OPERATIONAL LANGUAGE IN THE COCKPIT/FLIGHTDECK COMMUNICATION ENVIRONMENT OF AUSTRALIAN CIVIL AVIATION AIRCRAFT

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ABSTRACT - A recent survey of cockpit noise and communications in 44 Australian civil aviation aircraft included the compilation of a corpus of operational language material heard by aircrew during the performance of their duties. Preliminary analyses were made of the lexicon, syntax and message content of 1,726 transmissions. Constraints found upon the operational vocabulary and message-set construction heard by pilots present opportunities for applications of current speech technology to the civil aviation cockpit. Access to a suitable language database could be very useful for such applications.

INTRODUCTION

Evaluation of speech systems for aviation purposes should be performed under realistic airborne conditions. The proper assessment of speech system performance, in areas such as recognition accuracy, intelligibility and general utility, necessarily involves the use of speech materials with appropriate familiarity and syntactical construction. Wheale (1983) provides an example of a specific evaluation of a speech synthesizer to output a limited number of warning messages appropriate to the flightdeck of a large turbo-jet aircraft. Other systems may operate upon different input/output requirements. Jackson and Waterworth (1986) examined the confusability of a 44 word vocabulary, including the International Civil Aviation Organization (ICAO) alphabet, to a commercial speech recogniser running in isolated word mode. It would be helpful, therefore, to quantify the lexicon, syntax and communication topics of aircrew as an aid in the design and evalution of robust speech hardware and software.

Situational and linguistic constraints operating in aviation operations language have long been recognised (Frick and Sumby, 1952), but rarely quantified in a systematic or comprehensive manner. Databases restricted to the vocabulary and syntax used by pilots of high performance fighter aircraft are being developed by the U.S. Air Force Flight Dynamics Laboratory (Porubcansky, 1985), but a large civilian database is lacking. An analysis of the language heard by by Air Traffic Controllers (ATC) and Flight Service (FS) Officers formed part of the recent development of speech-based hearing test materials for these personnel (Clark, Koob, Hoult and Newall, 1987). A current project being conducted by the authors for the Australian Civil Aviation Authority has resulted in a similar investigation of the operational language heard by aircrew. This paper briefly outlines some of the lexical and syntactical features of this workplace-specific sublanguage.

DATA COLLECTION

During the in-flight recording of cockpit/flightdeck ambient noise, described in an accompanying paper, (and see also Clark, Kennedy and Koob, 1988), it was possible to make simultaneous recordings of radio-telecommunication (RT) and intercrew messages on a separate channel of a Technics RD-686DS cassette recorder. This was achieved by recording directly from the aircraft communications system, configured to access both the aircraft intercom and appropriate VHF and HF communication channels. Use was made of a spare headset socket wherever this was available. Messages obtained in this way were added to messages directed to pilots that had been recorded in ATC and FS operations areas during an earlier research project (Clark, Koob *et al*, 1987). A total of 1,726 radio transmissions and intercrew messages were included in a corpus of language items heard by aircrew during the performance of their duties.

LANGUAGE ANALYSIS

Database construction

The R/T transmissions, containing 19,632 words and comprised of 1,137 different lexical items, were transcribed and analysed. The messages were classified by the class of aircraft which was their intended destination and also by the source of the message. The representation of each aircraft class destination was: general aviation (44.8%); regular passenger transport (RPT) (41.5%); and rotary-wing (11.8%). A small number of ATC transmissions to military aircraft (1.9%) were included in the database as these messages are also received by civilian pilots and have the same potential to inform or create confusion as any other transmission. The source of the recorded messages was: ATC (65.0%); FS (23.3%); fellow crew-members (6.6%); pilots of other aircraft (5.1%). ATC personnel actively direct traffic in controlled air space, consequently their messages are in the imperative mood. FS officers have the task of monitoring aircraft and relaying information, so messages received from this source tend to be more advisory in nature. Messages from fellow crew-members for information transfer and crew coordination were collected from the multi-crew flightdecks of large regular passenger transport (RPT) aircraft and included several inflight checklists (of which each half, the challenge or response items, were counted as only one message). R/T transmissions from pilots of other aircraft were mostly of a general nature, advising any aircraft in a particular vicinity of their position and intentions, although occasionally pilots will direct specific requests for information to other aircraft when outside of controlled airspace.

