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Article

Radio miscommunication: EL2 pilots in the Australian General Aviation environment

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Abstract

Communicating effectively via the radio in General Aviation (GA) is a challenging task for most pilots. This is even more challenging for non-native speakers of English (EL2) who are required to master not only a second language but 'Aviation English' to communicate with both Air Traffic Control (ATC) and other pilots. In two pilot studies conducted in Eastern Australia, we investigated the ability of GA pilots, both native and non-native speakers of English, to effectively communicate with ATC and with other pilots over the radio, in order to assess the contribution of native language to incidents of miscommunication and the impact it may have on air safety. The results revealed that indeed communication is difficult for EL2 pilots as well as for native pilots. Irrespective of native language, pilots found communicating with one another the most challenging task while communicating with ATC was found to be the least challenging. These results are discussed from an operational perspective.

KEYWORDS: AVIATION ENGLISH; RADIO COMMUNICATION

1. Introduction

Cushing (1994), in his wonderfully titled 'Fatal Words: Communication Clashes and Aircraft Crashes', analysed a number of examples of miscommunication in aviation. Although his work spurred the aviation industry into even more rigorous standardization of an already extremely highly coded

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and scripted form of communication, there still have been new examples of aviation accidents and incidents where (mis)communication is known to have been a factor, for instance the 'Brazil 2006' accident (Oliveira, 2007). Over the past decades a number of researchers have looked at particular aspects of aviation communication, from the work of Charlotte Linde (NASA, USA) on the 'Linguistic Analysis of Aviation Accidents' (Goguen and Linde, 1983; Linde, 1988) to that of Maurice Nevile (Australia) on 'communication in the cockpit' (Nevile, 2001, 2005, 2006, 2007, 2008; Nevile and Walker, 2005) or Paul Falzon on discourse management by ATC (Falzon, 2009). Our current research is directed towards investigating the underlying problems associated with radio communication for pilots whose first language is not English.

Communicating effectively via the radio in General Aviation (GA) is a challenging task for most pilots. This is even more challenging for non-native speakers of English who are required to master not only a second language but also 'Aviation English' to communicate with both Air Traffic Control (ATC) and other pilots. We conducted two pilot studies in Eastern Australia (around Sydney and Canberra) to explore the ability of GA pilots, both native and non-native speakers of English, to effectively communicate with ATC and with other pilots over the radio and the impact of miscommunication on air safety.

Our research has so far focused on linguistic factors affecting radio communication, such as comprehension, phraseology, intonation, speech irregularities and the use (or misuse) of pauses, with the aim of assessing the impact of communication difficulties upon air safety within GA. Other factors known to affect radio communication include: (a) quality of transmission; (b) noise in the cockpit; and (c) the operational expectations of both pilots and ATC. With regard to the quality of transmission between two aircraft, there is evidence to suggest that it negatively affects effective communication (Shimizu *et al*., 2002). The cockpit is a very noisy environment, especially in small GA aircraft, and the presence of noise makes it more difficult to understand speech, even with good headphones. This is known to be worse for EL2 speakers (Gat and Keith, 1978); Shimizu *et al.* (2002) also found that, as the signal to noise ratio increased (from white noise to aircraft noise), native Japanese speakers found it much harder to discriminate between different English phonemes, and according to Mayo *et al.* (1997) the difficulty in discriminating between English phonemes for EL2 speakers is off-set with years of exposure to English, but never reduces to that for native speakers (NS). At the same time, operational expectations play an important role for both pilots and ATC: 'we hear what we expect to hear' (Cushing, 1994; Hutchins and Klausen, 1996), irrespective of native language.

It is well-known that all these factors contribute to miscommunication. However, as evidenced by some of the answers to the two studies presented here, as well as by frequently heard casual remarks, there is a widely held view

in the Australian aviation community that EL2 pilots are a threat to GA safety in Australia. The present research was directed at assessing the contribution of native language to incidents of miscommunication and the impact it may have on safety, in order to identify areas where training of pilots and ATC might be improved for communication with EL2 pilots.[1]

This paper has two main parts: in the first part, we give a general overview of the importance of communication and the potentially dramatic consequences of miscommunication in the aviation environment (Section 1), and then we present the specific linguistic aspects of miscommunication in aviation (Section 2), drawing on the work of Cushing (1994) and others, with additional examples from Australian GA which point to the issues faced by aviation training organizations with EL2 pilots in an English-speaking environment. The second part (Section 3) reports on the first results of the two pilot studies conducted in Eastern Australia. In the first study (Estival and Molesworth, 2009), 36 pilots of varying flight experience and from nine different language backgrounds completed an anonymous questionnaire regarding their experience with radio communication. In the second study, a revised version of that questionnaire was completed by 83 pilots from 11 language backgrounds and with a wider range of flight experience. This paper presents the new results of the second study and draws conclusions from the analysis of both studies. Although participants' numbers are small, they provide evidence that the most difficult communication task for pilots is understanding other pilots, irrespective of native language and level of flight experience. This has implications for GA pilot training, both NS and EL2. The answers we collected also confirm that the use of non-standard phraseology, especially in unexpected circumstances, caused communication difficulties between ATC and pilots and reinforce the need for more rigorous training in that area. In the Conclusion (Section 4), we outline the next steps of the project and propose some solutions.

2. Real life (and death) importance of communication

In the review prepared for the International Civil Aviation Organization (ICAO), Matthews (2004) reported that 'Between 1976 and 2000, more than 1,100 passengers and crew lost their lives in accidents in which investigators determined that language had played a contributory role'.

More specifically, Alderson and Horák (2009) stated that:

> In three accidents alone, 1,006 people died at least in part because of language that gave rise to communication problems.
>
> In 1996, a Kazakhstan Airline aeroplane collided mid-air with a Saudi Arabian Boeing 747 over New Delhi in India, killing 351 people. The air traffic controller was Indian and the pilots were Saudi and Russian.

