The Ecology of Language Practices in Worldwide Airline Flight Deck Operations

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Abstract

A large fraction of flight operations in the global commercial aviation system are conducted using a mixture of English and some other language(s). We examine the institutional factors that create this situation and the language practices adopted by non-native English speaking pilots to adapt within a complex ecology of constraints on language usage. We focus on an especially complex case, that of Japanese airlines.

Introduction

Spoken and written language play essential roles in the operation of commercial airliners. Spoken language appears in conversations among the crew, between the crew and Air Traffic Control (ATC), in aural alerts to the pilots generated by on-board systems, between the crew and a variety of company personnel (dispatchers, mechanics, etc), and in public address messages to the passengers. Written language appears in the labels on cockpit controls and indicators, on displays and communication screens, in dispatch and other paperwork, on navigation charts, checklists, airplane operations manuals, personally made annotations on other documents, and notes of ATC clearances.

Flight safety depends on the effective propagation and transformation of linguistic representations both among and within operators (Hutchins, 1995). The use of multiple languages and especially languages that are not fully mastered may therefore affect the safety and efficiency of flight operations (Campbell-Laird, 2004). Language use practices are simultaneously cognitive and consequential.

The English language plays a special role in the global aviation system. English is the official language of worldwide ATC and is the language that both major airframe manufacturers use for labels and displays in their flight decks. However, many (perhaps the majority) of pilots and controllers working in the global commercial aviation system are not native speakers of English. Thus, a significant fraction of flight operations worldwide are conducted in conditions that require the integration of English language representations with representations in other languages. In this paper we will describe the language practices of pilots as situated in this complex ecology.

Methods

We are now in the early stages of a worldwide investigation of the roles of language and culture in commercial airline flight deck (cockpit) operations. Our ethnographic data collection procedures include the observation of airline pilots in revenue flight and in high fidelity simulators, and interviews with pilots and other airline personnel. From the observer's seat in the flight deck, we take extensive written notes, capture digital still images, and collect copies of all of the flight paperwork. These data are subsequently integrated into hyperlinked field notes. Video data from the flight simulator are transcribed and the micro-scale language and culture practices are documented. This research involves many challenges. Access to flight decks is difficult to obtain, and in fact, we have not been able to make observations in North America since September 11, 2001. Furthermore, the interpretation of the behavior of any airline pilot requires a wealth of technical knowledge about aircraft and airline operations. Understanding and interpreting patterns of behavior of pilots from other cultures requires a deep knowledge of the language and culture involved. Fortunately we have been able to assemble a research team that includes technical pilots and human factors specialists from Boeing in addition to a cognitive anthropologist. Our work with Japanese airlines has included an expert on Japanese language and culture. To date the project has collected data on three non-US airlines in three field trips to Japan and one to New Zealand. Our research team has observed more than 60 segments of revenue flight and has recorded more than 40 hours of video data in flight simulators. For this report, we also draw on 12 years of flight deck observations in North America (1989 – 2001) and on a small number of additional observations in Europe and Latin America.

Exogenous Factors in the Language Ecology

The ecology of language use, as it is experienced by the pilots, is shaped by many factors that originate outside the flight deck. Virtually all airline pilots must deal with some English language materials. How much English they encounter and how foreign the English language appears to them varies considerably around the globe.

Policies of Nations

National education programs and language practices at the societal level may produce entire societies that are multilingual (Scandinavia, for example) or conversely, may produce effectively mono-lingual societies (much of the native-born US, for example). It is clear that English is, on average, more foreign for some pilot populations than it is for others. English is more foreign to Mexicans than to Swedes or Dutch (as a result of education policies and societal language practices), and probably more foreign to Japanese than to Mexicans (as a result of the Japanese language being radically different from English in lexicon, syntactic structure, phonology and orthography); this in spite of Japanese education policies that stress English instruction.

ATC language practices are set by national policy and differ by nation. In France, for example, French speaking pilots speak to controllers in French. Controllers speak English to non-French speaking crews flying in the same airspace. The same pattern holds in Mexico and much of Latin America. In these nations, foreign pilots can expect to receive ATC services in English upon request, but those who do not speak the national language are denied the situation awareness that comes from monitoring communications between ATC and other aircraft on the same frequency (party-line). All ATC communications in Japan are conducted in English.

