and on the numeral for altitude ('4000' instead of '4500').

| | | |
|---|---|---|
| (8) | *Expected*: | (Track) 150. (Climb to) 4500. When clear of the zone, (contact Sydney Centre), 124.55. ABC. |
| | *Actual* (P7): | Track 150 degree. Descend to 4000 feet. Contact Sydney Centre 124.55. ABC |

Example (9) from Flight 2B is a case where the numerical error (Frequency '110.1' instead of '126.7') shows confusion with another numeral, the Heading '110' given in the instruction 'Track 110'.

| | | |
|---|---|---|
| (9) | *ATC*: | ABC. You are approaching Wilton, identified at 4500 in Danger area. Contact Wilton 126.7. Track 110 and climb to 5500. |
| | *Expected*: | (Contact Wilton Centre) 126.7. (Track) 110. (Climb) 5500. ABC. |
| | *Actual* (P2): | Climb to 5500 and contact 110.1. ABC. |

Since the main aim of this analysis was to examine differences in terms of omissions or mistakes between words or numerals, as opposed to examining differences based on pilot qualification or language background, the dependent variables were the percentage of items omitted or incorrectly stated from the total number of items transmitted for all participants.[9] The first dependent *t* test compared percentage of total omissions (relative to opportunity) between the A and B flights. The second dependent *t* test compared percentage of omissions of numerals (relative to opportunity) between the same A and B flights, while the third compared percentage of omissions of words (relative to opportunity) between the same two flights. The same pattern of analyses was employed for the data pertaining to mistakes: total mistakes, mistakes with numerals and then mistakes with words.[10]

### *Locus of errors: errors by item type*

To some extent, the more interesting question from a linguistic point of view is which types of item are more likely to give rise to errors. This is also a crucial question from the point of view of aviation safety, as each item type carries a different potential threat if read back incorrectly. For instance, omitting the aircraft call-sign at the end of a transmission may result in additional calls from ATC to clarify the identity of the station calling or in confusion for ATC and other pilots, but not in an immediate threat to flight safety. On the other hand, a mistake on assigned altitude or heading may result in traffic conflict and potential mid-air collision. An incorrect radio frequency may result in an aircraft being out of contact and unable to hear further calls from ATC or other transmissions by aircraft in the same airspace. The complete list of the item types in our data is given in Table 7.4, with illustrative examples.

*Table 7.4* Item types

| *Item type* | *Examples* |
|---|---|
| Traffic | Traffic sighted |
| | Looking for traffic |
| Altitude | 4500 |
| Heading | 180 |
| Radio frequency | 124.55, Canberra Approach |
| Transponder code | 3000, 1200, 5033 |
| OCTA | Remain outside controlled area |
| Call sign | ABC, YWD |
| Location | 2RN, Crosswind, Wilton |
| ATIS | Information Hotel |
| Approach | Clear visual approach |
| Land | Clear to land |
| Entry Point | Join downwind 29 Right |
| Other | Confirm inbound |

The percentages of errors committed by item type relative to the total number of expected items of that type for each flight are presented below. As it was not expected that the flight condition would significantly affect which items would give rise to errors, the results are presented for all the flights together, in Tables 7.10 and 7.11.

In the next section, the results of the analysis are presented for each of the four flight condition pairings: Speech Rate, Information Density, Workload and Radio Congestion; with details for each of the dependent variables: number of incorrect transmissions, number of incorrect items, nature of error (omissions/mistakes), category of error (words or numerals) and locus of error (item type). They are then summarized across the flight pairings in the *Results overview* section.

## Results

At the beginning of the study, based on the rather simple assumption of a one-to-one mapping between pilots' hearing and understanding and their responses, we expected that there would be five theoretically possible outcomes, measured by the verbal responses of the pilots and by their actions:

1 not hear – no readback;
2 hear but not understand – request repetition or clarification;
3 hear what you expect – erroneous readback;
4 partial hear – partial readback; and
5 hear and understand – correct readback.

These expectations had to be revised in light of the findings and of our analysis of the data, presented below. In particular, we recognized that there is a much more complex relationship between hearing and reading back. Partial or no hearing may be due to a number of factors: mechanical (e.g. faulty radio), physical (e.g. hearing loss), cognitive overload, or fatigue. No readback or a partial readback can be due not only to partial or no hearing, but also to cognitive overload, stress or distraction and might not indicate that the pilot failed to hear the ATC transmission they should have read back.

### *Speech rate condition*

For this flight pairing, the pilots were expected to make 16 transmissions (readbacks or reports) in each flight. The wording of the ATC calls was the same in both conditions, but the rate of speech from ATC was faster in Flight 1B, with no pauses between items in a call (see the earlier section titled 'Audio stimuli recording').

#### *Speech rate condition: number of incorrect transmissions (calls)*

Although the results failed to reveal a main effect for flight condition (i.e. no significant difference between performance in Flight 1A and Flight 1B), or an interaction between flight condition and language background or an interaction between flight condition and licence type, there was a three-way interaction between flight condition, language background and licence type. That is, notable performance differences during Flight 1B were evident for the EL2 pilots only, suggesting that EL2 pilots with low levels of pilot qualification found it more difficult to communicate accurately during the flight with faster rate of speech in ATC communications than the other pilots.

There was also a significant main effect, i.e. for Flights 1A and 1B combined, for language background (i.e. between NES and EL2 pilots), and a main effect for pilot qualification, as well as an interaction between language background and pilot qualification, as seen when comparing Figures 7.1 and 7.2 below.

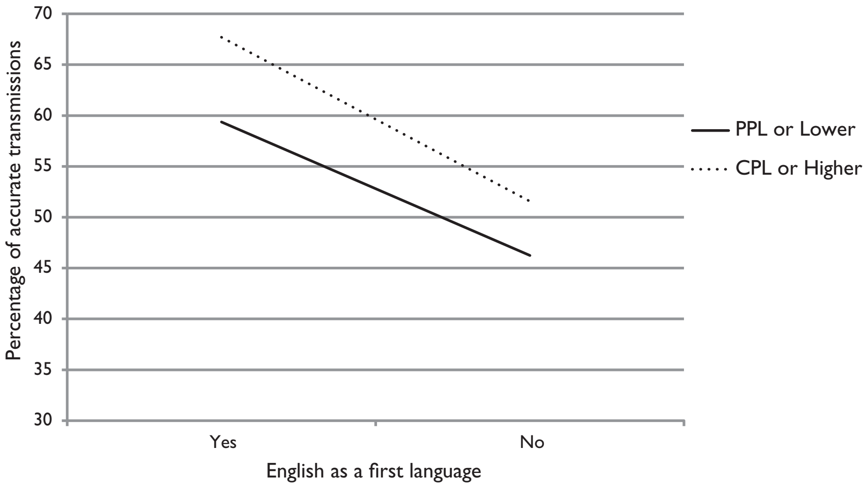


*Figure 7.1* Language background and pilot qualification in Flight 1A

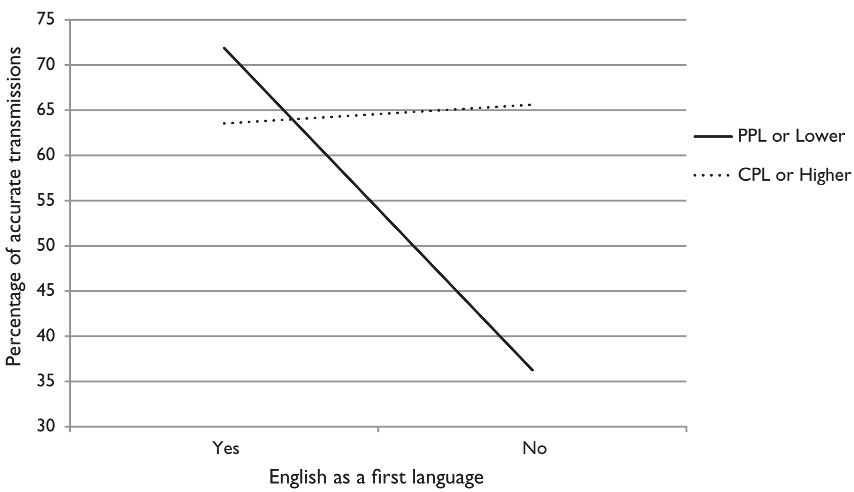


*Figure 7.2* Language background and pilot qualification in Flight 1B

This confirms that EL2 pilots in general found communicating more difficult and as a result committed more communication errors than NES pilots. The effect for pilot qualification indicates that pilots with a CPL or higher qualification had a greater number of accurate transmissions than pilots with a PPL or lower pilot qualification.

There was no main effect between flight condition and pilot qualification, indicating that the difference in communication accuracy in Flight 1A and Flight 1B was not significantly different for pilots with higher or lower levels of training. Two separate correlational analyses were performed, one for Flight 1A and one for Flight 1B, to compare levels of accuracy for pilots with different amounts of experience. In other words, would pilots with fewer flight hours, and therefore lower experience in radio communication, perform differently across the two conditions? The results failed to reveal a relationship between flight experience and communication accuracy in this flight pairing. Combined with the main effect found for pilot qualification, this suggests that what is important in terms of communication accuracy is the level of training received (for instance, reaching CPL level) rather than the total number of hours flown, as is often assumed.

### *Speech rate condition: number of incorrect items*

The total number of items for Flights 1A and 1B was 48. On average pilots transmitted 12.12 items incorrectly (range 4 to 25) in Flight 1A, and 11.24 in Flight 1B (range 2 to 25). Hence, the number of correct items was on average 35.88 (75 per cent) for Flight 1A and 36.76 (77 per cent) for Flight 1B.

The results failed to reveal a main effect for flight condition (i.e. no significant difference between performance in Flight 1A and Flight 1B), an interaction between flight condition and language background, an interaction between flight condition and licence type, or a three-way interaction between flight condition, language background and licence type. This indicates that ATC speech rate had no noticeable effect on pilots' communication accuracy measured in terms of items correctly transmitted. Regarding the between-group factors, the main effect for language background was significant: the percentage of correct transmissions for NES pilots was 81.77, in contrast to 71.95 for the EL2 pilots (see Figure 7.3). Overall NES pilots performed better than EL2 pilots, regardless of their level of training.

