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SPEECH ERRORS MANAGEMENT IN AIR TRAFFIC CONTROL COMMUNICATIONS: A DETAILED STUDY

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Many studies have reported on some human factors influencing the communication process, especially in aeronautical framework (see Davison (2003) for example). When spoken, communication comprises three different components: production, perception and understanding. The communication is often disturbed by one or many errors that affect one or several of these components. Consequently, one way to make air traffic control (ATC) communications more efficient and robust is to have as much knowledge as possible on these problems and their usual management. This paper presents the interests brought by corpus-based studies to Air Traffic Control (ATC) applications, especially interactions/communication between controllers and pilots. The corpus recorded represent dialogues during exercises where air-traffic controllers being formed interact/converse with people simulating pilots in practice. We propose error and strategies typology in accordance with the phraseology Then, we describe the principles and the specification adopted both for the recording and the annotation of corpus. Then, we report first results obtained from corpus analyses on errors and correction strategies of the air-traffic controller, and comment them in regards with ATC oriented applications.

Introduction

In the context of air controllers' activity, error handling is a very important thing, since it concerns the management of traffic and its security. The communication between air-traffic controllers and pilots must respect a phraseology (communication principles and rules).

We report how this handling is made during the air-controller formation. It consists to exploit a corpus of spoken dialogues that take place during air controllers' formation. We will show how this exploitation is made, via several levels of annotation (orthographic, semantic and dialogic) to study errors and corrections made during their formation. This goes through strategies of correction and self-correction. They are peculiar features of spontaneous speech, especially in stress and apprenticeship situation, as is the case with air controllers in formation. Indeed, because of the necessity of managing errors, each one has imperatively to be detected and corrected as soon as possible. We distinguish several categories of errors and different correction strategies.

In a first part, we will present the goal and the characteristics of the corpus, and the context in which it has been recorded. We will also comment/report the needs of a multi-layer annotation level for conducting natural language researches in the ATC domain. Then, we will present the annotation specification we chose for this work. Finally, we will give the results we obtained concerning errors and corrections and the categorizations it led us to.

Description of Corpus

Characteristics of controllers – pseudo-pilots communication

The formation of the Air Traffic Control (ATC) controllers includes theoretical teachings, but also consists of a lot of training sessions. These sessions are made of communication between air-traffic controllers being formed and "pseudo-pilots operators" (that is, people simulating pilots in practice).

The aim of the exercises is to train apprentice controller activities, and then evaluate them. It consists of managing several planes that are in a controlled area, for example by assigning them a given speed and/or position. Two languages were used: French and English (French being the majority). The exercise conditions were as near as possible from real environment: controllers worked with screen giving the radar position of virtual "planes"; the air traffic was simulated by several persons assuming the role of one or many pilots. Some background noises (overlapping conversations, sounds emitted by microphones, etc.) also occurred.

Figure 1 below is a formalization of the communication between a controller (C1) and a given pilot (pilot#1) until the controller addresses to another pilot (pilot#2).

The utterances produced by the controller, as well as the pilots' ones, must respect the phraseology. It describes, for example, the way the speaker must pronounce the planes call signs, or the order that the different components of a message have to follow. Two speakers can't speak at the same time, due to technical limitations: the audio channel is only assigned to one speaker. During the formation step, the phraseology is not always strictly respected even in real work conditions. But its general guidelines are kept. However, its learning and mastering was also aimed by exercises.