In spite of the differences in language used, there are common schemata for clearances that hold across languages. ATC language has a distinctive syntax and lexicon in every language. A departure clearance, for example, always contains the same set of key elements, regardless of the language in which it is delivered.

International Governing Bodies

In an attempt to address perceived deficiencies in the ability of non-native English speaking operators to integrate English language representations into their aviation activities, the International Civil Aviation Organization has proposed a new set of standards for proficiency in a subset of English called "aviation English." (MacBurnie, 2004) Improving aviation English proficiency worldwide certainly seems to be a laudable goal, but the implementation of an infrastructure for standardized training, testing, and certification of English proficiency on a global scale is a daunting task. Furthermore, it is not clear how the effects of these policies will fit into existing language ecologies.

Manufacturer and Airline Policies

As mentioned above, the major manufacturers (both US-based Boeing and France-based Airbus) determine some central aspects of the language ecology by their use of English for airplane systems and supporting documentation. Flight deck labels and display text mostly consist of abbreviations and acronyms derived from English words and phrases. While many airlines recognize the value of providing pilots written documentation in their native language, this is often not done because the translation of flight deck support documents costs time and money. Some airlines based in non-English speaking societies eventually translate some or all of these documents into the native language of their pilot population. But this tends not to happen immediately when the aircraft is introduced into service. In poorer nations, it may not happen at all. So, airplanes that are new to a non-English-speaking context are likely to be flying with flight deck support documentation that is not in the native language of the pilots. Furthermore, as airplane systems become more complex, the interfaces to the airplane are increasingly automated and language-based (Gras et al., 1991). For example, the latest generation of airplanes is equipped with Electronic Checklists (ECL). At present, the ECL is available only in English.

Patterns of Language Use

These exogenous institutional arrangements inject a variety of forms of representation of flight relevant information into the flight deck and require a variety of transformations of representations inside the flight deck. They also shape the tools and skills that pilots have available for performing the required transformations.

Task demands include entering data from printed representations to computer (preflight the Flight Management Computer: FMC), reading back spoken clearances from ATC, setting instrumentation from spoken representations of flight parameters, reading or hearing procedure descriptions and then executing the described procedure, checking the accomplishment of procedures in written or spoken form, and of course, understanding the meaning of any of these representations in terms of their consequences for the larger flight situation.

The interactions of these constraints produce a wide range of patterns of language use. The three simplest patterns appear to be the following

1. All aspects of flight conducted in first language (typically this is the case for native English speakers flying an English speaking context. This also occurs where all supporting documents have been translated, Aeroméxico domestic MD80 operations, for example. Flight deck labels remain as abbreviations and acronyms derived from English (Pérez, 1996)).
2. ATC conducted in second language and everything else in first language (Aeroméxico MD80 international operations in the US, for example).
3. All aspects conducted in second language (non-native English speakers operating in an English speaking context. For example, a German speaker flying for an airline based in Luxembourg, or a Punjabi speaker flying for a Canadian Airline).

Much more complex patterns are also common.

The Ecology of Language Use in Japanese Airlines

In order to illustrate the complexity of language use in the international airline flight deck, we will now describe some

Table 1: Takeoff briefing conducted in one carrier in Japan.