While the Pearson product–moment correlation for Flight 1B failed to reveal a relationship between flying experience (measured in number of flying hours) and communication accuracy (as a percentage of correct items), the Pearson product–moment correlation for Flight 1A revealed a moderate negative relationship between flight experience and communication accuracy, indicating that contrary to expectations pilots with higher experience performed less well on this flight than pilots with less experience. One explanation for this result might be that the more experienced pilots in the easy flight condition (Flight 1A) were complacent. Another explanation might be that the pilots were used to ATC speaking at a faster speech rate and found the slower speech rate unusual (see Cooke et al., 2014).

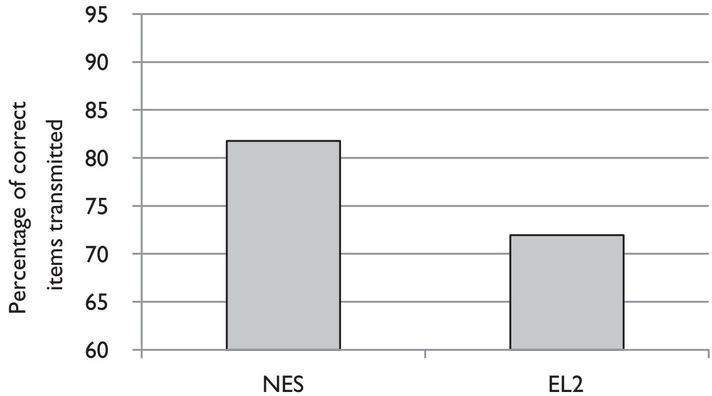


*Figure 7.3* Percentages of items correctly transmitted in the easy (Flight 1A) and hard (Flight 1B) 'Speech Rate' conditions for native English speakers (NES) and English as a second language (EL2) pilots

*Speech rate condition: nature of error (omissions/mistakes)*

Looking at omitted and erroneous items, the analysis also failed to reveal a main effect for flight condition, an interaction between flight condition and language background, an interaction between flight condition and licence type or a three way interaction between flight condition, language background and licence type. This suggests that the nature of communication error did not change between flights as a result of different speech rates for ATC calls. However, in terms of the between-group factors, a main effect for licence type was significant: as shown in Figure 7.4, for CPL or higher licence pilots, 14.49 per cent of the incorrect items were mistakes as opposed to 23.95 per cent for PPL or lower pilots.

This main effect for licence type indicates that pilots with a higher qualification are less likely to make an erroneous readback or report. In other words, a smaller proportion of the errors committed by pilots with a CPL or higher licence consisted in making a mistake and a higher proportion consisted in not transmitting. In raw numbers, this translates into 2.40 erroneous items for the higher qualified pilots and 4.71 erroneous items for less qualified pilots, out of a possible 96 items to be transmitted across the two flights.

The main effect for language background (NES vs EL2) was not significant, but there was an interaction between licence type and language background. Figure 7.5 displays the performance of the two pilot licence groups based on language background in the easy flight (Flight 1A) and Figure 7.6 shows the same information for the harder flight (Flight 1B).

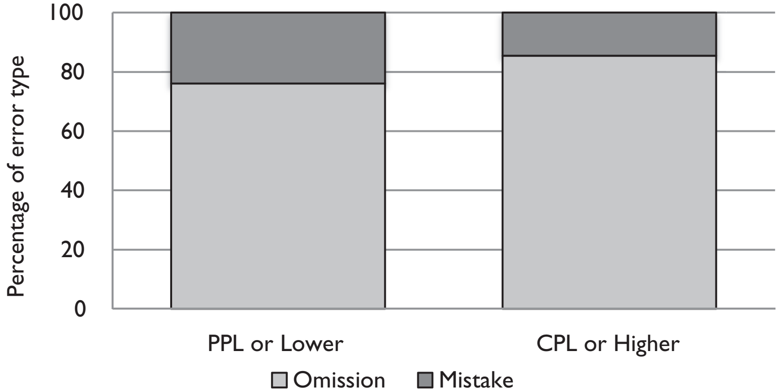


*Figure 7.4* Omissions and mistakes out of total incorrect items, in the combined easy (Flight 1A) and hard (Flight 1B) 'Speech Rate' flight conditions for low and high pilot qualifications

As is evident in Figure 7.5, performance varied notably in Flight 1A for the NES pilots based on pilot licence qualification: the percentage of mistakes was greater for NES pilots with lower qualification and decreased when they held a higher pilot licence, while there was no such difference for the EL2 pilots. Two Mann–Whitney *U* tests were employed, one comparing performance between the two pilot licence groups for the NES pilots (left side of the graph), and one comparing performance between the two language groups for the lower pilot licence holders (solid line). With a

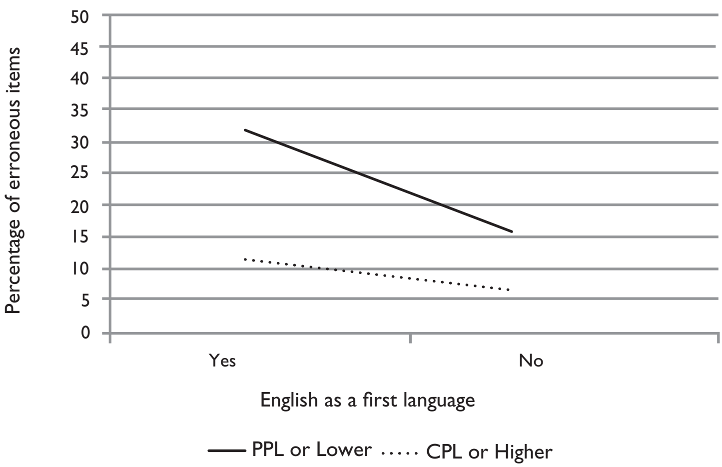


*Figure 7.5* Percentage of erroneous items in the easy (Flight 1A) 'Speech Rate' flight, distributed across pilot licence and language background

Bonferroni adjusted alpha of .025 to control for family wise error, the results of the Mann–Whitney nonparametric tests failed to reveal any differences. This indicates that, in spite of the apparent greater difference for NES pilots in the graph in Figure 7.3, there was no significant difference in the level of performance of NES and EL2 pilots with higher qualifications, nor between low and high qualification EL2 pilots (right side of the graph).

As shown in Figure 7.6, performance also varied notably in Flight 1B on the basis of pilot qualification, but this time for both language groups and not in the same direction.

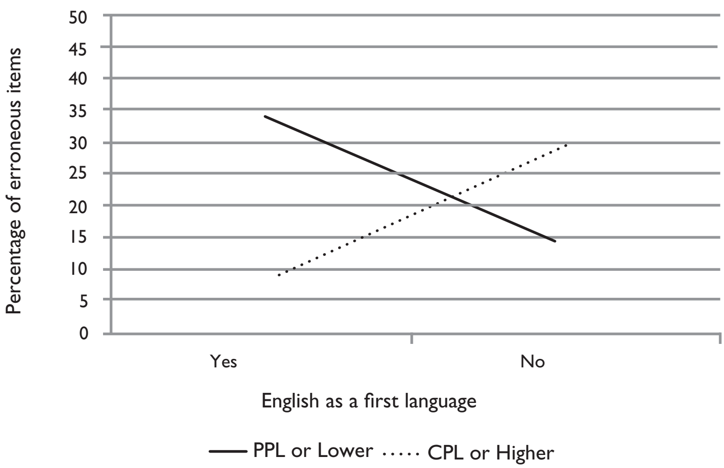


*Figure 7.6* Percentage of erroneous items in the hard (Flight 1B) 'Speech Rate' flight, distributed across pilot licence and language background

As with Flight 1A, two Mann–Whitney *U* tests were employed for Flight 1B, one comparing performance between the two pilot licence groups for the NES pilots (left side of the graph), and a second comparing performance between the two pilot licence groups for the EL2 speakers (right side of the graph). With a Bonferroni adjusted alpha of .025 to control for familywise error, the results of both Mann–Whitney nonparametric tests revealed a marginally statistically significant result. This indicates that, when communication was more difficult, low qualified NES pilots made a higher proportion of mistakes than higher qualified NES pilots. In contrast, low qualified EL2 pilots made a smaller proportion of mistakes than the higher qualified EL2 pilots.

We propose to explain these results in terms of the different development of flying skills and aviation communication skills, in addition to increased language proficiency, for NES and EL2 pilots. NES with higher pilot qualifications have learnt to communicate better in the aviation environment, and hence commit fewer mistakes. Whereas when EL2 pilots acquire greater aviation skills, they also become more confident in their aviation communication skills, which in some cases may translate into an overconfidence resulting in them making more mistakes.

#### *Speech rate condition: category of error (words or numerals)*

With assumptions of normality met, all dependent *t* tests failed to reveal a statistically significant difference between Flight 1A and Flight 1B. This result suggests that increasing ATC rate of speech has little impact on whether errors (either omissions or mistakes) occurred with numerals or with words.

### ***Information density condition***

This flight pairing, in which there were more items per ATC transmission during Flight 2B (four or more items) than in the ATC transmissions during Flight 2A (three or fewer items), is the only one of the four flight pairings where pilots were expected to make different calls and different numbers of calls in the two conditions. This is because, since the ATC transmissions were intended to be meaningful for the flight, some of the additional items were requests which the pilots had to comply with. Examples (10) and (11) show instances where the expected pilot readbacks or reports were the same in Flight 2A and Flight 2B (although pilots could, and did, include extra information in their transmissions in Flight 2B):

(10) *Example where the expected pilot readbacks are the same in F2A and F2B*

(F2A) *ATC*: ABC. Traffic is 2 gliders south of the airfield. Climb to 2500 and track 210.

(F2B) *ATC*: ABC. Overhead departure approved. Traffic is 2 gliders south of the airfield. Climb to 2500 when clear of traffic, and track 210.

*Expected*: Looking for traffic. (Climb to) 2500 (and track) 210. ABC

(11) *Example where the expected pilot reports are the same in F2A and F2B*

(F2AB) *Expected*: Wilton Centre, ABC at 4500.

Examples (12) and (13) show instances where the pilot readbacks are different in Flight 2A and Flight 2B, while (14) is an example where the pilot is required to make an additional call in Flight 2B:

(12) *Example where the expected pilot readbacks are different in F2A and F2B*

(F2A) *ATC*: ABC. Wilton. Climb to 5500. Track 190. When established, contact Sydney Centre on 124.55.
*Expected*: (Climb to) 5500. (Track) 190. (Contact Sydney Centre) 124.55 when established. ABC.