An instance of a simple order that an air controller can formulate to a pilot is: "Delta Tango Charlie climb level 9 0". We find, first, the call sign of the pilot's plane ("Delta Tango Charlie"), and then the order itself. In a regular grammar (Dourmap & Truillet,

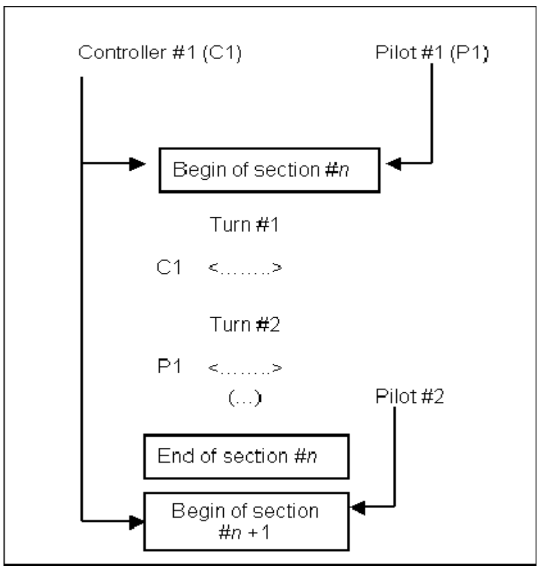


Figure 1: *Sections of sequences and turns*

2003), this utterance is composed by a call sign and the order. This last one is composed of a command, "climb", that plays the role of a predicate, whose argument is a value (for instance, "9 0" in our example). More complex utterances can also occur, composed of a sequence of simple orders. For a complete description of the French call signs and orders, see (Dourmap & Truillet, 2003).

Description of Corpus

The recordings were made on July 2001 at the ENAC (Ecole Nationale d'Aviation Civile; in English: National School of Civil Aviation) from Toulouse, in the framework of the VOICE[1] project.

A DAT (Digital Audio Tape) was used. They were sampled at 16 kHz (16 bits). For recording reasons, the speech signal quality sometimes suffers from saturation or noises such as interferences. However, it stays intelligible. There were 16 speakers, and the total length of the corpus is 36 hours 50 minutes.

Transcription and Annotation Methodology

Multi-level annotation

According to the need, transcriptions and annotations of oral corpus can be opered at different levels:

1. Orthographic: putting what is said in writing, along with, possibly, the environment sounds. This level can also be augmented by labels of prosodic and extra-linguistic phenomena, such as pauses, hesitations, and so on;
2. Phonetical: transcribing what has been said in an I.P.A. (International Phonetic Alphabet). This level is useful to learn acoustic models for automatic speech recognition system and the various pronunciation of a word according (maternal language for instance).
3. Grammatical: assigning grammatical categorization to words of sentence. Some analysts also proceed to a lemmatization of words; that is to say, any inflected word is reduced to a canonical, basic form, called a lemma;
4. Semantical: this level can be processed according to different ways. For instance, one may seek to annotate words and/or sentence according to their meaning. On the other hand, the annotator can also focus his interest on the language acts expressed in sentences (in (Austin, 1962) sense). In the case of a corpus containing dialogs, such as our, it can also be the dialogs acts (Bunt, 1996) that are of interest. This kind of corpus can also be annotated according to a fourth level: dialogic one.
5. Dialogic: it concerns the structuring of the utterances produced by participants of dialogue. The annotation methodologies for this level are generally inspired from the works aiming to modeling dialogue and the combination of its components. One of the most famous is presented in (Roulet et al., 1985). To sum up, it consist in subdivide dialog in different

[1] Initially named VICTOR (Truillet & Vigouroux, 2001). VOICE goals are the study of spoken interaction utility and usability in the ATC area. To reach these aims needs: firstly to formalize under language models (like in (McTait et al. 2004) and (Dourmap & Truillet, 2003) for example) the phraseology used in real situation (Maugis, 1995); secondly to conceive a training environment where the pseudo-pilots will be replaced by spoken agents.

hierarchical levels. The main ones, from higher to lower, are: language act (the smallest unit), intervention (made by a given speaker, can be constituted of several language acts), and exchange (set of interventions related to a given topic).

As we have shown in this brief state of the art[2], there is a very large set of annotation methodologies. The choice is made according to the study aim of the corpus. We will show now in which way this study subject has led to the choice of a given way of transcribing and annotating.