	Speaker	Original Speech	Translated Speech
1.	PF:	では、Takeoff briefing やります。	*Then, Let's do* Takeoff briefing.
2.	PM:	はい。	*OK.*
3.	PF: {PM}:	えー、weather information、**Quebec** 了解。えー、using **runway <u>three-four</u> right**。{はい}。先ほどperformance確認しました。えー、<u>いちーごーいちいち</u>、**braking action、poor**。えー、**<u>五十九万八千</u>pound**。{はい}。ということで、plan weightとほぼ同様と。えー、fuel minus<u>百</u>ですけれども、{はい}現在recoverして、まぁ<u>二万二千</u>{はい}、order fuel、同様。{はい} え一、performance、check。え一、**TOKYO HANEDA** は、え一、above take off、え一、below landing minimum {はい}。Takeoff alternateはNARITA、{はい} [2 seconds] えー、とります。	*Let's see.* Weather information, **Quebec**, *roger. Well*, using **runway <u>three-four</u> right**. {*Yes*}. *(We have) already checked* the performance *before. Uhhh*, <u>*one-five-one-one*</u>, **braking action, poor**. *Well*, ***<u>five hundred and ninety-eight thousand</u>* pounds**. {*Yes*}. *So, (it) is almost the same as plan weight. Ah... fuel is minus <u>one-hundred</u>, though,* {*Yes*}, *it is recovered now, and **about <u>twenty-two thousands</u>**,* {*Yes*}, order fuel *is the same.* {*Yes*}. *Well*, performance, check. *Uhh*, **TOKYO HANEDA** *is, uhh.., above take-off, ahh, below landing minimum* {*Yes*}. NARITA *is* [2 seconds] *ahh taken as* a takeoff alternate {*Yes*}.
4.	PF: {PM}:	えー、風は<u>二百五十</u>度<u>十</u>knotですね。{はい}。**<u>にーきゅーはちーきゅー</u>**、set。えー、NOTAMは、なし。えー、**<u>七百一</u>番**から、えー、**runway <u>three-four</u> right** full length。{はい}。Flapは、runwayのendまでいってからおろして、{了解}、えーcontrol check して、えーstatic takeoffを行います。えー、RTOに関して。'Before <u>eighty</u>'は、any malfunction 、え一、reject。えー'<u>Eighty</u> to V <u>one</u>'に関しては、engine fail、それから、fireもrejectします。{はい}。それからmaster warning 等、離陸の継続に重大な支障があると判断した場合には、rejectします。{はい}。	*Ahh, wind is <u>two hundred fifty</u> degree <u>ten</u> knots, isn't it?* {*Yes*}. ***<u>Two-nine-eight-nine</u>***, set. *Well, no* NOTAM. *Ahh.., from number <u>**seven hundred and one**</u>, ahh,* **runway <u>three-four</u> right** full length. {*Yes*}. Flap *will get down after going to the* end *of the* runway, {*Roger*} *uhh* check control, *well, do a static takeoff. Let's see... About* RTO. *At* 'before <u>eighty</u>', *(with) any malfunction, ah.., (the takeoff will be)* rejected. *Ahh, as for* '<u>eighty</u>' *to* V <u>one</u>', reject *(the take-off) will be held at engine fail and also* fire. {*Yes*}. *And then, in case (I would) judge that something such as* master warning *which cause critical troubles in continuation of departure, (we are) going* reject *(the takeoff)*. {*Yes*}.
5.	PF: {PM}:	'After V one'に関しては、reference procedureをfollowして、えー、<u>三百</u>feetのright turn。えー、オーパイを使っていきます。{了解。}	*Regarding* 'after V one', *(we will)* follow reference procedure, *and uhh.., then (do)* right turn at <u>three-hundred</u> feet. *Ahh..., (we) will be using* O-pai.{*Roger*}

ways that Japanese pilots flying the Boeing 777 shape their practices to meet the needs of flying. It should be noted that the most common function of the use of language and other communicative means in the flight deck is to coordinate joint activity (Clark, 1996). It is not surprising, then, that pilots show a preference for their native language to do this work.

In Japanese airlines, most utterances in the flight deck (revenue flights) are produced in Japanese. English is used only for communication with ATC, reading text that arrives in the flight deck in English (for example, the text of electronic checklists displays, ACARS [1] messages, and dispatch paperwork), and some technical call-outs such as "V one," "Flaps five," and "Push Autopilot". All other utterances, for example conversations about how to fly an approach, where traffic or weather are located, how the airplane is performing, as well as informal conversations, public address messages to the cabin (on domestic routes), communication with cabin crew, and communications with company personnel, are conducted in Japanese. Japanese is also used to strengthen social relationships among crew members. For example, every trip begins with a briefing in which the flight and cabin crew gather in the airplane. They introduce themselves to one another and discuss the day's flight in Japanese. Status differences are marked in these briefings and throughout the flight in forms of address, body language, and in choice of speaking register.

Code switching driven by the language ecology

Some activities are conducted almost exclusively in Japanese, but in other activities Japanese and English are thoroughly intermixed. Table 1 is a transcript of a takeoff briefing conducted by a pilot flying (PF) and pilot monitoring (PM) in a simulator training session. Numbers in brackets [ ] represent silent seconds, braces { } indicate the other speaker's remarks (mostly acknowledgement tokens produced by the addressee (Bangerter & Clark, 2003)), and parenthesis ( ) indicate the addition of features that are usually omitted in Japanese language. Underlined words are numbers, bold font letters are information presented on displays or papers in the pilots' visual field, and italic letters in the translated speech table represent remarks spoken in Japanese in the original speech table. Comparing the original speech and translated speech tables, readers can appreciate the differences in lexicon and syntactic structure between the two languages. The mixing of Japanese and English is also evident.