(F2B) *ATC*: ABC. Wilton. Climb to 5500. Track 190. Maintain 190 until clear of traffic. Area QNH 1023. When established, contact Sydney Centre on 124.55.
*Expected*: (Climb to) 5500. (Track and maintain) 190 until clear of traffic. (Contact Sydney Centre) 124.55 when established. ABC.

(13) *Example where the expected pilot readbacks are different in F2A and F2B*

(F2A) *ATC*: ABC. Climb to 3500. Track 240. Traffic is a Cessna at your 3 o'clock at 3500.
*Expected*: (Climb to) 3500. (Track) 240. Looking for traffic. ABC

(F2B) *ATC*: ABC. Climb to 3500. Track 240. Traffic is a Cessna at your 3 o'clock at 3500. What level do you intend to fly to Mittagong?
*Expected*: (Climb to) 3500. (Track) 240. Looking for traffic. 4500 to Mittagong. ABC.

(14) *Example where the pilot is required to make an additional call in F2B*

(F2A) *ATC*: ABC. Sydney Centre. Maintain 5500. Track 270.
*Expected*: (Maintain) 5500. (Track) 270. ABC.

(F2B) *ATC*: ABC. Sydney Centre. Track 270. Climb to 6500. Report when passing 6000. There is no traffic.
*Expected 1*: (Track) 270. (Climb) 6500. (Report when passing 6000). ABC
*Expected 2*: ABC passing 6000.

### *Information density condition: number of incorrect transmissions (calls)*

The total number of possible transmissions for each pilot was 18 in Flight 2A, and 20 in Flight 2B. There was a main effect for flight condition (i.e. a significant difference between performance in Flight 2A and Flight 2B), thus confirming that the increased number of items per transmission makes it more difficult for pilots to read back accurately what they have been told. No other main effects or interactions were significant, thus suggesting that increasing the number of items required in one radio communication significantly affects pilots' ability to accurately respond, irrespective of their language background or flight qualification, and confirming results by Barshi and Farris (2013).

The results of two separate correlational analyses, one for Flight 2A and one for Flight 2B, confirmed those reported earlier for flight pairing 1, suggesting that increased flying experience did not significantly improve communication accuracy and did not help pilots when the number of items per transmission was too great.

#### *Information density condition: number of incorrect items*

This flight pairing involved ATC providing instructions with 3 or fewer items (Flight 2A) or with four or more items (Flight 2B), therefore the number of items presented in each flight varied: 56 items for Flight 2A and 72 items for Flight 2B. Pilots transmitted an average of 15.47 incorrect items in the easy Flight 2A, whereas they transmitted an average of 22.24 incorrect items in the more difficult Flight 2B. Hence, the number of correct items for each flight was on average 40.53 (72 per cent) for Flight 2A and 49.76 (69 per cent) for Flight 2B.

The results failed to reveal any main effect or interactions, suggesting that the number of items in the radio transmission has little effect (no statistical significance) on the percentage of items correctly transmitted, and similarly nor does language background or licence qualification interact with this variable.

The two correlational analyses failed to reveal a relationship between flight experience and communication accuracy as measured by the percentage of correct items, for either Flight 2A or Flight 2B. This suggests that all pilots, irrespective of flying experience, performed similarly in terms of the percentage of items correctly communicated under this condition. In other words, even though they committed more errors in Flight 2B, because the total number of items to be transmitted was higher, all pilots managed to maintain the same proportion of correctly transmitted items in both flights. However, the nature of the error was different.

#### *Information density condition: nature of error (omissions/mistakes)*

Indeed, there was a main effect for flight condition on the nature of errors committed, i.e. a significant difference between performance in Flight 2A and Flight 2B: pilots had a lower percentage of mistakes in Flight 2A (8.67 per cent) than in Flight 2B (18.1 per cent). As can be seen in Figure 7.7, under the difficult condition (Flight 2B) the number of erroneous items transmitted increased.

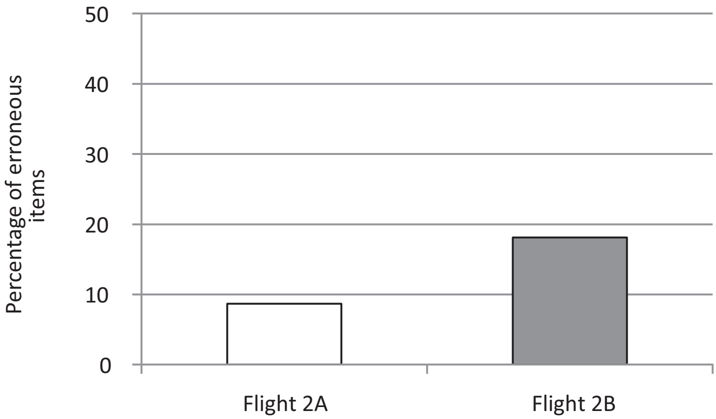


*Figure 7.7* Percentage of erroneous items out of total incorrect items in the easy (Flight 2A) and hard (Flight 2B) 'Information Density' paired flight conditions

There was no interaction between flight condition and language background, no interaction between flight condition and licence type, nor a three-way interaction between flight condition, language background and licence type. Regarding the between-group factors, a main effect for licence type was significant, with CPL or higher pilot licence holders having a lower percentage of erroneous items (8.65 per cent) compared to PPL or lower licence holders (18.12 per cent; see Figure 7.8). There were no other main effects or interactions.

This result indicates that pilots with a higher level of qualification are less likely to make erroneous readbacks, so that when a CPL pilot makes an incorrect transmission it is more likely to be an omission than a mistake, confirming the results for the 'Speech Rate' flight pairing.

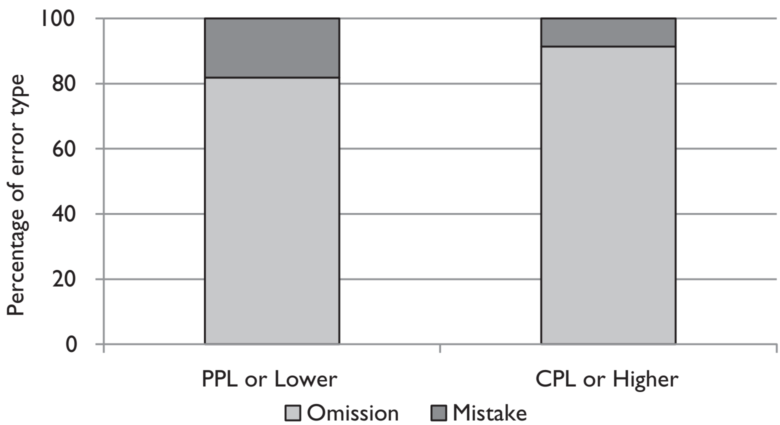


*Figure 7.8* Omissions and mistakes out of total incorrect items, in the combined easy (Flight 2A) and hard (Flight 2B) 'Information Density' flight conditions for low and high pilot qualifications

#### *Information density condition: category of error (words or numerals)*

The results of the dependent *t* test for the total omissions and omissions of numerals under the two flight conditions (Flight 2A and Flight 2B) failed to reveal a statistically significant difference. In contrast, the dependent *t* test for omitted words revealed a statistically significant difference between the two flight conditions: the percentage of words omitted by pilots increased from 41 per cent in Flight 2A to 58 per cent in Flight 2B. This indicates that increasing the number of items in ATC transmissions has a greater effect on word omissions than on number omissions. Indeed we would expect that pilots strive to read back or report numerical values, as these are the most important pieces of information for the conduct of the flight.

Regarding mistakes, the result revealed a statistically significant difference between Flight 2A and Flight 2B, both for total mistakes and for mistakes with numbers, but no statistically significant difference between mistakes with words: the percentage of mistakes with numerals increased from 4 per cent in Flight 2A to 10 per cent in Flight 2B. This result indicates that increasing the number of items in ATC transmission adversely affects the accuracy with which pilots transmit numbers.

### *Workload condition*

In this flight pairing, Flight 3A was a normal navigation flight but in Flight 3B pilots were asked after the beginning of the flight to calculate whether they had enough fuel on-board for a diversion to another destination, while continuing to fly the aircraft and to answer ATC calls.

#### *Workload condition: number of incorrect transmissions (calls)*

For this flight pairing, the ATC transmissions and expected pilot transmissions were the same in Flight 3A and Flight 3B. There was a main effect for flight condition (i.e. a significant difference between performance in Flight 3A and Flight 3B), but no interaction between flight condition and language background, flight condition and licence qualification, or flight condition, language background and licence qualification. This suggests that increasing the pilots' workload adversely affected all pilots' ability to communicate effectively. There was also a main effect for language background, confirming that NES pilots found it easier to communicate than EL2 pilots, irrespective of workload.

#### *Workload condition: number of incorrect items*

The total number of items for this flight pairing was 39 items per flight. There was a main effect for Flight Condition: on average, pilots transmitted 9.88 incorrect items in the easier Flight 3A, but an average of 14.06 incorrect items in the more difficult Flight 3B. In total, pilots in Flight 3A correctly transmitted 74.66 per cent of items compared to 63.95 per cent in Flight 3B (see Figure 7.9).

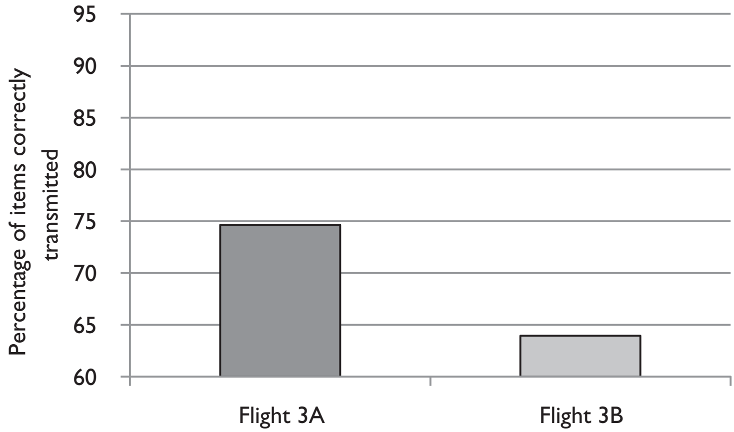


*Figure 7.9* Percentage of items correctly transmitted in the 'Workload' paired flight conditions (Flights 3A and 3B), distributed across the two flights

There was no interaction between flight condition and language background, no interaction between flight condition and licence qualification, nor a three-way interaction between flight condition, language background and licence type, suggesting again that increased pilot workload adversely affects all pilots' ability to communicate accurately.