In 1990, Avianca Flight 052 crashed en route from Bogota Colombia to JFK New York after the crew failed to communicate clearly to air traffic control that their aircraft was running out of fuel. The air traffic controller also failed to clarify the situation on board the aircraft.

In 1977, almost 600 people died at Tenerife airport when a KLM Boeing 747 collided with another plane on take-off during foggy conditions. There was a misunderstanding of the phrase 'at take-off', and the failure of the senior Dutch pilot of the KLM to recognise that messages between the English-speaking pilot of the other aircraft and the Spanish air traffic controller indicated that the runway was not yet clear.

The Teneriffe accident of 1977 involved a runway collision between a Pan Am Boeing 747 and a KLM Boeing 747, at Tenerife in the Canary Islands, with the loss of 583 lives. Although there were a number of contributing factors which have been extensively studied and described, a breakdown in normal communication procedures and the misinterpretation of verbal messages are considered to have been primary contributing factors. This is also one accident where the use of EL2 is considered to have played a crucial part, with the Air Traffic Controller a native speaker of Spanish, a Dutch crew for the KLM aircraft and a US crew for Pan Am. The relevant parts of the transcript for the final exchange are given in (1) (Cushing, 1994: 9–10).

(1) Tenerife, 27 March 1977

(a) Tower: KLM eight seven zero five, you are cleared to the Papa Beacon, climb to and maintain flight level nine zero, right turn after take-off...

(b) KLM 4805: Ah - roger sir, we are cleared to the Papa Beacon, flight level nine zero... We are now at take-off.

(c) Tower: OK, stand by for take-off. I will call you.

While there were other complications and sources of confusion in this accident (including the presence of fog and simultaneous radio calls causing interference), from a linguistic point of view, the two instances of miscommunications to note in particular are the phrases *cleared* and *at take-off*. The KLM pilot interpreted the initial clearance (*cleared to the Papa beacon*) as a clearance to take off, while it was meant as a clearance for actions after take-off. The KLM pilots then used *at take-off* to mean 'taking off' as in (2a), in a literal translation of the Dutch syntax. The Controller knew English, but not Dutch, and did not recognize the potential ambiguity in this non-standard phrase which he interpreted as the standard 'at take-off point', as in (2b).

(2) *at take-off*:

(a) We are already on the take-off roll / taking off.

(b) We are waiting at the take-off point.

Of course, the KLM pilot not only used non-standard phraseology but also should have waited for the clearance to take-off. Unfortunately, the Controller replied *OK*, also non-standard phraseology; this was meant as an acknowledgement but could be taken by the pilots as confirming the clearance they thought they had. The KLM captain was in a hurry and took off without a clearance, colliding with the other Boeing 747, Pan American PAA1736, still on the runway.

In another incident, also analysed by Cushing (1994: 11), the problem was due to the different interpretations of one single word. In this case, all the participants were native speakers of English but, as shown in the transcript given in (3), not only was there confusion between similar call signs (Air Cal 336 and Air Cal 931), but also confusion created by two distinct uses of the verb *hold*.

(3) California, 17 February 1981 --

(a) Tower: Air Cal three thirty six, you're cleared to land.

(b) Tower: Air Cal nine thirty one, let's do it taxi into position and hold, be ready.
.....(another aircraft approaches)

(c) Tower: OK, Air Cal three thirty six, go around three thirty six, go around.

(d) AC 336 Captain to copilot: Can we hold, ask him if we can – hold.

(e) Tower: Air Cal nine thirty one, if you just go ahead and hold.

(f) AC 336: Can we land Tower?

The Tower consistently used *hold* in its Aviation English meaning *stop what you're doing* when talking to AC 931 in (3b) and (3e), while in the cockpit of AC 336, the Captain used the plain English meaning of *continue what you're doing* in (3d) (Cushing, 1994: 11). The Tower contributed to the confusion by using plain English *if you just go ahead*. In the confusion that ensued, AC 336 tried to abort landing, but this was too late and the aircraft landed with its landing gear up, causing 34 injuries.

(4) *hold*:
  (a) *continue what you're doing* (plain English)
  (b) *stop what you're doing* (aviation English)

Although the Teneriffe accident led to more standardization of ATC/pilot communication and to increased English Language Proficiency (ELP) training for EL2 pilots, this example shows that standardizing phraseology for communication between pilots and ATC is only one step towards removing ambiguity and confusion: it would also have been necessary to prevent the pilots from communicating in the cockpit using conversational language during operations. This is in fact mandated for international commercial aviation, but it is more difficult to impose this linguistic discipline in the GA cockpit than to impose the use of fixed phraseology for talking to ATC.

While the two examples given above took place in commercial aviation and had serious consequences, misunderstandings also often occur in GA. They may be minor, only causing embarrassment, as in example (5), where the early solo pilot of the Cessna 152, in the circuit at Bankstown Airport, confused *Cherokee* (another very common light training aircraft) with *turkey* and was probably very red in the face when he landed, but where no other damage was done.

(5) General Aviation: Bankstown Airport, Sydney

(a) JNB: Bankstown Tower. Juliet November Bravo, 2RN inbound with alpha.

(b) Tower: Juliet November Bravo. Bankstown Tower. Follow a Cherokee turning downwind.

(c) JNB: Looking for traffic. Juliet November Bravo. Unable to locate the turkey.

(d) Tower: silence.
Juliet November Bravo. Preceding traffic is in your 2 o'clock and it is a white and blue CHE-RO-KEE. Report sighted.

(e) JNB: Traffic sighted. Sighted Cherokee.