Vocabulary/lexicon

The individual lexical items of the entire database were sorted and ordered by frequency of occurrence. These items were then edited to remove the following: i) Proper nouns, including names of localities, aircraft, airlines and persons; ii) Conjunctions and articles; iii) Contractions (don't, they're, I'm etc).

The remaining total of 17,037 words, comprising 939 different items, displayed some interesting characteristics. Numerical words comprised a large portion of the corpus, as might be expected from the constant requirement to quantify altitude, distance, time, radio frequencies, airspeed, compass headings and barometric pressure (QNH). The numbers 'zero' through to 'nine', plus 'hundred' and 'thousand', or just 12 different words, occurred 4,154 times, or 24.4% of the edited corpus. Also occurring frequently in the operational language heard by pilots are the words of the International Civil Aviation Organization alphabet (alpha, bravo, charlie etc.) hereafter referred to as 'ABC' words. These words are used in current R/T practice to convey aircraft callsigns and also as names for successive updates of ATIS (Automatic Terminal Information Service). Collectively these 26 words occurred 4,144 times, for a total of 24.3% of the edited corpus. Taking the numerical and ABC words together, it is possible to state that approximately 50% of all words heard by pilots of civil aviation aircraft are accounted for by a mere 38 items. As might be expected, this is quite similar to results obtained in previous work on the ATC/FS language corpus (Clark, Koob *et al*, 1987), where numerical words and ABC words respectively comprised 25 and 30% of all occurrences.

The group of words that comprised 95% of all words in the corpus numbered only 382 different lexical items. Thus removing the bottom 5% of words reduced the number of different items by 60%. Some 228 of these final 382 words occurred in the messages for all three civil aviation classes. Even allowing for sampling error, there remained a number of relatively high frequency words that were characteristic of one or two classes only. These highly specialised vocabulary items derive their distinctiveness from the fact that the operational practices of the the three aircraft classes are not entirely complementary. Rotary-wing aircraft, for example, often have their call signs preceded by the word *helicopter*, operate from *helipads* or *heliports*, but conversely operate below ten thousand feet so are unlikely to be told to climb to a particular *flight level*.

Listed below in descending order are the fifty most frequently occurring items in the edited database.

1) one	11) six	21) echo	31) clear	41) victor
2) zero	12) romeo	22) runway	32) uniform	42) kilo
3) two	13) juliet	23) at	33) november	43) roger
4) three	14) decimal	24) delta	34) quebec	44) report
5) five	15) on	25) hotel	35) foxtrot	45) lima
6) tango	16) thousand	26) papa	36) eight	46) approach
7) mike	17) charlie	27) you	37) golf	47) level
8) four	18) whiskey	28) zulu	38) is	48) india
9) alpha	19) contact	29) nine	39) sierra	49) your
10) seven	20) bravo	30) control	40) good	50) QNH

Table 1. Fifty lexical items of frequent occurrence in the operational language heard by civilian aircrew.

Message structure and content

Each recorded transmission was analysed for structure and content using an analysis system which considered both the purpose of the message and the nature of the information sought or provided. The transmissions were broken down into information units, which either were structurally complete in themseves ('climb to flight level two seven zero') or modified another information unit ('by time one four zero five'). These information units were described as advices, denoted A, (a message whose primary function is to supply the pilot with information), commands, C, (a message requiring the pilot to change or maintain the status of the aircraft or its equipment in a specified manner) or reports, R, (a message requiring a verbal response only). One transmission might contain several types of messages. The messages were further subjected to a content-coding technique involving thirteen descriptors of their subject matter, for example as relating to altitude, position, traffic, barometric pressure, airport vicinity operations, and so on.

Other structures identified in the transmissions included identifications of both the receiving (I) and transmitting (IO) stations; acknowledgments (ack) other than aircraft callsigns; forms of address (add) (e.g. thank you, please, good morning, sir); breaks (br) (a change mid-transmission in the aircraft being addressed); corrections (crr); negations (neg); terminal information (which follows a fairly standard format); and flight checklist items.

A hypothetical transmission received from ATC would be analysed as follows:

'[1. Alpha Bravo Charlie] [2. Control] [3. good morning] [4. climb to flight level two five zero] [5. break] [6. X-ray Yankee Zulu] [7. descend to seven thousand], [8. QNH one zero one five], [9. report final].'