While conducting this takeoff briefing, the pilots refer to and gesture toward dispatch papers, a chart of the engine-failure "reference procedure" for Runway 34R of HANEDA airport, a HANEDA airport map, and information on various flight deck displays.

The switching between Japanese and English may appear chaotic, but there are powerful regularities in this data. Virtually all of the words that were spoken in English in this briefing are either technical aviation terms or are read directly from English language text presentations in the pilots' environment. Numbers are read from displays in Japanese except runway number which is always

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[1] Aircraft Communications Addressing and Reporting System. This is a means of delivering text messages from ground stations to the flight deck where they can be displayed on a screen and/or printed out on paper.

communicated to ATC in English and "eighty" and "V one" which are required English language verbal callouts made during the takeoff roll. That is, in this language ecology, concepts are represented in English when the environment provides the representation in English or when English representation is required for coordination with institutional contexts that have made prior commitments to English.

Making English Less Foreign

As shown in Table 1, Japanese pilots are trained to use English aviation terms. For example, in general, pilots say "Autopilot," "Auto throttle," "Altitude," "Speed," "Runway," "Flaps," "Navigation display," "Take off," "Approach," and so on in English, even though corresponding Japanese terms are available.

The term "*o-pai*" in line 5 of the translation part of Table 1 is interesting. It is an example of one of many language use practices that make English language less foreign. The Japanese pilot community has created a new set of aviation terms by applying Japanese conventions for abbreviation to aviation English technical terms. "O-pai" is a hybrid abbreviation of the English "autopilot." Other Japanese-style abbreviations include "Gene" for Generator Switch, "Hydro Pre" for Hydraulic Pressure Switch, "Ereki Gene off" for Electric Generator off, and "Cabin Auto Inopure" for Cabin Auto Inoperative. These abbreviations are part of a much larger class of shortened technical terms that appear in other contexts of Japanese life, for example, "Paso-con" for personal computer. The shortened technical terms are invariably borrowed from other languages, but they are spoken using the Japanese sound system. The syllable boundaries of these shortened terms do not match English language syllable boundaries. For example, the syllable boundaries in the English word generator are 'gen.er.a.tor', but the shortened Japanese form is 'ge.ne.'

We found no evidence that acronyms or abbreviations are problematic for Japanese crews. Even though these acronyms and abbreviations are based in English language words and phrases, it appears that they are only rarely decomposed into their base forms even by English speaking crews. For example, a flight mode named "flight level change" is abbreviated FLCH on a flight deck display, and is pronounced "flitch" by native English speaking pilots. Such abbreviations become lexical items in a professional language of aviation and are associated directly with their functional properties rather than with the meanings of the words from which the abbreviation was derived. Non-native English speakers give these terms phonetically more comfortable pronunciations and then use them as they are used by native English speakers.

Checklists Some of the entries in the current generation of Electronic Checklist (ECL) procedures require readers to use implicit contextual cues to resolve semantic and syntactic ambiguities. One Japanese airline has edited the ECL on their newest airplanes to make the English easier for their crews to understand. The Japanese language handles double negatives and negative questions differently from English, and these constructions, among others, have been found to be quite problematic for Japanese speaking crews. English text can also be read aloud in ways that make it phonetically more congenial for non-native English speakers. We observed a Japanese pilot who spoke to ATC with nearly unaccented English, but when reading the ECL to his fellow pilot, he pronounced the words using Japanese sounds. He adopted a Japanese speaking rhythm and extended word final sounds (Stanlaw, 2004), adding vowels to words that end in consonants (e.g., "Arutitudooo," "Checkriiisto," and "…check erec synoputicuuu,"). The fact that this pilot has demonstrated the ability to speak English with almost no accent in the ATC context indicates that he is engaging in recipient design at the phonetic level when he is reading to his partner.