Nevertheless, communication problems can also be also quite serious for GA, in particular in Australia where training of overseas pilots is a large industry and where there are many student pilots whose native language is not English. In its Review of 2009, the Australian Civil Aviation Safety Authority (CASA) noted as a particular problem:

> *Students with English as a second language struggle with radio calls – particularly if they are flying solo.*
> (CASA Airspace Review of Bathurst Aerodrome, March 2009, p. 19)

As a more specific example, in 2010, a Malay student training at Bankstown Airport had passed the English Language Proficiency test mandated by CASA since March 2008, but the Control Tower nevertheless refused to let him fly solo in the circuit. The reason they gave was that ATC were 'unable to understand the student' and that the student was 'unable to respond'.[2] In this case, the consequences are more personal but still quite devastating for the flying career of the student.

3. Miscommunication from a linguistic perspective

We define miscommunication as a mismatch between the message intended by the speaker and the message processed by the hearer, whether it is the result of errors in understanding or errors in production. Looking more closely at what can go wrong in aviation communication from a linguistic perspective, it is important to first note that miscommunication can occur at all levels of linguistic analysis and representation. We find examples all the way from the speech signal and phonology to lexical and syntactic choices, as well as from the interaction of prosody with syntax and semantics (examples (6) to (14) below are from (Cushing, 1994)).

3.1. Miscommunication at different linguistic levels

Phonology and pronunciation

At the level of phonology, in example (6) two Air Traffic Controllers were talking to each other about the clearance to give an aircraft: (6a) is what one controller said, while (6b) is what the other controller understood.

(6) ATC to another ATC
  (a) I'll let you know.
  (b) Let him go.

In (7), during landing, the instructor said (7a) but the student understood (7b), resulting in a poor landing.

(7) Instructor to student
  (a) Last of the power. (i.e. reduce power)
  (b) Blast of power. (i.e. increase power)

In (8), the pilot requested clearance to cross a runway. ATC replied (8a), meaning *Don't* and the pilot understood (8b), i.e. *You can*.

(8) Pilot to AC: May we cross?
  (a) ATC: Hold short. (i.e. Don't)
  (b) Oh sure. (i.e. You can)

In (9), the confusion between *west* and *left* meant two different sides of the Tower.

(9) ATC to pilot
  (a) Pass to the left of the tower.
  (b) Pass to the west of the tower.

Syntax and lexicon

At the levels of syntax and the lexicon, the examples in (10) and (11) are both due to the homophony between the words *two* and *to*, resulting in very different interpretations for the altitude to be held by the pilot.

(10) (a) ATC: Descend two four zero zero. (i.e. 2,400 ft)
  (b) pilot: OK. four zero zero. (i.e. 400 ft)

(11) (a) ATC: Climb to five zero. (i.e. 5,000 ft)
  (b) pilot: Climb two five zero. (i.e. 25,000 ft)

In (12a), the pilot in command repeated what he thought he had heard, but was then corrected in (12b) by the co-pilot, who had correctly understood the clearance given by ATC.

(12) (a) PIC to P2: Cleared to seven. (i.e. descend to 7,000 ft)
  (b) P2 to PIC: Negative, cleared 27. (i.e. permission to land on runway 27)

Prosody and intonation

Prosody and especially pauses, or the lack of pauses, between phrases can affect syntax and meaning quite drastically, as in example (13), where (13a) is an instruction to descend due to conflicting traffic, while (13b) is only passing a piece of information not requiring any action from the pilot (except an acknowledgement).

(13) ATC to pilot
  (a) Traffic, level at 6,000. (i.e. descend to 6,000 ft)
  (b) Traffic level at 6,000. (i.e. you've got another aircraft at 6,000 ft)

Example (14) is similar to (7) in that the result was that the student increased power and mishandled the landing, but this time it is due to the lack of pause in (14a), causing the interpretation of (14b).

(14) Instructor to student
  (a) Back – on the power. (i.e. reduce power)
  (b) Back on the power. (i.e. increase power)

Finally, at the level of pragmatics, in the case of the Avianca Airlines 1991 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.

3.2. Non-standard terminology and unexpected interpretations

The most important linguistic factor for aviation communication is the choice of lexical items or phrases. This has long been standardized – 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. Australian pilot training organizations with overseas students have also long been aware of the problems caused not only by accents or dialectal differences, for instance between Australian English and Indian English, but also by the conversational use or interpretation of aviation terminology.

Although Australian ATC are trained to understand foreign pilots and may not suffer in their passive use of language, they may still sometimes use the colloquial meaning of terms in their language production, thus causing problems for EL2 pilots. McMillan, an ATC instructor, gave a telling example of such a misuse (McMillan, 2009, p.c.).

> 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 [Aeronautical Information Publication], 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 […] 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.

In this example, ATC used *confirm* as in (15b) rather than (15a), but the foreign pilot could not understand the colloquial usage nor interpret the utterance given the context. For the Thai pilot, as per the standard phraseology, *confirm* acts as a question, and there was no possible question at that point in the exchange.

(15) *confirm*:
(a) *to query something* (standard Aviation English)
(b) *to correct an incorrect readback* (informal use, plain English)

Many reported cases of non-standard terminology involve the use of local or colloquial names for locations. Example (16) was heard by the first author in the circuit at Bankstown Airport: ATC knew the pilot of aircraft ABC, 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.

(16)
(a) ABC: Request clearance.
(b) Tower: Alpha Bravo Charlie. Cleared for the Smoke.

Native speakers of English and local pilots may understand that *The Smoke* refers to the city of Sydney but a foreign student pilot probably would not and thus would lose the required situation awareness regarding other traffic. The problem here is that, even when a message is not addressed directly to other pilots, ATC communications must be understandable by other pilots who may need the information (Illman, 1998, p. 27).

ATC, however, may not always be understood by trainee pilots, even when they follow standard terminology. In our second pilot study (see Section 3), both NS and EL2 pilots contributed a number of examples where the use of standard terminology, when it is different from casual usage, can cause problems. In (17), the phrase *go to Tower* should have been interpreted as meaning *change to the Tower frequency*, not in the literal sense, while in (18), the term *diverge* should have been interpreted as meaning *take a different heading* (usually to avoid an obstacle or another aircraft).