Similarly with the between-groups analysis, no main effect or interactions were present. This would seem to indicate that the second flight involving the fuel calculation was so difficult that being a native English speaker or having greater flying experience was not enough to overcome the increased difficulty presented by the fuel calculation in addition to flying and communicating.

The two correlational analyses examining the relationship between flight experience and communication accuracy in the two flights condition failed to reveal any relationship. Again this result suggests that greater flying experience did not help with communication accuracy in either the easy flight condition or the hard flight condition.

### *Workload condition: nature of error (omissions/mistakes)*

The analysis failed to reveal any main effects or interactions, suggesting that when the workload is greater, but communication itself is no more difficult, the nature of error does not change. This result is of particular interest from a cognitive perspective, as it would seem to suggest that different cognitive processes are involved for the two distinct tasks employed in the current research, namely communication and fuel recalculation (discussed in the section *Flight training and language teaching*).

#### *Workload condition: category of error (words or numerals)*

The results of all the dependent *t* tests failed to reveal a statistically significant difference between the two flight conditions (Flight 3A and Flight 3B), indicating that increasing the workload of pilots had no impact on the nature of the errors (i.e. words or numerals), either as omissions or mistakes. Again, this would suggest different cognitive processes for communication and for the other flying tasks.

### *Frequency congestion condition*

For this flight pairing, the transmissions expected from the pilots were the same in Flight 4A and Flight 4B and the ATC transmissions directed at the pilots (with call-sign 'Alpha Bravo Charlie') were identical. However, in Flight 4A, there was only one other aircraft transmitting on the same frequency, while in Flight 4B there were nine other aircraft, two of which had been given similar call-signs ('Alpha Bravo Delta' and 'Charlie Bravo Charlie'). Twelve additional ATC calls were directed at those other aircraft in Flight 4B, for a total of 10 ATC calls in Flight 4A and 22 in Flight 4B, and there were 16 transmissions from those aircraft. Thus there was less time, though still sufficient time available, for the pilots to make their own readbacks and reports.

#### *Frequency congestion condition: number of incorrect transmissions (calls)*

In both Flight 4A or Flight 4B, 11 transmissions were expected from the pilots of 'Alpha Bravo Charlie'. Although there were 28 additional transmissions on the same frequency during the same time period in Flight 4B, the results failed to reveal any main effect or interaction, suggesting that radio frequency congestion does not affect pilots' ability to communicate effectively, irrespective of their language background, pilot qualification or flying experience.

#### *Frequency congestion condition: number of incorrect items*

The total number of items for this flight pairing was 29 items per flight. On average, pilots transmitted 6.11 incorrect items in Flight 4A and 5.35 in Flight 4B. The number of correct items for each flight was on average 21.09 (79 per cent) for Flight 4A and 18.26 (82 per cent) for Flight 4B. As would be expected from this data, the analyses failed to reveal any main effect or interaction, suggesting that radio congestion has no effect on pilots' ability to communicate, and that neither language background, licence qualification or flight experience interact with this variable.

### *Frequency congestion condition: nature of error (omissions/mistakes)*

A large number of pilots did not make any erroneous readbacks at all, in either Flight 4A or Flight 4B. Therefore, the data pertaining to erroneous items were non-normally distributed (severe positive skewness), and employing any transformation procedure would be inappropriate.[11] Hence only raw data is presented in Tables 7.5 and 7.6. As can be seen in these tables, performance in Flight 4B did not vary based on language background or licence qualification. In Flight 4A, there was some variation in performance based on language background (approximately 12 points); however, this needs to be interpreted in context, given the large standard deviation present with the NES pilots. Though the difference in mean performance on Flight 4A between the two different licence qualifications was notably smaller, the standard deviation for the CPL or higher licence group was also very high. Hence, caution should be exercised when drawing any conclusions about the differences between these groups.

*Table 7.5* Percentage of omitted items from total incorrect items for the 'Radio Congestion' paired conditions (Flights 4A and 4B), distributed across language background (NES vs EL2 pilots)

| | *Native Language Background* | | | |
|---|---|---|---|---|
| Flight condition | EL2 (n = 9) | SD | NES (n = 8) | SD |
| F4A (no radio congestion) | 97.56 | 5.12 | 85.00 | 35.05 |
| F4B (high radio congestion) | 100 | 0 | 100 | 0 |

*Table 7.6* Percentage of omitted items from total incorrect items for the 'Radio Congestion' paired conditions (Flights 4A and 4B), distributed across pilot licence qualification (PPL or lower vs CPL or higher)

| | *Pilot Licence Qualification* | | | |
|---|---|---|---|---|
| Flight condition | PPL or lower (n = 7) | SD | CPL or higher (n=10) | SD |
| F4A (no radio congestion) | 94.00 | 8.28 | 90 | 31.62 |
| F4B (high radio congestion) | 100 | 0 | 100 | 0 |

*Frequency congestion condition: category of error (words or numerals)*

Unsurprisingly, given the results, none of the six dependent *t* tests revealed a statistically significant difference between Flight 4A and Flight 4B, indicating that increased radio congestion had no noticeable impact on whether communication errors occurred with words or numerals, whether omitted or mistakenly stated.

### *Results overview*

The main aim of these experiments was to investigate the effect of four different flight conditions on the communication accuracy of pilots. In addition, we investigated whether known factors such as language background, pilot qualification or flight experience interacted with the pilots' ability to communicate accurately during these flights. The results revealed a complex relationship between all these variables. Contrary to expectations, radio frequency congestion had no impact on pilots' communication performance. Increased pilot workload, as expected, had a profound effect and degraded communication accuracy for all pilots. Also as expected, information density was found to adversely affect communication performance, with the effect being more pronounced for low hour NES pilots and EL2 pilots. The impact of speech rate on communication accuracy was more complex: high qualified NES pilots seemed to be immune from its effect, while low qualified NES pilots and all EL2 pilots were adversely affected by faster ATC speech rate (Molesworth and Estival, 2015a). Thus, increased rate of speech and absence of pauses in ATC transmissions is particularly problematic for EL2 pilots with low pilot qualifications.

In terms of language background and performance, the results largely failed to reveal any surprises, with NES pilots producing more correct transmissions as a whole (63 per cent) compared to EL2 pilots (51 per cent) (for the Speech Rate, Information Density and Workload flights). Irrespective of language background, pilots seemed to find communicating during the approach and landing flight scenario (Flight 4A/Flight 4B) much easier than the navigation scenarios, even with radio frequency congestion. On average, 68 per cent of the pilots' transmissions were correct in Flights 4A and 4B, while, in contrast, just over half (53 per cent) of pilots' transmissions during the other six flights (tracking south from Camden to Wollongong, Goulburn or Canberra) were correct. What is surprising, however, is the large number of errors in radio transmissions by pilots in the first place. For NES pilots, the percentage of incorrect transmissions was approximately 40 per cent, while for EL2 pilots this approached 50 per cent. Therefore, combining EL2 and NES pilots, the accuracy of communications over the radio in General Aviation is a little less than 50 per cent.

The flight condition that yielded the worst performance among both NES and EL2 pilots was the high Information Density Flight 2B. Increasing the number of items in ATC transmissions (four or more items) adversely affects communication accuracy for all pilots, and neither being a native speaker nor having higher pilot qualification can compensate for the increased communication difficulty.

Pilot workload also adversely affects communication performance and, again, neither being a native English speaker nor having higher pilot qualification could compensate for the increased cognitive difficulty. This suggests that the act of communicating over the radio is cognitively taxing and, when combined with other high workload tasks, performance deteriorates. For pilots, this may come as no surprise as it highlights the importance of the well-known adage: 'Aviate, Navigate, Communicate'. If the flying operational requirements become too demanding, even high English language proficiency is not enough to guarantee accurate communication.

As seen in the results from the radio frequency congestion flight pairing, all pilots, including low qualification pilots and EL2 pilots, were able to filter out any radio transmissions that were not relevant to them. While this seems a positive result, it does raise the question whether pilots were actually filtering or were in fact ignoring those transmissions; if the latter, this has important safety implications and warrants further investigation.

Table 7.7 gives the percentages of correct calls and correct items for each of 8 flights.

*Table 7.7* Percentages of incorrect calls and incorrect items for all flights

| | *% of correct calls* | *% of correct items* |
|---|---|---|
| F1A – Speech rate: slow | 56 | 75 |
| F1B – Speech rate: fast | 59 | 77 |
| F2A – Information: low | 59 | 72 |
| F2B – Information: high | 41 | 69 |
| F3A – Workload: normal | 60 | 75 |
| F3B – Workload: high | 50 | 64 |
| F4A – No radio congestion | 69 | 79 |
| F4B – High radio congestion | 69 | 82 |

### *Interpretation of results (number of correct calls)*

Not surprisingly, overall NES pilots committed fewer errors than EL2 pilots in their radio transmissions. However, when the task was a routine one, such as arriving at the local aerodrome (Flight 4B), or when the radio transmissions were particularly difficult (Flight 2B), both NES and EL2 pilots found it equally easy or hard. For all the other flights, EL2 pilots committed more communication errors than NES pilots.

What is of particular concern is the overall poor communication performance of all pilots and the large number of incorrect radio transmissions by pilots in the first place (see Table 7.7). This would suggest either that aviation communication is very difficult or that GA pilots are poorly trained when it comes to radio communication (or indeed a combination of the two). Although we would argue that aviation communication is in fact harder than generally considered, it is clear that the quality of the communication training needs to be improved. The results further suggest that relying on the natural development of communication skills as a progression of flight experience is not the solution, as licence qualification and not hours of flight experience yielded differences in communication performance.

*Interpretation of results (number of correct items)*

Looking at raw data alone, pilot performance in Flight 3B was lower than in any other flight, suggesting that pilots found the high workload condition to be the most difficult. It was also the only flight where pilot communication performance was statistically different from its paired easy flight condition. Performance on Flight 2B was lower than in Flight 1B or any of the easy flights, suggesting that the high information density condition was the next hardest condition for pilots, irrespective of language background or flying qualification.

*Interpretation of results (nature of error: omissions vs mistakes)*

In terms of the type of error (mistake versus omission) and how this changed as a result of flight condition, pilot licence qualification or language background, the results revealed that in two of the three flights that shared similar characteristics (i.e. navigation flights from the same departure point), the nature of the error varied based on pilot licence qualification (see Table 7.8). The main result from the analyses presented earlier is that pilots with higher qualifications are less likely to make factual errors in their readbacks than pilots with lower levels of qualifications. Importantly higher qualification does not mean more flying hours, but better training.