Many Japanese find written English easier to understand than spoken English [2]. When two pilots do a procedure together, one of them reads the procedure while the other executes the actions described. The ECL is presented on a display in the center of the flight deck. We observed many cases in revenue flight and in the simulator in which both pilots read the ECL together. If the checklist procedure is performed using a paper checklist, the pilot reading the checklist leaned toward the other pilot and placed the paper checklist in the line of sight of the other pilot. Both of these practices make the written representation available in addition to the spoken representation (See Figure 1). Among other effects, this practice provides the second pilot with a representation of the procedure that is less foreign than the spoken representation [3].

Figure 1: Written English is easier to understand than spoken English.

Even though the checklist procedures are presented and read in English, additional discussions between pilots about the meanings of checklist items are usually conducted in Japanese.

Number Representations Numbers representations are interesting for several reasons. Most of the content of flight

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[2] This may be due in part to the Japanese education system's emphasis on English reading and writing skills over speaking skills.
[3] This pattern of behavior is also observed in mono-lingual English flight decks where it seems to facilitate the establishment of common-ground understandings.

dispatch paperwork consists of numbers. Japanese has its own native orthography for the written representation of numbers. But the Arabic numeral system has become an alternative orthography for number representation in everyday Japanese life. Japanese people read Arabic numeral fluently and conceive of the quantities in Japanese terms (see Figure 2). This means that while a native English speaker might see a dispatch flight log, for example, as a document composed entirely in English, a Japanese pilot may see the very same document as only a little bit English. Flight dispatch documents include many numbers that must be entered correctly into the flight management computer system. Among these are so called "killer items" which must be entered correctly, because a mistake with a "killer item" may render the airplane difficult or impossible to control after takeoff. The excerpt below from a final weight and balance report issued by a Japanese airline shows that special attention is given to the representation of the "killer item" numbers (ZFW and MAC). In addition to appearing in numeric form, the digits of the numbers, including the decimal point in the case of MAC, are spelled out in individual English words. These words will be read and spoken aloud while keying in the data. We have not observed this spelling-out of number values at any mono-lingual English airlines.

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W 348900
 (THREE FOUR EIGHT NINE ZERO ZER
B  34000   TXW 382900
C  25.4  (FL 15.9--AL 39.0)
 (TWO FIVE POINT FOUR)
X 2713( 39000)
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Figure 2: The representation of the "killer item" numbers in a weight and balance report.

The Japanese language represents large numbers differently from English. In Japanese, ten-thousand is denoted by "man," not "juu-sen (literally, ten-thousand)." So, for example, twenty-two thousand would be formed as "ni-man ni-sen (two ten-thousands and two thousands)" in Japanese. Japanese pilots represent altitudes using Japanese composite format when referring to altitude in a briefing or in general communication with a fellow pilot (See Table 1). They represent altitudes in English, using global aviation conventions, when communicating with ATC and when setting the value of the altitude alerter window. Similarly when dealing with other large numbers, such as fuel quantities, the pilots represent large numbers in Japanese format when they consider the implications of a quantity, and use English format to represent the same quantity when transferring data from a written English representation to keypad entry. In general, Japanese is used when the meaning of the represented quantity is paramount and English is used when the preservation of the form of the number is paramount. The linguistic representation chosen thus depends on the relation of the representation to other representations in the ecology at that moment.

Non-normal Procedures The constraints of the language ecology on the choice of representation format are also apparent in the use of the Quick Reference Handbook (QRH). Figure 3 is an excerpt from the QRH for the Boeing 747-400 operated by AirFrance.
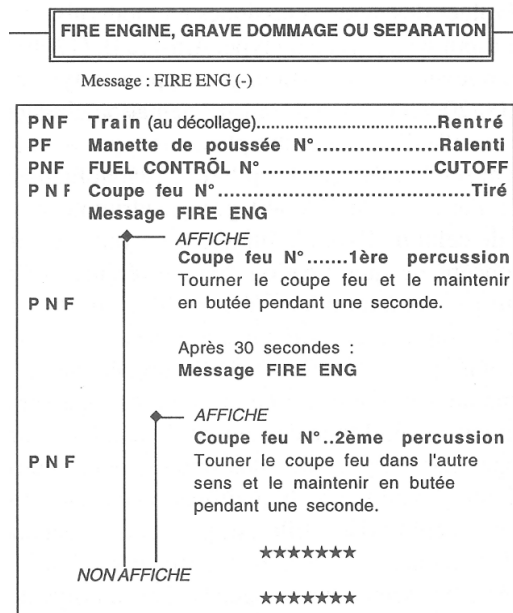