(17) NS Pilot:
On Ground Frequency in the run up bay for circuits (3rd solo) tower told me go to tower and I did not understand. [] I thought ATC was saying taxi.

(18) EL2 Pilot:
The ATC told me to diverge left and I was under the understanding that this meant to turn left.

Such communication problems are not limited to GA pilots; military pilots, who are highly trained, can also experience them. Example (19) was provided by a military ATC who was working on a joint exercise with NZ and French forces.[3] In this example, the French liaison used a direct translation from the French *6 heures*, instead of the standard 'clock code' of English.

(19) 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*.

3.3. Constraining the language – NS and EL2

So, what can be done? Since the beginnings of radio communication, three approaches have been taken to prevent potential miscommunication:

- **Simplification**: making each transmission as short and succinct as possible.
- **Standardization**: prescribing the use of specific phraseology, the sequences of information in each transmission, and the sequences of transmissions in an exchange.
- **Safeguards**: requiring readbacks to acknowledge pilots' understanding of ATC's transmissions.

Together, simplification of transmissions, standardization of phraseology and safeguards such as required readbacks can be claimed to have achieved substantial success in most aviation communication situations. Nevertheless, in a number of aviation accident cases, miscommunication is known to be due in part to EL2, for instance in 'Avianca 1990' (Helmreich, 1994), 'Teneriffe 1977' (Cushing, 1994) and more recently 'Brazil 2006' (Oliveira, 2007), and proficiency in English has been identified as an important part of international aviation safety (MacBurnie, 2004). In response, the ICAO has mandated that all new pilots and ATC personnel pass an English Language Proficiency (ELP) test prior to obtaining their qualifications. This rule came into effect in Australia on 5 March 2008 and can be expected to help improve communication by EL2 pilots.

Nevertheless, although improving ELP for EL2 pilots is definitely an aim for achieving air safety, the ELP test is not sufficient. The example of the Malay student who could not be understood by ATC in spite of having passed the ELP test (see Section 1 above) shows that the test in itself is no guarantee of successful communication in the real environment. This is an issue for flight training organizations and for Aviation English trainers.

A second issue is that imposing certain levels of ELP on EL2 pilots cannot be sufficient, since the use of spontaneous English by NS is also known to contribute to miscommunication. This is due in part to their higher use of

informal language, which may also contain non-standard phraseology. For instance, Mell (2006) reported on a study in which the recording of the radio transmissions of a British pilot who got lost in the French airspace and used non-standard spontaneous English, given on (20), could not be adequately understood by French trainee air traffic controllers.

(20) I've got an emergency. Short on fuel- and I'm steering to the beacon on 112.3, and I've been told to tune on to the IFR to get me into an airfield. I have less than 15 minutes fuel supply sir.

The point here is that the British pilot would score high on the ELP test but this does not ensure effective communication. Not only are some of the lexical items used in (20) not standard, but the whole message is in colloquial English. Indeed, Drury and Ma (2002: 8) found that 'native English speakers should be taught how to communicate simply, slowly and precisely with their non-native English speaking colleagues'. Example (3) above also showed than it would be advantageous to prevent NS pilots from using spontaneous colloquial language, even in wholly English-speaking environment. However, a recent study by EUROCONTROL noted that this might be more difficult than to force EL2 pilots to learn standardized phraseology and one of the recommendations is 'Be aware that you tend to be less vigilant when speaking in your native language' (Isaac, 2007: 34).

In fact, the problem is even more complex. Flight training organizations usually focus on training EL2 pilots to use Standard English, adding aviation specific phraseology and jargon, but R/T training is done in the cockpit. Although teaching standard conversational English includes using pauses in appropriate places, as well as intonation to emphasize important or relevant information, it is well-documented that these non-lexical features are not used by ATC in the way they are in normal conversation. Indeed, the lack of intonation, rhythm and pauses which are typical of rapid radio communication in the aviation environment are known to be particularly problematic since no visual cues are present (McMillan, 1998; Prinzo, 2008; Nevile, 2008). This is particularly a problem at busy GA training airports where a high number of EL2 pilots are learning to fly at the same time they are learning R/T. On the other hand, teaching R/T on its own will not provide EL2 pilots with the ability to handle unexpected messages, especially in difficult situations.

We hypothesized that instances of EL2-related miscommunication would also be attributable to comprehension difficulties caused by both ATC (mostly NS of English in Australia) and pilots (both NS and EL2), rather than simply to production difficulties of EL2 pilots (i.e. their being unable to express themselves clearly). As described below, what we found was that problems

are mostly due to lack of adherence to phraseology by ATC, and their rapid prosody when using standard phraseology, both making understanding by pilots difficult, as well as to the extra layer of difficulty caused by the accent and pronunciation of some EL2 pilots, causing difficulties for both ATC and other pilots.

4. Pilot studies in Australian General Aviation

4.1. Goals and method

The research project in which these pilot studies were conducted aims at investigating communication challenges in GA. The original aim was to investigate potential miscommunication between Air Traffic Control (ATC) and pilots (both NS and EL2), e.g. pilots misunderstanding a clearance given to another aircraft as being meant for them. The ultimate goal is to alleviate ATC-pilot communication difficulties by making both ATC and EL2 pilots aware of potential communication problems, e.g. intonation, rhythm and pauses, which are particularly problematic for radio communication but not adequately addressed in the ELP test.[4]

To help determine the extent of the problem and assess the impact of EL2 on communication in Australian GA before proposing any solutions, we conducted two pilot studies in Eastern Australia. The approach taken here is to gather evidence of possible 'safety threat events' where the pilots recognized that communication had been a problem and to ask what aspects of communication contributed to that problem. The advantage of this approach is that it allows us to identify where problems are known by pilots to occur, without recording, transcribing and analysing many hours of ATC-Pilot communication to identify errors. It also allows us to have access to 'safety threat events' which would not necessarily be evident in recorded data, i.e. where the pilots may know they made a mistake but do not verbalize it. In addition, communication errors involving misunderstanding are by definition internal to the individual and are not necessarily accessible through recorded data, e.g. the pilots may know they misunderstood a message but do not ask ATC to repeat it.