In the Speech Rate and Information Density flights, the higher licenced pilots (i.e. CPL or higher) committed fewer erroneous readbacks than the lower licenced pilots (see Table 7.8). In the flight pairing where Workload was manipulated (i.e. Flight 3A and Flight 3B), irrespective of licence type, the percentage of erroneous items remained similar. This suggests that, when workload is manipulated, experience as indicated by licence qualification does not alter the nature of the communication error. However, when communication itself is manipulated in the way the information is presented, the type of communication errors varies according to pilot

*Table 7.8* Percentage of erroneous items out of total incorrect items for the three flight pairing conditions that shared the same departure point, distributed across licence qualification group

| | *Pilot Licence Qualification* | | | |
|---|---|---|---|---|
| Flight condition | PPL or Lower (n = 7) | SE | CPL or Higher (n = 10) | SE |
| Speech rate | 23.95 | 3.03 | 14.49 | 2.34 |
| Information density | 18.12 | 2.15 | 8.65 | 1.66 |
| Workload | 9.68 | 4.92 | 11.93 | 3.80 |

qualifications. It seems that the less experienced pilots are more likely to make a mistake if they speak, while the more experienced pilots are more likely to refrain from speaking and thus commit fewer mistakes. Hence, experience, as measured by licence qualification, appears to temper pilots' willingness to communicate when they are uncertain about the correct communication protocol.

In terms of language background, the results overall revealed little difference between NES pilots and EL2 pilots, except for the 'Speech Rate' Flight 1B. In this flight pairing, the performance of the EL2 pilots was significantly different compared to the NES pilots, where NES pilots made fewer communication errors than EL2 pilots. This has implications for the training of EL2 pilots (Henley and Daly, 2004).

The question then is: what does the ratio of omissions and mistakes in readbacks as a proportion of incorrect items mean? That is, what does not repeating vs repeating incorrectly (e.g. 3500 instead of 4500) tell us about comprehension and cognitive load?

### *Interpretation of results (category of error: word or numeral)*

Words and numerals do not give rise to the same number of opportunities for mistakes and for omissions, because some words are not required. For example, the item 'Climb 4500' gives rise to 3 possible errors: omission of the numeral, as in (15.a); mistake on the numeral as in (15.b), or mistake on the instruction, as in (15.c). Omission of the instruction itself is not an error (AIP, 2005), therefore the two readbacks 'Climb 4500' or '4500' are counted as correct. Possible errors would be as shown in (15):

(15) a. Climb. [omission of the numeral]
b. Climb 3500. [mistake on the numeral]
c. Maintain 4500. [mistake on the instruction]

Table 7.9 shows the percentage of items in pilot's transmissions in which the error (mistake or omission) affected a word (or phrase) or a numeral. The

*Table 7.9* Percentage of omissions and mistakes, distributed across word items and numeral items for the four flight pairs, relative to opportunities for omissions and mistakes

| *Flight* | *Omission word %* | *SD* | *Omission numeral %* | *SD* | *Omission words + numerals Total* | *SD* | *Mistake word %* | *SD* | *Mistake numeral %* | *SD* | *Mistake words + numeral Total* | *SD* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F1A – Speech rate: slow | 39.61 | 16.30 | 9.14 | 9.11 | 24.52 | 10.18 | 0.63 | 1.20 | 3.01 | 2.43 | 1.82 | 1.25 |
| F1B – Speech rate: fast | 32.61 | 15.56 | 8.56 | 6.86 | 20.59 | 10.05 | 0.38 | 0.81 | 5.39 | 3.93 | 2.88 | 2.12 |
| F2A – Information: low | 41.03 | 20.14 | 17.13 | 9.74 | 29.08 | 13.72 | 0.38 | 1.09 | 3.94 | 4.96 | 2.16 | 2.48 |
| F2B – Information: high | 57.88 | 22.72 | 16.90 | 8.22 | 37.39 | 14.47 | 1.63 | 2.22 | 9.55 | 6.25 | 5.59 | 3.60 |
| F3A – Workload: normal | 36.81 | 11.48 | 10.37 | 7.03 | 22.00 | 8.22 | 0.53 | 1.19 | 6.67 | 6.89 | 3.60 | 3.81 |
| F3B – Workload: high | 36.81 | 11.49 | 17.04 | 7.38 | 26.92 | 7.77 | 0.80 | 1.26 | 9.94 | 8.84 | 5.37 | 4.78 |
| F4A – No radio congestion | 19.57 | 11.11 | 3.70 | 4.06 | 11.63 | 7.11 | 0.38 | 0.81 | 2.32 | 0.93 | 0.30 | 0.57 |
| F4B – High radio congestion | 20.92 | 10.07 | 1.85 | 2.34 | 11.39 | 5.30 | 0 | 0 | 0.06 | 0.25 | 0.03 | 0.13 |
| *Total* | 35.36 | 14.31 | 10.57 | 6.85 | 22.77 | 9.43 | 0.59 | 1.07 | 5.11 | 4.31 | 2.72 | 2.34 |

percentages are given relative to the opportunities for those omissions and mistakes, i.e. from the total number of items to be transmitted by all participants, distributed across flight pairing.

As can be seen in Table 7.9, irrespective of flight pairing, there was a higher percentage of omissions than mistakes (see Molesworth and Estival, 2015b). On average, just under a quarter (22.77 per cent) of all errors were omissions, while mistakes represented just over 2 per cent (2.34 per cent) of all errors. Interestingly, when a communication error was an omission, it was more likely to involve a word than a numeral. In contrast, when a communication error was a mistake, it was a numeral which was more likely to be stated incorrectly. In other words, mistakes rarely occur with the limited vocabulary of Aviation English phraseology, but are more frequent with the actual numbers to be transmitted, which are less predictable from context.

It is also worth noting that, in just over 40 per cent (42 per cent) of the cases where a word item was omitted, this was the aircraft call-sign. Although, call-sign errors can and do occur in real flights (e.g. in the case of the Malaysian Airlines flight number MH370, which went missing in 2014, the pilots stated their call-sign as MAS377, not MAS370 when requesting clearance to taxi), no mistakes occurred with call-signs in our data. Table 7.10 presents the number of word items omitted and the percentage of those omissions which were the expected call-sign.

*Table 7.10* Total number of omitted word items, number of omitted call-signs and percentage of omitted call-signs from omitted word items, distributed across flight conditions

| *Flight* | *Word Items omitted* | *Call-sign omitted* | *% of Call-signs from word items omitted* |
|---|---|---|---|
| F1A – Speech rate: slow | 139 | 64 | 46.04 |
| F1B – Speech rate: fast | 120 | 54 | 45.00 |
| F2A – Information: low | 151 | 70 | 46.36 |
| F2B – Information: high | 234 | 101 | 43.16 |
| F3A – Workload: normal | 116 | 49 | 42.24 |
| F3B – Workload: high | 152 | 70 | 46.05 |
| F4A – No radio congestion | 72 | 27 | 37.50 |
| F4B – High radio congestion | 81 | 26 | 32.10 |

### *Interpretation of results (locus of error, item type)*

As with the type of error (omission vs mistake) and the category of error (word vs numeral), with the locus of error we are not examining the magnitude of the error, but which errors occur and where they occur. However, there was no expectation that the flight condition would affect the locus of error and this is borne out by the figures shown in Table 7.11.

*Table 7.11* Percentage of errors relative to opportunity for error for each item type across all flights

| *Item Type \ Flight* | *F1A Speech rate: slow* | *F1B Speech rate: fast* | *F2A Information: low* | *F2B Information: high* | *F3A Workload: normal* | *F3B Workload: high* | *F4A No radio congestion* | *F4B High radio congestion* |
|---|---|---|---|---|---|---|---|---|
| Traffic | 31.25 | 18.75 | 46.88 | 32.77 | 36.67 | 44.12 | 18.75 | 28.24 |
| Altitude | 8.75 | 6.88 | 8.93 | 11.27 | 9.49 | 13.12 | 9.38 | 2.94 |
| Heading | 5.47 | 7.42 | 7.67 | 10.54 | 6.30 | 14.71 | 15.63 | 5.88 |
| Radio Freq. | 21.88 | 24.22 | 29.06 | 28.68 | 24.17 | 26.47 | N/A | N/A |
| Tx Code | 12.50 | 21.88 | N/A | N/A | 16.67 | 35.29 | N/A | N/A |
| OCTA | 6.25 | 25.00 | N/A | 52.94 | 0 | 0 | N/A | N/A |
| Call-sign | 25.00 | 21.09 | 24.31 | 29.71 | 19.22 | 24.22 | 15.34 | 13.90 |
| Location | N/A | N/A | N/A | N/A | N/A | N/A | 28.75 | 23.53 |
| ATIS | N/A | N/A | N/A | N/A | N/A | N/A | 56.25 | 47.06 |
| Approach | N/A | N/A | N/A | N/A | N/A | N/A | 0 | 0 |
| Land | N/A | N/A | N/A | N/A | N/A | N/A | 6.25 | 17.65 |
| Entry Point | N/A | N/A | N/A | N/A | N/A | N/A | 6.25 | 5.88 |
| Other | 0 | 0 | 0 | 0 | N/A | N/A | 0 | 0 |

The percentages of errors committed for each item type do not vary significantly across flight pairs (the A and B flights), nor indeed between the four flight pairs.[12] What is of interest is which item types give rise to errors and the relative frequency of these errors, as shown in Table 7.12.

As seen in Table 7.12, by far the most common error is the failure to respond to traffic information. This is of particular concern in a visual flight rules (VFR) environment, where the 'See and avoid' principle is assumed for all aircraft. Although the prevalence of this error in our data may be an artefact of the experimental setup, as pilots were probably not as concerned about the consequences of a mid-air collision as in a real flight, pilots are trained to respond 'Looking for traffic' when they are alerted by ATC to traffic in their vicinity and they have not yet seen the other aircraft. Even more of a concern was the high proportion of pilots answering 'Traffic sighted'. This was not counted as a communication error, since it is a possible reply. However, given there never were any other aircraft in the display, the concern is that this could be an automatic answer by pilots when they have not actually seen other traffic. This should be investigated further as there are serious implications for air safety.