1. Identification of station called; 2. Identification of transmitting station; 3. Address; 4. Command / Altitude; 5. Break; 6. Identification of station called; 7. Command / Altitude; 8. Advice / QNH; 9. Report/Operations

Table 2 below shows the relative frequency of the different message types and subject areas. The fact that the transmissions could be described using such specific and finite number of descriptors indicates the enormous commonalities amongst them.

Of the other structures, identifications and callsigns of the called and sending stations were most prominent, as were other types of acknowledgement and forms of address.

	Message Type			
Descriptor	COMMAND	ADVICE	REPORT	Total
A Altitude	194	36	92	322
D Distance	16	54	12	82
F (radio) Freq.	213	12	9	234
G General	20	129	65	214
I (radar) Ident.	38	61	5	104
O Operations	366	173	42	581
P Position	32	38	29	99
Q QNH	--	83	--	83
R Route/heading	199	46	26	271
S airSpeed	41	5	11	57
T Traffic	2	214	3	219
TM TiMe	14	42	19	75
W Weather	--	34	5	39
Total	1135	927	318	2380

Table 2. Classification of information units by message purpose and subject

The twenty most common orderings of the structures and information units for entire transmissions from ATC or FS are ranked in Table 3, with examples of each. Shown in brackets are the respective frequency of occurence out of a total of 1,525 (ATC + FS) transmissions

I (207) Alpha Bravo Charlie
I CO (106) ABC hold short of the intersection
I CF (105) ABC contact Sydney control one two seven decimal three
I RA (46) ABC present altitude?
I CA (44) ABC climb to seven thousand
I IO (37) ABC, Departures
I ack AO (23) ABC roger, you're number two
I CR (23) ABC turn left heading zero six zero
I RG (23) ABC say again
I AQ (15) ABC area QNH one zero one nine
I CF CP (15) ABC contact one two five decimal eight at Brooklyn bridge
I AI (14) ABC identified
I IO RG (14) ABC, Melbourne control, do you read?
ack (13) Roger
I AG (13) ABC standby
I IO AO (13) ABC, Tower, continuous operations runway zero seven
I add (12) ABC good morning
I CR CR (12) ABC turn right heading two three zero for pilot intercept of the two two zero radial
add (10) Good day
I RP (10) ABC what's your present position?

Table 3. Frequently occurring R/T transmissions in ATC and FS messages to aircrew.

While the more common transmission structures listed above are fairly restricted in the number of structures and information units they contain, it is not unusual for pilots to receive six or more of these in rapid succession within the one transmission from ATC or FS. In these cases the pilot is usually aided by a very high level of situational and linguistic redundancy.

CONCLUSIONS

The development of a large language database for the airborne environment should prove beneficial in the application of speech technology systems to all types of civil aviation aircraft and cockpit simulators used for flight training. This paper has merely sought to illustrate some of the more basic information which can be extracted from the language corpus, with further analysis of specific interactions (e.g. ATC to RPT aircraft) easily obtainable.

The obvious constraints on pilot lexicon and message set construction reveal the highly structured and uniform nature of aviation communications, although it should be recognised that any system containing a human element will never achieve absolute standardisation in the manner in which particular information is conveyed. While these constraints are factors which should enhance the accuracy of speech recognisers, permit the use of encoded speech synthesis systems, and make possible the development of voice interactive systems which possess realistic dialogue simulation ability, systems must be robust enough to allow for slight inconsistencies in user practices. It may be beneficial to incorporate situational and task constraints on the language into systems design, for example to enhance the performance of speech recognisers by adjusting the accessibility of certain parts of the vocabulary to the operational mode of the aircraft. Due to the fact that many of the information units previously described are very concise in nature, it may also be possible to use those isolated word recognisers which can cope with longer durations to recognise these short clauses.

While the sophistication and flexibility of speech systems will no doubt increase with improvements in the quality and capacity of speech encoding and decoding hardware, and with advances in artificial intelligence capabilities, it would appear that opportunities exist for current speech technology to be applied to a variety of civil aviation cockpit tasks. These include communications, navigation, preflight data entry, airspeed warnings, threat management, ground proximity, and checklist interrogation. While many difficulties remain, the continued integration of speech systems into the cockpit will depend largely on the development of relevant databases.

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