The pilot studies we conducted allowed us to identify what communication challenges pilots have experienced and what they consider to be the impact on aviation safety. The method we used was an anonymous paper-based survey distributed at flight training organizations. This survey was specifically designed to elicit self-reports of radio communication problems and was not intended to assess the pilots' level of English proficiency. Indeed, we were careful not to make student pilots think they were being assessed and we stressed that results and answers would not be

communicated to their flying schools. We collected questionnaires from both NS and EL2 pilots in order to compare the experience of these different groups.

The questionnaire used in both studies (see Appendix A for the final version used in the second study) consisted of six groups of questions. The first two elicited background information about the pilots' native language and amount of English experience and about their level of flight training and flight experience. The other questions asked the pilots about their experience with radio communication, both with other pilots and with ATC. The pilots were also asked to rank in order of difficulty five radio communication tasks: *Remembering what you have to say; Saying what you have to say; Understanding ATC; Understanding other pilots; Reading back*. Finally, they were encouraged to give examples of situations where 'a problem with radio communication (other than radio malfunction or failure) resulted in an incident or a potential incident' in order to elicit reports of instances which might never have been reported to the authorities and listed as a safety concern.

Following the analysis of the results of the first survey and the conclusions presented in (Estival and Molesworth, 2009), the questionnaire was revised as described in Section 3.2 and distributed more widely at flying organizations in New South Wales (NSW) and the Australian Capital Territory (ACT).[5]

4.2. First Pilot Study

As reported in (Estival and Molesworth, 2009), in the first study, 36 General Aviation pilots with a mean flight experience of 342 hrs (Range: 15–2,800) completed the questionnaire distributed at several flying organizations at Bankstown Airport (NSW, Australia). Table 1 shows that there was a range of flying experience represented, with a large proportion of student pilots: 13 pilots had passed the General Flying Progress Test (GFPT) or were at the Pre-solo and Solo stages of training;[6] 12 pilots held a Private Pilot Licence (PPL) and 11 pilots held a Commercial Pilot Licence (CPL).

Table 1: Respondents in the First Pilot Study (Questions 1 and 2)

Training Level	# of Participants	Mean Flight Hours	EL2
Pre-Solo	2	15*	2
Solo	5	48*	4
GFPT	5	53	2
PPL	12	222*	3
CPL	11	701*	1
Total	35* (out of 36)	342*	12*

(* indicates that some respondents did not answer the question)

The respondents came from nine language backgrounds, with 23 English Native Speakers (NS) from two varieties of English: *Australian English* (22) and *British English* (1). There were 13 non-native speakers of English (EL2): *Tamil* (4), *Cantonese* (3), *Malaysian* (2), *Malayalam* (1), *Telugu* (1), *Urdu* (1) and *Korean* (1).

Table 2 presents the responses to the two questions asking pilots about their experience of communication difficulties.

Table 2: Responses to the questionnaire in the first Pilot Study

Question: *Have you ever been in a situation where you did not fully understand what ATC was telling you?*	
21 pilots answered 'Yes': 14/23 NS (60%); 7/13 EL2 (54%) 15 pilots answered 'No': 9/23 NS (40%); 6/13 EL2 (46%) (20 Pilots asked ATC to repeat, and 1 had their instructor explain)	
Message content:	
Clearance	(4)
Runway direction	(4)
Aircraft call sign	(1)
Navigation	(1)
Breach of control airspace	(1)
Radio interference	(1)
Question: *Have you ever been in a situation where ATC asked you to repeat what you said?*	
26 pilots answered 'Yes': 17/23 NS (74%); 9/13 EL2 (69%) 10 pilots answered 'No': 6/23 NS (26%); 4/13 EL2 (31%) (25 pilots were understood the 2nd time)	
Message content:	
Aircraft call sign	(10)
Clearance information	(7)
Upwind	(1)
Flight information	(1)

As we would expect from the point of view of the theory of communication (Shannon, 1948), cases of ATC not understanding pilots and of pilots not understanding ATC occur when the message is less predictable from the context: this is the well-known factor of 'Hearing what you expect to hear'. For ATC, these messages are aircraft call signs, which ATC cannot anticipate, and unusual or unexpected clearance requests from pilots, either on departure or arrival. For pilots, unexpected messages from ATC are clearances, instructions, information about runway direction changes, and (presumably unanticipated) information about having breached controlled airspace or about conflicting traffic.

The most unexpected result from the first pilot study came from the answers to the question asking pilots to rank the five communication tasks in order of difficulty. As shown in Table 3, *communicating with ATC was judged the least difficult task.*

Table 3: Ranking of radio communication tasks in the First Pilot Study

Understanding other pilots	(Mdn = 1.97, Range 3)
Remembering what you have to say	(Mdn = 2.57, Range 4)
Reading back	(Mdn = 3.14, Range 4)
Saying what you have to say	(Mdn = 3.62, Range 4)
Understanding ATC	(Mdn = 3.71, Range 4)

In order to determine if the differences observed with task difficulty could be explained by native language, a one-way analysis of variance (ANOVA) was employed. Since the data violated the assumptions underpinning parametric tests (i.e., homogeneity of variance), a Kruskal-Wallis non-parametric test was used. With alpha set at 0.05 the results failed to reveal any statistical significant differences, $X^2\,(5, 21) = 3.77$, $p = 0.58$. *This result suggests that native language was not an influencing factor in what pilots found difficult with radio communication.*

In order to determine if the differences observed with task difficulty could be explained by pilot qualifications (level of training), a Kruskal-Wallis non-parametric test was employed. Consistent with the previous analysis, a one-way ANOVA alternate (Kruskal-Wallis test) was employed since the data violated the assumptions underpinning parametric tests. With alpha set at 0.05 the results failed to reveal any statistical significant differences, $X^2\,(3, 20) = 5.77$, $p = 0.12$. *This result suggests that flight qualification had no impact on which radio communication task pilots found most difficult.*