The next common error for the pilots in our experiments was the failure to include the aircraft call-sign in their transmissions. Not giving the call-sign may be perceived as not very important by pilots but it is important for ATC, as it allows them to distinguish between aircraft. Interestingly, although a missing call-sign was a common error, in some cases it was the only items some pilots managed to read back correctly.

*Table 7.12* Item types ranked by percentage of errors across all flights

| *Item Type* | *% of errors* | *Comments and Examples* |
|---|---|---|
| Traffic | 32.18 | Failure to respond to traffic information |
| Call-sign | 21.60 | Omitting call-sign in readback or report. |
| Radio frequency | 19.31 | Not saying the frequency, giving wrong frequency. |
| ATIS | 12.91 | Failure to state received information. |
| Tx code | 10.79 | Not reading back the transponder code, giving the wrong code. |
| OCTA | 10.52 | Failure to read back instruction to remain outside controlled airspace |
| Heading | 9.20 | Not reading back the heading, giving the wrong heading. |
| Altitude | 8.84 | Not reading back the altitude, giving the wrong altitude; failure to report passing altitude. |
| Location | 6.53 | Not reading back the altitude, giving the wrong altitude; failure to report passing altitude. |
| Land | 2.99 | Failure to read back 'Cleared to land'. |
| Entry point | 1.52 | Failure to read back the entry point (e.g. 'Downwind 29R') |
| Approach | 0 | Failure to read back 'Cleared visual approach'. |
| Other | 0 | – |

## Implications of the findings

### *Cognitive implications*

From a cognitive perspective, an erroneous readback could be interpreted as confusion, distraction or even inattention, to name a few possible explanations. The type of error committed (omissions or mistakes) under the 'Information Density' and 'Workload' conditions show some of the effects of cognitive workload, brought on by multitasking and task difficulty. In light of the theories relating to attention, namely Broadbent's Bottleneck theory, which hypothesizes a biological restriction on the quantity of sensory information an individual can attend to (Broadbent, 1958), and Kahneman's capacity model, which hypothesizes a psychological restriction on the quantity of sensory information an individual can attend to (Kahneman, 1973), it would appear that the results from the present research support the latter theory. Moreover, it is clear that pilots can complete numerous tasks at once; however, when the cognitive resources required to complete these tasks exceed those available, performance degrades. In the present study, this point was brought on by increasing the information presented in the radio calls, as well as increasing the task difficulty, as seen with the results at the calls level (number of correct transmissions).

The results of the present study could also be interpreted from different theoretical perspectives, such as theories of memory and information processing. For example, Wickens (1984) proposes an Information Processing model in which all sensory information which is attended to undergoes cognitive operations (i.e. processing) in working memory. One prominent theory of working memory (often interchanged with short-term memory) is Baddeley's Multicomponent Model of Working Memory (Baddeley, 2000). According to Baddeley, working memory consists of an attentional controller, a central executive, a multidimensional temporary store, an episodic buffer and two subsidiary storage systems: a phonological loop and a visuo-spatial sketch pad. The components of interest to the present research are the central executive, the phonological loop and the visuo-spatial sketch pad. The central executive is said to control and coordinate the two subsidiary storage systems, as well as cognitive tasks such as mental arithmetic and problem solving. The phonological loop component deals with both spoken and written material (Baddeley and Hitch, 1974), and all information is converted, if needed, into speech form, while the visuo-spatial sketch pad maintains and manipulates visual and spatial information. Hence, it is in these three components where information is processed prior to being transferred to long-term memory. In relation to the present study, and based on Baddeley's model, it is assumed that tasks such as fuel calculation would be performed by the executive function of working memory. Similarly it is assumed that communication tasks would be performed by the phonological loop component of working memory. If this is the case, it would explain why increased workload in the workload flight, where pilots were asked to perform a fuel calculation, did not affect the type of communication errors, but did affect the frequency of those errors.

From an air safety point of view, the high number of incorrect transmissions in GA is a concern as it increases radio frequency congestion. If ATC must ask pilots to repeat their readbacks or reports (or part thereof), this results in an increased workload for ATC and potential distraction from other tasks. Due to the one-way nature of radio, during these repeated transmissions other calls cannot be transmitted on the same frequency. In the worst case scenario, this means a distress call might not be heard, leading to potential serious consequences. Another serious consequence is that not hearing the transmissions from another aircraft will reduce pilots' knowledge of other aircraft in the same airspace (commonly known as 'situation awareness', as discussed in Chapter 5). For the pilots having to repeat their calls, this is potentially a diversion or distraction from other tasks, such as flying the aircraft or navigating. It is widely known that distractions can, among other things, interfere with task flow, causing the operators to forget what they were doing or their position (Regan et al., 2011).

### *Flight training and language teaching*

There is a need to practice listening and speaking for both NES and EL2 pilots; indeed, all pilots need to practice these skills to higher standards than is currently required. Since our results show that the number of hours of flight experience is not as important in achieving communication accuracy as level of qualification, it seems the level of training regarding communication skills for GA pilots is not adequate. A similar criticism could be directed towards training institutions and governing bodies, which seem to assume that communication skills develop as a result of exposure. The results clearly highlight that this is not the case, and greater focus needs to be directed to rectify this deficiency if improvements in pilot communication are to be achieved. Hence, greater focus needs to be on the skills required for effective listening in order to prevent errors and to recognize and recover from the commission of an error.

We saw earlier that when communication was more difficult NES pilots with low qualifications (PPL or lower) made a higher proportion of mistakes than NES pilots with high qualifications (CPL or higher), whereas EL2 pilots with low qualifications made a smaller proportion of mistakes than the EL2 pilots with high qualifications, and we proposed to explain these results in terms of the different development of flying skills and aviation communication skills for NES and EL2 pilots. From a flight training perspective, this would suggest that NES pilots need to be taught to refrain from speaking too quickly until they have mastered both flying and aviation communication skills. On the other hand, when EL2 pilots have acquired greater aviation skills they need to be reminded to be more cautious and not to feel overconfident.

The condition that had the greatest negative impact on communication performance was increased information density (number of items) in ATC transmissions. This was particularly evident in the decreased accuracy with which pilots transmitted numbers. The implication for flight training is that student pilots should be encouraged to ask ATC to repeat long instructions. Too often, student pilots, especially EL2 ones, are too shy and pretend to have understood, only to remain silent or make mistakes. They should also be taught from the beginning of their training to write down numbers so they are able to read them back.

## Conclusion and further research

The project investigated the impact of four flight conditions on the communication accuracy of pilots with different language backgrounds (NES vs EL2) and with varying flight training levels. The results showed that:

1 increased ATC speech rate is particularly problematic for EL2 pilots with low pilot qualifications;
2 including four or more items in a radio transmission adversely affects communication accuracy and native language or pilot qualification cannot compensate for the increased level of difficulty;
3 increased pilot workload adversely affects communication performance and a native language background could not offset this effect; and
4 all pilots, including low qualification and EL2 pilots, are able to filter out irrelevant radio transmissions.

We found that the effect of information density (the number of items per ATC transmission) on communication accuracy is more pronounced than the effect of ATC speech rate (the speed at which a radio transmission is communicated) or of the pilot's workload (in-flight fuel recalculation). What remains unknown, however, is how these variables interact, for instance high workload and fast ATC speech rate or high workload and high information density.

We would also want to study the effect of context on those errors. For instance, in the case of numerical errors, we want to know whether there was a possible confusion between Heading (always given as a 3-digit group, e.g. '1 8 0' for '180°') and Radio Frequency (also given as separate digits, e.g. '1 2 4 5 5' for '124.55'), between the altitude to climb and the reporting level (given as spelt-out numbers, e.g. 'four thousand five hundred' for '4500 feet', or between QNH, radio frequency and transponder code: see examples (8) and (9) earlier). Another question is that of a possible serial effect regarding the order in which the information is given.

Finally, we want to know whether the communication error occurs in a readback, when the pilot must respond promptly to a call from ATC, or in a report, when the pilot has more time to plan what to say. We want to see whether the failure to read back a report request (not obligatory) leads to failure to make that report (obligatory). Future research should also investigate:

- how accent of both pilot and ATC affects miscommunication;
- the effect of different noise levels (e.g. 95 dB for general aviation vs 80 dB for commercial aviation); and
- the confusability of sounds in instructions (e.g. 'maintain' vs 'vacate') or in values (e.g. 'nine thousand' vs 'five thousand').

## Notes

1 For example, pilots from India who obtain their CPL in Australia may be required to take the ELP test again when applying for a position with an Indian airline.

2 Certainly, TV shows and children's stories are quite different in the US, the UK and Australia. Similarly not all NESs are able to understand, or function in, other accents or dialects, and someone from one of the US southern states may find it difficult to communicate with a Scot, an 'Aussie' or a 'Kiwi' (and probably would not even know that the terms 'Aussie' and 'Kiwi' refer to Australians and New-Zealanders).

3 http://www.bbc.co.uk/news/mobile/world-asia-china-15980197, retrieved 31 July 2014.

4 This research was the subject of a feature article on 'Aviation Communication' in *Flight Safety Australia* magazine published by CASA (Wilson, 2012).

5 A Balanced Latin square would have led to undesirable adjacency between the two flights in each pair, i.e. some pilots would have been asked to fly the 2 flights in a flight pair one after the other.

6 Flight 1A, Participant 12, 6 transmissions; Flight 1B, Participant 15, 16 transmissions; Flight 2A, Participant 12, 18 transmissions; Flight 3A, Participant 12, 17 transmissions and Participant 13, 17 transmissions; Flight 4A, Participant 12, 11 transmissions.

7 See Molesworth and Estival, (2015a) for a more detailed presentation of the statistical analysis at the call level, (Molesworth and Estival, 2015b) for the item level and the nature of error, and (Estival and Molesworth, 2015) for the category of error and locus of error.

8 It is of concern that there were a large number of omitted traffic readbacks in our data, and even more of a concern that there were a large number of 'Traffic sighted' reports when such sightings were patently impossible.

9 For flight pairing 1, the results for P12 were amended to reflect the percentage of recorded data over the total possible transmissions (6 transmissions not recorded in F1A) and P15 was removed from the analysis (no recording for F1A); hence, only 16 participants were considered for this analysis. In flight pairing 2, P12 was not included (no recording for F2A), leaving 16 participants for the analysis. In flight pairing 3, P12 and P13 were not included (no recording for F3A), leaving 15 participants for the analysis. In flight pairing 4, P12 was not included (no recording for F4A), leaving 16 participants for the analysis.