Figure 3: The QRH for the Boeing 747-400 operated by AirFrance. (from Jouanneaux, 1999)

The QRH is a ready-to-hand notebook containing written procedures for dealing with non-normal conditions. Non-normal conditions that are detected by the airplane systems are brought to the crew's attention by a message that appears on a central display panel. When a string of characters such as "FIRE ENG 3" appears on the display, the crew must locate the corresponding procedure in the QRH. As the figure shows, the steps to perform when the message appears can be translated into the native language of the pilot population (we have seen similar documents in Japanese), but the strings of characters that name the procedure cannot be translated, because translation would destroy the correspondence between the form of the message and the form of the procedure name. Terms that refer to the exact text of flight deck labels, such as the CUTOFF position for the fuel control switch, are also not translated.

Annotation of Charts and Other Paperwork Japanese pilots applied more annotations to their charts and other paperwork than the pilots at any other airline we have observed.

Figure 4 is a heavily annotated hand-drawn representation of a complex instrument approach prepared by a young Japanese first officer to be reviewed just prior to flying the approach. This document is a sort of microcosm of the language ecology of the Japanese flight deck. The

annotations are a complex mix of English and Japanese. Character strings that appear in English on navigation charts or flight deck displays while flying this approach are rendered in English. Required callouts and expected communications with ATC that must be produced in English while flying the approach also appear in English on this document. Commentaries, interpretations, techniques, and discussions of tricks and traps are represented in Japanese.
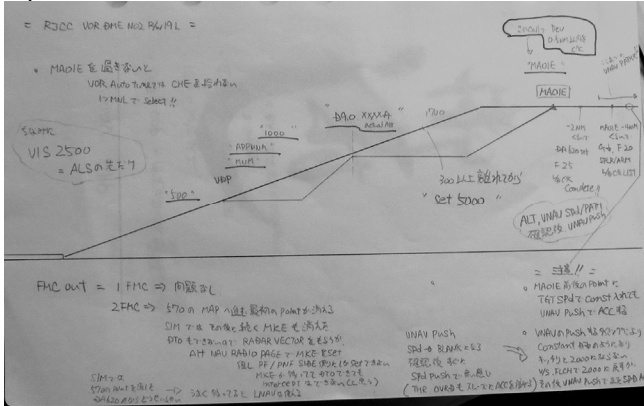

Figure 4: A heavily annotated hand-drawn representation of a complex instrument approach.

Japanese pilots also annotate operational documents. In training they annotate lesson plans and maneuver descriptions. Some of this may be imported from the well-developed Japanese culture of studying and test taking.

The significance of the presence or absence of annotation is complicated by the relations to other elements of the ecology. Normally, pilots have responsibility for possessing and maintaining their own collection of navigation charts. These are carried in a "route manual" by each pilot in his or her flight bag. In New Zealand, our research team was initially surprised by the fact that pilots on domestic routes never annotated the charts. We soon discovered that by airline policy, the charts belong to the airplane, not to the pilot, and pilots are specifically prohibited from adding annotation to charts.

Principles of Adaptation in the Ecology of Language Use

A foundational assumption for this work is that the language ecology in the flight deck is grounded in the wider ecology of language use in the everyday lives of the pilots. To the extent that most pilots live their everyday lives in their native language, the pilots' everyday native language practices constitute the unspecialized background with respect to which language in the flight deck can be said to be specialized. Our working hypothesis is that when a pilot-generated linguistic representation must be coordinated with other representations that are constrained by exogenous factors to be in English, then the pilot is likely to use English. When a pilot-generated linguistic representation is not constrained by relations to English language

representations, it is likely to be in the pilot's native language. The use of native language representations is especially likely if the pilot must use them while reasoning about complex meanings.

Future Work

In the coming year we expect to be able to make field visits to at least three more airlines in Oceania and Asia. Given the terms under which we gain access to this field site, we are limited to airlines that are flying and acquiring Boeing airplanes. We intend to further explore the full range of patterns of language use. The distribution of exogenous factors creates a number of natural experiments in the global aviation system. For example, as aircraft cross international borders, it is often the case that a single independent variable – e.g., language used for ATC – changes. There are also many cases in which two or more airlines representing two or more different languages and cultures fly the same model of aircraft on the very same international routes. Parallel observations in these settings may allow us to better differentiate the roles of various factors in the organization of the language use ecology.

Acknowledgements

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