Finally, only three pilots responded in the free text part of the survey, provided to suggest other areas of difficulty with radio communication. These three answers are given in full in (21); it is worth noting that all three are from NS pilots and that they all blame communication problems on EL2 pilots, with Pilot #36 only bothering to express his comment with one derogatory phrase.[7]

(21)
(a) #1: pilots whose first language is not English
(b) #20: it's very hard when pilot is mumbling/broken English
(c) #36: Bloody Indians

Even though the use of English as a second language may contribute to communication difficulties in GA, there was limited evidence from the data, apart from the free text responses given above, to suggest that EL2 pilots are

the primary source of communication problems in GA: both native English speaking pilots and EL2 pilots find it difficult to understand other pilots and both experience the same problems communicating with ATC.

Thus the first pilot study gave us precious information about the actual communication challenges faced by GA pilots and led to an unexpected result. However, there were a number of shortcomings to this first study, most importantly the small sample size. Therefore, we conducted a second survey with a more substantial sample base, expanding participant numbers from all demographics, i.e., NS pilots and EL2 pilots from a variety of language backgrounds, as well as more pilots with different levels of training. We also expanded the distribution of the survey to tertiary education institutions in addition to flight training organizations. As with the first survey, in order to protect potentially sensitive information, we ensured a strict anonymity protocol.

Second, even though the study was anonymous, pilots may have been reluctant to report difficulties in flight which could have led to an incident or a potential incident: 15 out of 36 pilots said they never had to ask ATC to repeat a message, while 10 out of 36 denied having been asked by ATC to repeat a message. It is extremely unlikely that so many pilots never had either of these experiences, if only being asked to repeat their call sign. Any pilot knows that this is a frequent occurrence and not in itself a cause for concern. Thus we modified the way these questions were asked, so that the emphasis is not on *whether* such incidents occur, but *when* they do occur.

Third, the first study did not provide any frequency information, so the second questionnaire was designed towards investigating the frequency of communication problems in order to prioritize the approach to mitigate such occurrences.

Finally, we also modified the phrasing and layout of the questions to elicit more precise information about the details and factors surrounding communication problems. For instance, whereas the first questionnaire simply gave as a choice of flight stages: *Circuit*, *Departure*, *Approach*, or *Nav*[*igation*], with a possible ambiguity between 'Approach to land' and 'Approaching an airfield or a terminal area', i.e. during a navigation flight, the second questionnaire clearly distinguishes between the stages of a circuit and those of a navigation flight.

4.3. Second Pilot Study

We revised the questionnaire as described above and conducted a second pilot study, this time distributing the surveys more widely through NSW and the ACT. Eighty-three general aviation pilots completed the survey. The total flight experience of the pilots ranged from two flight hours to 13,000 hours (mean 700 hours). Table 4 shows that there was a wider range of experience than in the first study (see Table 1): 34 pilots held a Student Pilot Licence (SPL), 23

pilots held a General Flying Progress Test licence (GFPT), eight held a Private Pilot Licence (PPL), 13 held a Commercial Pilot Licence (CPL) and three held an Air Transport Pilot Licence (ATPL).

Table 4: Respondents in the Second Pilot Study

Training Level	# of Participants	Mean Flight Hours	EL2
SPL	34	26	3
GFPT	23	59	4
PPL	8	312	1
CPL	13	3,011	3
ATPL	3	4,500	0
Total	81* (out of 83)	700*	11

(* indicates that some respondents did not answer the question)

Eleven language backgrounds were represented, with the vast majority (71) of pilots reporting *Australian English* as their first language. There was a different distribution of languages for the EL2 pilots: *Korean* (2), *Cantonese* (1), *Malayalam* (1), *Telugu* (1), *Mandarin* (1), *Polish* (1), *German* (1), *Hindi* (1), *Vietnamese* (1) and *Marathi* (1). On average, they reported having spoken English for 13.5 years (range 1–24).

Table 5 presents the answers to the two questions asking pilots about their experience of communication difficulties (compare with Table 2 in Section 3.2). An interesting result is the fact that 82% of the EL2 pilots said they had at least once not fully understood ATC (as opposed to 64% of NS pilots), and that 45% of EL2 pilots admitted having been asked to repeat by ATC (as opposed to 17% of NS pilots).

Table 5: Responses to the questionnaire in the Second Pilot Study

Question 6: *Have you ever been in a situation where you did not fully understand what ATC was telling you?*	
46 pilots answered 'Yes': 37/72 NS (51%); 9/11 EL2 (82%)* 31 pilots answered 'No': 29/72 NS (40%); 2/11 EL2 (18%)*	
Stage of Flight	
Navigation	(15)
Circuits	(13)
Departure	(7)
Approach	(1)
Taxiing	(1)
Training area	(1)

Question 7: *Have you ever been in a situation where ATC asked you to repeat what you said?*	
17 pilots answered 'Yes': 12/72 NS (17%); 5/11 EL2 (45%)*	
64 pilots answered 'No': 57/72 NS (79%); 6/11 EL2 (55%)*	
Stage of Flight	
Circuits	(5)
Navigation	(4)
Departure	(2)
Approach	(2)
Other	(1)

(* indicates that some respondents did not answer the question)

In contrast with the first study where we did not collect any information about the frequency of these occurrences or their recency, the second study provides us with some information in this respect.

Pilots not understanding ATC

Table 5 shows that, in response to the question**:** *Have you ever been in a situation where you did not fully understand what ATC was telling you?* Forty-six pilots (out of 83) answered they had. The vast majority of these reported less than five occurrences throughout their flying experience. Specifically, nine noted once, 14 noted twice, four noted three instances, seven noted four instances and six noted five instances. Five separate pilots noted this experience has occurred 6, 9, 16 and 20 times. Two other pilots noted this had occurred 10 times.