10 For all analyses, alpha was set at .025 (.05/2 Bonferroni adjusted) to control for family wise error, as a result of the repeated use of the data.
11 All the outliers were from the population under examination and, according to Tabachnick and Fidell (2013: 73), outliers should only be transformed if the outlier is 'not a member of the population'.
12 Except for 'OCTA', which did not occur in F2A.

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Chapter 8

# Conclusions and future research

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In this book, we have highlighted both the need for a common language, or lingua franca, for the specific purpose of air traffic controller–pilot communications, and the difficulties associated with achieving that goal. Our discussions have focused around not only the use of language itself in the aviation context, but on the broader context in which these communications take place, including policies and other contextual factors that relate to the effectiveness of communication in this high-stakes environment.

Error free communication in aviation remains elusive (Molesworth and Estival, 2015a, 2015b). It is also evident from the various examples provided throughout this book, and in other references to accidents in commercial aviation (Cushing, 1994), that miscommunication is not only an issue for general aviation (as shown by the data presented in Chapter 7), but a problem that is present in commercial aviation, including RPT, the mode of transport many readers would use regularly. The origins of miscommunication are too often attributed to pilots for whom English is not a native language (EL2 speakers). As illustrated throughout this book, and in particular in Chapter 7, pilots who are native English speakers commit, in some cases, as many communication errors as EL2 pilots. This demonstrates that Aviation English is a language variety which has to be learned and is not native to any one group. As the title of the book suggests, it is in fact a common working language between speakers with a variety of native languages (i.e. a lingua franca) for use in a specific domain, namely aviation. No doubt, native English speakers are at a distinct advantage when learning this specific language variety, because they already know a large part of the vocabulary, but this advantage does not guarantee error free performance.

Aviation English is more than just a compilation of words and phrases for specific purposes. As described in Chapter 2, it is a scientifically structured language variety, with words and phrases used to convey specific messages, and with specified pronunciation for minimum ambiguity or confusion. The standardization and simplification of Aviation English are the main defences against miscommunication, together with structured readbacks and rigid turn-taking in the interactions between pilots and ATC. Factors such as dialectal differences, unfamiliar accents or the use of colloquialisms all conspire to undermine the standardized nature of the aviation language and thus weaken the defences put in place against miscommunication. Nevertheless, as discussed in Chapter 3, a variety of accents and dialects are, of course, realities in the global aviation context and the aviation community continues to search for a balance between natural variation and the need for standardization in the interest of mutual comprehensibility.

Regarding the ICAO LPRs and the associated rating scales, we and a number of other researchers in the applied linguistics and language testing research communities have identified gaps or weaknesses in the current policy. Many of these are discussed in Chapters 3 and 4. While recognizing that ICAO and the professionals who assisted in the development of Document 9835 (ICAO, 2004, 2010) rose to a significant challenge in creating worldwide language proficiency requirements for aviation professionals, the ICAO LPRs and the associated rating scales should be regarded as a work-in-progress. There is still much work to be done in defining the construct of Aviation English. A number of discrepancies in the policy also remain unresolved. One such example that has been discussed at length in this book and elsewhere is the relationship between ICAO's intended role for native or expert-level speakers in the global aviation context versus ICAO's operationalization of that role in the policy. As discussed in Chapter 3, the current role of native or expert-level speakers in ensuring effective communication is, as outlined in the policy, ambiguous. Although ICAO clearly states that, in Aviation English interactions, native English speakers share the responsibility of ensuring effective communication through the use of what could be considered accommodation strategies (see ICAO, 2010: 5.3.3.2), the Level 6 descriptors of the rating scales do not require them to demonstrate such abilities, nor does the policy stipulate that native speakers be assessed in the context of a formal language proficiency test. Rather, in the case of native or expert-level speakers, the language proficiency of aviation personnel can be assessed in the course of their training, which will not necessarily include the accommodation or adaptation strategies ICAO describes. This is problematic since such skills are likely to be important for effective communication involving the use of Aviation English as a lingua franca. Furthermore, if such skills are considered important for effective communication, then the training and assessment of these skills should not be limited to expert-level speakers of English. Speakers at all levels of proficiency could benefit from such training and assessment (Farris and Turner, 2015).

While we do not claim that NES and EL2 learners will have the same training needs in relation to language and communication, we do argue that the end result of training should be that all speakers communicate effectively with each other, and demonstrate not only knowledge of the specific language and procedures associated with aviation communications, but also awareness of the challenges inherent in those communications. As discussed in Chapter 3, the ICAO policy provides some useful guidance material that is quite separate from, and sometimes in contradiction with, the rating scales included in the ICAO Standards and Recommended Practices (SARPs) (ICAO, 2010). As also highlighted in Chapter 3, ICAO member states are required to adhere to the SARPs, whereas the guidance material can be regarded as recommendations. We strongly recommend that training organisations and test service providers look beyond the requirements outlined in the criteria of the rating scales and use the guidance material of Document 9835 when designing training and testing materials in relation to the ICAO LPRs (Farris and Turner, 2015). There is evidence that this is already being done in aviation language testing. For example, based on information currently available, it appears that the ELPAC test for Level 6 discussed in Chapter 4 operationalizes the intended role for the expert-level speaker, requiring native or expert-level speakers to not only pass the same test taken by Levels 3–5 candidates, but also that they demonstrate proficiency in the following skills:

- understand and avoid idiomatic English;
- recognize and avoid ambiguity;
- use clear and concise English;
- negotiate meaning; and
- clarify potential misunderstandings.

Clearly, following ELPAC's example, it is possible under the current ICAO LPRs for training and test service providers to reconcile, at least to some extent, the contradictions inherent in the ICAO policies, in light of what we currently understand about language training and testing for language for specific purposes and English as a lingua franca. The aviation language training and testing communities need not wait for ICAO to take the lead, and the intended role for native or expert-level speakers can begin to be operationalized now. Of course minimum requirements outlined in the ICAO Standards and Recommended Practices (ICAO, 2010) must be adhered to, but, in the interest of ensuring effective communication involving the use of Aviation English, test service providers can move beyond these requirements and include native or expert-level speakers in their language training and assessment programmes. Furthermore, the accommodation or adaptation strategies that are recommended for native or expert-level speakers can be included in training and assessment for speakers of all levels.

In Chapter 4, we discussed the challenges associated with implementing the ICAO LPRs in relation to language testing. Aviation language training and testing existed long before the introduction of the ICAO LPRs; however, there has been an increase in the development and availability of training and assessment materials in response to the ICAO LPRs. As Knoch (2009), Alderson (2011) and Moder and Halleck (2009) have noted, a number of issues have been identified by users of the ICAO rating scales, indicating a possible need for revisions. If these or similar scales continue to be used, further development and validation may be required; however, as discussed by Farris and Turner (2015), beginning by revisiting the rating scales might not be the most effective response to the issues that have been identified. Rather, Farris and Turner recommend careful, evidence-based consideration of the assumptions that underlie the ICAO LPRs, such as the role of plain language in routine as well as non-routine communications, the relationship between standard phraseology and plain language, the role of the English language versus other languages, and the usefulness of the native versus non-native speaker distinction. As explained in Chapter 3, making changes to the ICAO LPRs, particularly elements of the LPRs that are included in the ICAO Standards and Recommended Practices (ICAO, 2010), such as the rating scales, is not a simple matter and would, if deemed necessary, take time to resolve. In the meantime, however, there is much that can be done within the operational community (including Aviation English language trainers and testers) to ameliorate the current situation.

The aviation communication and language testing research communities can continue to conduct research to support the further development of context-specific language training and assessment for pilots and air traffic controllers. As mentioned earlier, there is much work to be done in defining the construct of Aviation English for training and assessment purposes in relation to the ICAO LPRs. It is important to remember that the primary focus of the ICAO LPRs is on radiotelephonic interactions between air traffic controllers and pilots. Therefore, research conducted from a social interactionist perspective will be an important contribution to a more complete understanding of the nature of air traffic controller–pilot communications for language training and assessment purposes. It is somewhat ironic that Aviation English takes place in a highly constrained environment but over a vast geographical expanse (i.e. worldwide). Given the wide variety of contexts in which controller–pilot communications take place, and the wide variety of interlocutors involved in these communications, a large number of discourse studies is required in order to understand how Aviation English is actually being used (Farris and Turner, 2015). This is one area in which applied linguistics and language testing researchers worldwide can make a valuable contribution.

We extended our discussion of Aviation English to include factors that impact on communication in the operational context, as we consider the investigation of context-specific factors important to understanding the use of language for specific purposes. Aviation English was designed to ensure aviation safety through efficient communication, and safety is the primary factor in understanding aviation communication. As illustrated in Chapters 5, 6 and 7, contextual factors play an important role in determining performance, including communicative performance, in the operational environment. In Chapter 5 we discussed the impact of characteristics of air traffic controller messages and pilot cognitive workload on communication and performance accuracy.

The studies discussed in Chapter 5 show that it is possible to examine some questions that are relevant to the aviation context without access to pilots, air traffic controllers or high fidelity simulators, since a number of the challenges that are inherent in the air traffic controller–pilot communicative environment are inherent in communication in general. Air traffic controllers and pilots, as human operators, demonstrate social and cognitive abilities and constraints that are common to humans more generally, and the broader fields of applied linguistics and language testing – and language for specific purposes in particular – have much to offer in that regard. However, as with all good science, it is important to test (i.e. compare) the results of the studies without the target population or contextual factors (e.g. noise) to those of the target population prior to recommending any change. As mentioned in the preface to this book, Aviation English may be viewed through a variety of lenses, including language for specific purposes, and we recognize the need for a wide range of perspectives and methods in the investigation of this complex phenomenon. Therefore, we consider an interdisciplinary approach, such as the one we have attempted to achieve in our own collaborations, to be effective, and aviation human factors has been an important part of our work.