For the EL2 pilots who were able to recall a situation where they did not fully understand what ATC was telling them, a correlational analysis was performed to determine if a relationship existed between the frequency of such event and the number of years they had been speaking English. Due to the small sample size, a non-parametric analysis was performed. The results of the Spearman Rank correlation coefficient analysis failed to identify a statistical significant relationship, $r(9) = -0.434$, $p = 0.244$.

This result suggests that *the actual number of years of speaking English had no impact on the EL2 pilots' ability to understand ATC*.

When asked how many times this had occurred in the past three months, the vast majority said that it had not (52 pilots). In contrast, 11 pilots noted this had occurred once, six noted twice, three noted three times, one noted once, four noted five times and one noted this occurred eight times.

For the pilots who had noted they had been in a situation where they did not fully understand what ATC was telling them, 15 were on a navigation flight at the time, 13 were completing circuits, seven were on departure, and one pilot each on approach, taxiing and within the training area. Three other

pilots failed to provide an answer despite ticking the 'other' box, and five pilots neglected to answer the question.

ATC not understanding pilots

Table 5 also shows that the majority of pilots (66/83) reported they were not able to recall a situation where ATC asked them to repeat what they had said. When asked how many times this had occurred in the past three months, the vast majority said that it had not (69 pilots). Six pilots noted this had occurred once, two noted twice, and two other pilots noted this occurred three and five times respectively.

For the EL2 pilots who were able to recall a situation where ATC asked them to repeat, a correlational analysis was performed to determine if a relationship existed between the frequency of such event and the number of years of they had been speaking English. Due to the small sample size, a non-parametric analysis was performed. The results of the Spearman Rank correlation coefficient analysis failed to identify a statistical significant relationship, $r(5) = -0.667$, $p = 0.219$.

This result suggests *that the actual number of years of speaking English had no impact on the number of miscommunications with ATC*.

To the question about the phase of flight in which this had occurred, five pilots answered this occurred while completing circuits, two on departure, two on approach, four during a navigation exercise and one pilot noted 'other' but failed to state what this was.

Ranking of communication tasks

The ranking of the five radio communication tasks, shown in Table 6, is consistent with that of the first study (given in Table 3). It is worth noting that the change in ranking of *Understanding ATC*, from fifth in the first study to third in the second study, can be correlated with the number of remarks about a new ATC trainee who was a non-native English speaker at one of the airports during that period.

Table 6: Ranking of radio communication tasks in the Second Pilot Study

1. Understanding other pilots	(Mdn = 3.70, Range 4)
2. Remembering what you have to say	(Mdn = 3.05, Range 4)
3. Understanding ATC	(Mdn = 2.97, Range 4)
4. Reading back	(Mdn = 2.81, Range 4)
5. Saying what you have to say	(Mdn = 2.48, Range 4)

As in the first study, in order to determine whether the differences observed with task difficulty could be explained by native language (NS vs. EL2), a

one-way analysis of variance (ANOVA) was employed. Since the data violated the assumptions underpinning parametric tests (i.e., homogeneity of variance), a Kruskal-Wallis non-parametric test was used. With alpha set at 0.05 the results failed to reveal any statistically significant differences, X^2 (1, 66) = 0.21, p = 0.65. As with the first study, this result suggests that *native language was not an influencing factor in what pilots found difficult with radio communication.*

In order to determine if the differences observed with task difficulty could be explained by pilot qualifications (level of training), a Kruskal-Wallis non-parametric test was employed. Consistent with the previous analysis, a one-way ANOVA alternate (Kruskal-Wallis test) was employed since the data violated the assumptions underpinning parametric tests. With alpha set at 0.05 the results failed to reveal any statistically significant differences, X^2 (4, 64) = 6.98, p = 0.14. This result again suggests that *qualification had no impact on which radio communication task pilots found most difficult.*

Free text answers

Finally, as we were hoping would be the case, the revised questionnaire elicited more answers in free text for the second study. Those answers, given by both NS and EL2 pilots, provided more useful information, as the examples (22)–(23) illustrate. These examples are given with the punctuation and spelling found in the surveys.

The responses to Question 6 (Pilot not understanding ATC) show that NS find ATC sometimes difficult to understand, as illustrated by (22).

(22) (a) NS pilot:
`Information given too quickly & too much in one transmission for readback`
(b) NS pilot:
`T/O from YSCB - TWR call Turn right "when ready". sounded like "heading ...?"`
[Take-off from Canberra – the Tower call …..]

The responses to Question 7 (ATC not understanding Pilot) provided typical examples of EL2 pilots' difficulties, as shown in (23).

(23) (a) EL2 pilot:
`Over Mayfield, difficulties to say all information in sequence to ATC when inbound.`
(b) EL2 pilot:
`Inbound call at Prospect the ATC didn't hear my call sign, has happened numerous times`

The responses to Question 9 (free text about any other situation) give a wider range of answers and situations where misunderstandings can arise.

(24) (a) NS pilot:
Misunderstood a clearance [ ] and began to diverge onto a different runway before being corrected by an instructor.
(b) NS pilot:
Generally ATC speak too quickly.
(c) NS pilot:
Very difficult to understand overseas pilots so their position reports approaching & within circuit at busy airports means constant & dangerous guess work.

Answers such as (22a) and (24b) confirm earlier studies (e.g. McMillan, 1998; Prinzo, 2008) about the problems associated with the rapid rate of speech and the amount of information in one transmission from ATC, while (24c) shows the perception of difficulties due to EL2 pilots' language proficiency.

In summary, the second study confirmed the results of the first (Estival and Molesworth, 2009), namely that the most challenging type of communication for pilots is not with ATC, but with other pilots, and that pilots, irrespective of native language or qualifications, find communicating with other pilots difficult. Whether the main source of the problem is due to noise in pilot-to-pilot transmission or to the poor aviation communication skills (production and/or understanding) of the pilots remains an area for future research. However, the results from question 6 asking if pilots had been in a situation where they did not fully understand what ATC was telling them appears to suggest it may be the latter. Specifically, over half of the pilots (46) noted that they had experienced such a situation but, when asked whether ATC had asked them to repeat a message, less than one quarter said this had occurred.

5. Conclusions and future work

Communication problems are held to pose a threat to general aviation safety and it is undeniable that some of the instances reported in both our pilot studies could have led to negative outcomes. Fortunately, they were either satisfactorily clarified or resolved in some other way and were not formally reported. Even though there is a strong perception in the aviation community that EL2 in particular is a threat to safety, our data (although limited) shows that the problem is much more complex and involves NS ATC as well as both NS and EL2 pilots. The research reported here provides new examples of mis-

communication which the pilots themselves thought posed a safety issue, but which would not have been reported elsewhere (i.e. no accident or incident report).

As demonstrated again by our two studies, communicating effectively over the radio in a noisy and stressful environment is a challenge which is made more difficult when one of the participants is a second language speaker, even when the language to be used is highly scripted. Our two pilot studies have confirmed that miscommunication can occur in situations where it might impact on aviation safety and the answers we collected suggest that the standard of English employed by EL2 pilots may contribute to the difficulties of radio communication in GA. However, we also found that understanding other pilots is reported as the task that poses the greatest challenge to pilots, irrespective of their native language or licence qualification. By contrast, pilots consistently reported that communicating with ATC was the least challenging communication task, which may be explained in part by the intensive training provided to ATC and by the standardized phraseology now regularly employed (Cushing, 1994; Hutchins and Klausen, 1996; McMillan, 1998). Nevertheless, a large number of the examples of miscommunication provided by the pilots surveyed also pointed to the rapid speech and terminology used by ATC as contributing factors.

Our research will continue to be directed towards determining the actual impact of ELP on effective radio communication and analysing the causes of miscommunication between EL2 pilots and ATC. We will also attempt to determine whether ATC experiences are similar to those of their flying counterparts and we will investigate the issues faced by EL2 ATC (currently very rare in Australia).

In order to identify particular areas of communication breakdown, following the model of the study by Farris *et al.* (2008), we will conduct experiments with EL2 pilots of different proficiency levels and under different workloads, investigating the accuracy of interpretation (*comprehension*) and the ability to repeat instructions (*repetition*) under four different conditions (instead of two): two external conditions (with low traffic and high traffic) and two internal conditions (low workload and high workload) and in realistic pilot tasks (instead of paper-based tasks). Future research is also planned examining the effectiveness of noise cancelling technology (e.g., headphones) as a method of alleviating miscommunication between pilots.

Once the areas of miscommunication and their impact on air safety have been identified, we propose a three tiered approach to improve aviation communication:

1. educate both ATC and pilots about typical areas of miscommunication with EL2 pilots (and ATC);
2. teach more effective communication strategies to both ATC and pilots; and
3. develop and implement a computer based training tool to improve English proficiency and maintain communication skills.

Notes

1. The first author is a GA flight instructor with more than 800 hours of GA flight experience, including 200 hours of instruction in small aircraft.
2. The instructor who provided this example wishes to remain anonymous.
3. Thanks to Julie Choi for this example, contributed by a student in her class at UTS, Monique Van derVeen (LEUT, RAN).
4. There are very few EL2 ATC in Australia – but see the comments on Table 6 in Section 3.3.
5. We thank the Chief Pilots and Chief Flying Instructors who allowed us to conduct the surveys at their organizations and who helped us distribute and collect the questionnaire.
6. As indicated by '*' in the tables, some respondents did not answer all the questions, and the numbers given in some cells may be derived from the answers to other questions, e.g. if the level of flight training was not given, but the number of hours was very low, the student pilot was considered not to have achieved the GFPT.
7. One reviewer for (Estival and Molesworth, 2009) was offended by this language and wanted it removed from the paper, or marked as 'expletive'. However, it is important to note that this language is widely used in the GA community and that it is evidence of the larger problem at the time, when Indian students were revealed to be the target of attacks in Australia. In addition, the term 'bloody' is extremely common in Australian English, where it is less offensive than in other dialects.

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Appendix A: Questionnaire

[Ethics and Contact details omitted to keep submission anonymous]

This study aims to identify difficulties in radio communication in General Aviation. The survey is both voluntary and anonymous (no personal information is recorded). The questionnaire will take approximately 10 minutes to complete.

1. What is your current pilot licence? (please circle)

Student GFPT PPL CPL ATPL

2. What ratings do you hold? (please circle) Instructor rating Instrument rating

3. Flying experience: _____ hours over _____ years

4. Total flying experience in the past three months: _____ (hours)

5. Is Australian English your first (native) language? Yes ☐ / No ☐

If "No", what is your native language? _____

How long have you been using English? _____ (years)

6. How many times have you been in a situation where you did not fully understand what ATC was telling you? _____ (estimate)

a. How many times has this occurred in the past three months? _____

b. In the most recent situation where this occurred, please describe what happened:

c. What were you doing at the time? (please circle)

Circuit (upwind, downwind, base, final) Departure Navigation Approach Other (_____)

7. How many times have you been in a situation where ATC did not fully understand what you were telling them? _____ (estimate)

a. How many times has this occurred in the past three months? _____

b. In the most recent situation where this occurred, please describe what happened:

c. What were you doing at the time? (please circle)

Circuit (upwind, downwind, base, final) Departure Navigation Approach Other(_____)

8. Please **rank** in order from a-e (a = least challenging, e = most difficult), what you find most challenging in radio communication?

Remembering what you have to say	☐
Saying what you have to say	☐
Understanding ATC	☐
Understanding other pilots	☐
Reading back	☐
Other (please specify) _____	☐

9. Have you ever been in a situation where a problem with radio communication (other than radio malfunction or failure) resulted in an incident or a potential incident?

Please provide a brief description (use other side if needed).