As illustrated in Chapter 6, factors such as noise and fatigue impact on both language understanding and production thus rendering the defences against miscommunication even more necessary in the operational environment. Molesworth et al. (2014) have repeatedly demonstrated that the background noise of a commercial aircraft is enough to adversely affect communication, with a more pronounced effect for non-native speakers. Performing the various tasks and duties required of pilots (i.e. aviating and navigating) also impacts on communication. As demonstrated in Chapter 7, increasing a pilot's workload is sufficient to impair communication accuracy, and neither being a native English speaker nor having a high level of pilot qualification is sufficient to obviate this impact. On the other hand, when presented with a task that is either very easy (the radio frequency congestion task) or very challenging (four or more items in each radio transmission) all pilots perform similarly, irrespective of language background. Chapter 7 also reinforces the importance of limiting message length for effective communication, where four or more items in a transmission were found to adversely affect communication performance, confirming the findings from Barshi (1997) and Barshi and Farris (2013). Together, these results suggest that the cognitive limitations of individuals play a leading role in communication performance. In Chapter 7, we applied Wickens' (1984) Information Processing model to describe the way sensory information is attended to and undergoes cognitive operations. In this model, all information attended to is processed cognitively in working memory. It is known that unattended information, including sounds such as irrelevant speech or aircraft engine noise, is processed in the same working space (see the original work on the 'cocktail party' effect: Cherry, 1953). Combined with the demands of the tasks being engaged in, a person's performance is further constrained by their working memory capacity and by their residual cognitive capacity. The importance of understanding how an individual processes information and the limitations of the processing system cannot be overstated for domains such as the aviation industry, where human performance has a direct impact on safety.

Regarding the guiding theme of this book – Aviation English as a lingua franca, and its use by both native and non-native speakers of English – from a cognitive perspective, it is known that noise affects non-native speakers more than native speakers. One hypothesis attempting to account for this effect of noise relates to the additional load noise places on working memory for processing sounds, whether these sounds are meaningful or not, in addition to the cognitively taxing exercise of (unconsciously) searching the memory stores for words and their meanings. This process might be more cognitively taxing for a non-native speaker, either under the assumption that lexical access is performed on all the listener's lexicons (Von Hapsburg and Peña, 2002), or the assumption that noise decreases the clarity of the phonemes and, as a result, listeners need to be more attentive (or concentrate harder) to overcome the noise effects (Tabri et al., 2011). Conversely, the effect of noise on speech perception may be the same for both native and non-native speakers, but the different level of experience with the language (e.g. size of the lexicon, understanding of word meanings and of word usage in different contexts) may make it easier for native speakers to accurately guess the words which are masked or distorted by the noise. As discussed in Chapter 6, performance differences in communication between native and non-native speakers may be the result of lateralization, where bilingualism built on one hemisphere is more susceptible to interference from noise, than bilingualism built on both hemispheres (Hull and Vaid, 2007).

Nevertheless, error-free or at least effective communication remains a goal that all aviation personnel strive to achieve. As demonstrated throughout this book, a number of challenges remain for the realization of this goal. These challenges can be characterized from a technological, operational or individual perspective, all of which warrant further research. From a technological perspective, we can include improvements in: radio transmitters and microphones; hearing/listening devices, e.g. speakers or headphones; airframe construction, including insulation of flight deck; aerodynamics of aerofoils to achieve less ambient noise; and engine and exhaust design for quieter engines. Datalink (controller–pilot datalink communication in civil aviation involves the transmitting and receiving of digital information, commonly presented in the form of text) is a good example of technology intended to obviate the problems of spoken language (Hooey et al., 2000), but it is not the final answer and cannot replace spoken language for several reasons. First, it takes longer to type than to speak, so datalink would not always be the optimal medium of communication, especially in an emergency situation where time is critical. Second, datalink is constrained, with predefined options for data entry, and therefore would not necessarily provide the options required in an emergency situation. Finally, as with all computer technologies, the quality of the output is reflective of the quality of the input: an error in input will result in an error in the output. Another type of technology which could be used to alleviate communication problems would be speech recognition and speech synthesis, both of which are already being investigated for training ATC and pilots in flight simulators.

From an operational perspective, factors which are known to impede effective communication, such as workload, time pressure and noise, need to be appropriately managed by the organisations. Under high workload, an individual is more likely to experience a reduction of residual cognitive resources, which can lead to a narrowing of attention and of the visual field, information shedding and reduced detection of stimuli including auditory information. Depending on the phase of flight, pilots experience various levels of workload. Therefore, future research should examine the impact of workload on miscommunication in different phases of flight in order to suggest better management of the working conditions by the organisations, especially regarding schedules and pressure to conduct operations.

From an individual perspective, challenges include improvements in language proficiency, adherence to the prescribed phraseology, and the ability to accommodate other speakers. Individuals also need to be mindful of some of the personal factors which contribute to miscommunication, such as fatigue, distractions and sleepiness. These are often related to the workload and time pressure constraints imposed by the organisations and require the individuals to take responsibility in managing them.

In addition, future research should also investigate the relationship between 'non-meaningful' noise (here defined as noise containing no discernible speech, although the engine sound does carry meaning for pilots, as stated in Chapter 6) and pilot performance. While the effect of meaningful noise, such as speech, on individual performance is well established for non-pilots, and the effect of non-meaningful noise (e.g. aircraft noise) on individual performance is also reasonably well understood for non-pilots, the effect of non-meaningful noise on pilot performance remains largely unknown. The little that is known (as discussed in Chapter 6) is limited to general aviation, and indicates that aircraft noise reflective of a Cessna 172 during cruise at 95 dB(A) is enough to adversely affect short-term memory as well as speech discrimination (Jang et al., 2014). For native English speakers, the use of active noise attenuation headphones is enough to counter noise effects, but, for non-native English speakers, these seem to be of minimal help. Experience within the aviation domain, including with aviation language, did prove beneficial in the presence of noise for non-native English speakers, suggesting that proficiency with Aviation English can offset some of the noise effect. Whether the levels of proficiency required to offset these effects coincide with the ELP levels set by ICAO (i.e. 4, 5 and 6) remains unknown and hence is an important area for future research.

Future research should also attempt to quantify the impact of accent on effective communication in aviation. It is widely believed that controller or pilot accent increases the likelihood of communication difficulties, at least as reported by pilots (Estival and Molesworth, 2012; EUROCONTROL, 2006); the extent to which misunderstandings due to accent actually occur during aviation communication remains unknown, however, nor has it been established whether the effect is more pronounced for non-native speakers.

The recurring theme of aviation safety throughout this book should not be interpreted as implying that aviation is not safe; it remains one of the safest, if not the safest, modes of transportation (Savage, 2012). Indeed, one of the reasons it is so safe is the systems approach to managing safety. Pilots form part of a system, in which they continually monitor and check each other, on the ground and while flying. When it comes to communication between pilots and ATC, pilots are supported by the specific aviation language, with its carefully constructed phraseology, specified pronunciation and turn-taking rules. They are also monitored by ATC, and by other pilots on the same frequency. This systems approach to safety provides multiple redundancies which, in the unlikely event of an error, capture the error and allow for correction, or at least minimize potential consequences from the error.

Language itself can be seen as a hazard, defined as potential to cause harm, just like weather, workload, fatigue and even maintenance. Language can be the cause of misunderstanding though ambiguities and potential confusions and, as shown in Chapter 2, when aviation personnel revert to conversational English, they breach the defences erected against miscommunication (e.g. carefully constructed phraseology), increasing the likelihood of miscommunication.

An interesting and somewhat unexpected finding from the experiments described in Chapter 7 was that pilot licence type seems to be a better predictor of correct aviation communication than exposure to Aviation English as measured by total flying hours. This result suggests that it is the quality of training as opposed to the quantity of exposure that yields performance improvement in aviation communication, and in Aviation English. At first glance, this result appears counterintuitive and runs counter to the advice provided by many flight training organisations, and maybe also against the received wisdom in the general public about language learning. More practice is not always the best way to achieve proficiency without quality of training. The implications of this finding cannot be understated, as still too many flight instructors and flight training organisations think student pilots will eventually become proficient by flying more and by practising their calls on their own. What remains unknown is whether improvements in aviation communication and Aviation English proficiency as a result of higher levels of licence qualification translate into greater resilience to known factors that affect miscommunication such as non-standard phraseology, accent, noise and fatigue. What appears more certain is that aviation would benefit from specific courses teaching Aviation English, an area which has so far not received enough attention, and then only in the commercial environment. Although Aviation English training is a highly developed field, with a number of Aviation English courses and training service providers, most NES pilots do not participate in any Aviation English course or even specific aviation communication training modules.

Aviation is often at the forefront of technological advancements. However, one constant in this rapidly changing industry is the need to communicate in a language common to all involved, including key personnel such as pilots and air traffic controllers; hence the vital role of Aviation English. Globally, more people speaking English are EL2 rather than NES speakers. Even in countries considered English-speaking, such as Australia, English is often a second language and it cannot be taken for granted that all aviation personnel are NES. In fact, the aviation industry involves people from all language backgrounds and understanding how people communicate effectively in such an environment as well as the factors leading to miscommunication is vital.

We finish by outlining a specific research project which we (Estival and Molesworth) hope to carry out in the near future. Building on the results of our previous study on general aviation, we will investigate miscommunication in commercial and general aviation by analysing live ATC recordings, using Molesworth and Estival's framework (Molesworth and Estival, 2015a, 2015b). This research will aim to uncover how key contributing factors impact on communication error, and the relationship between error and the English language proficiency levels mandated by ICAO for pilot qualification. The research will also aim to provide a detailed understanding of the linguistic properties responsible for miscommunication, the impact of English language proficiency on communication errors, the interplay between English language proficiency and contributing factors such as workload, phase of flight, controller accent. The results of this research should translate into improved knowledge to help determine how aviation communication should be taught and assessed in order to improve effective radio communication; they will provide a sound basis for suggestions for the language training of all pilots, whether NES or EL2 and for guidelines for ATC to recognize potential pilot difficulties. Such knowledge will suggest ways to mitigate miscommunication in aviation which can be applicable to other high stress situations requiring processing of information in a complex environment.

This book has explored various facets of the concept of Aviation English and the role of Aviation English in aviation communication. We have tried to untangle the notions of Aviation English as a lingua franca as distinct from ELF and of aviation language, too often confused with English itself. We showed that AE is a restricted variety of English designed and used for the specific purpose of communication in the aviation environment. Throughout this book we have emphasized that NES have a privileged position in that their knowledge of English is an advantage in learning AE, but that they are also sometimes at a disadvantage, not always recognizing the boundaries between English and Aviation English and their responsibility in ensuring intelligibility by all aviation personnel, NES and EL2. Aviation English, unlike other Englishes for specific purposes, has been designed – and is regularly modified – to ensure one goal: aviation safety through efficient communication.

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