TranscriptionAannotation Methodology

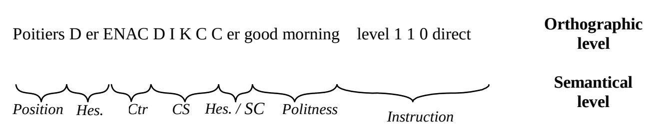
We transcribed dialogues as well as annotated them according to some specifications ((Coullon & Gralia, 2000) and (Coullon et al., 2001)). The authors also made a distinction between the orthographic transcription and annotation. Annotation corresponds to an interpretation (at semantic, dialogic levels, etc.) of the orthographical string. These two tasks correspond respectively to the first, fourth and fifth levels described in the above multi-level annotation. Let's see more details.

Specifications are defined, firstly to determine elements that have to be transcribed. Secondly, to obtain homogeneity of transcriptions in case where several annotators processed the tasks. They consist essentially of rules to follow to transcribe technical ATC items such as call signs, speeds, etc. It also gives instructions to transcribe extra-linguistic events like hesitations, pauses, or accentuations. While transcribing the formation corpus, we believed that this specification wasn't sufficiently fine grained to mark out specific phenomena. Consequently, we contributed to the specifications by creating other classes of phenomena necessary to transcribe. We also refined existing one with sub-categories. Indeed, we considered the fact that the annotator could possibly not have access to the recordings, or not have time to refer to it for a given detail. Consequently, it is necessary to spot any phenomenon that could be interpreted as a marker for a language act, and accessible only via recordings hearing. For example, we introduced several tags corresponding to different pause lengths. This was based on the observation that, while a short pause could occur when one get his breath back, a longer one could spot something interesting in the speaker's behavior. For instance, he can have been disturbed by noticing he did an error, and seeking to fix it. We will come back on this example in the part devoted to correction study. In the same way, we noticed that frequently, the words produced when the speaker realize that he did an error are affected by a slight acceleration. Considering that this phenomenon could be considered like a marker of a correction, we decided to mark it with a special tag. It appears that, by doing this, we reach beyond the framework of "raw information" given by specifications. Indeed, this decision is based upon an interpretative act. However, we thought that if it wasn't done during the transcription, the annotator would miss some interesting phenomena.

[2] For a more detailed overview, interested readers can confer to (Truillet & Vigouroux, 2001). Many works have been made on corpus; one of the nearest from our is (McTait et al., 2004).

We see here an illustration of the interconnection between the different levels of transcription/annotation we spoke about above. This lead us to the presentation of the transcription work.

As stated above, the aim was to give additional comments and labels to the transcribed elements. Thus, it would be possible to extract data according to a maximum number of criteria, and to carry out statistical researches (Coullon & Gralia, 2000, p.12). The information to give consists in two main categories. The first one corresponds to the identification of data related to the flights, like their coordinates, their ID, identity of speaker etc. The second aims to label the content of phrases, notably in terms of illocutionary function. This last category includes many fields. They marks for example opening and closing of dialog, politeness, or correction. In the second part of this article, we describe the study made on this last illocutionary act.



Caption : *Ctr*: Center ; *CS*: Call sign ; *Hes.*: Hesitation; *SC*: Self Correction

Figure 2: *Annotation of a simple order at two levels*

Work tool

The tool we used for transcription is Transcriber. It is a software developed at the DGA (Délégation Générale pour l'Armement: in English; General Delegation for Armament) to permit the transcription of broadcast (Barras et al., 2000). It offers advanced functions of transcription and annotation. It also allows to align transcription on signal. Furthermore, Transcriber gives opportunity to save transcription under several electronic formats, among which XML[3]. This last format is conceived to be easily portable and handled.

[3] eXtensible Markup Langage.

Its usage is especially appropriate since this format has precisely been chosen to structuring the data obtained after the transcription of our corpus. Moreover, a DTD corresponding to the specifications was elaborated (Coulon et al., 2001). This DTD was completed by our added specifications.

These possibilities allow to simplify statistical enquires, such as counting the number of occurrences of the various strategies.

Exploitation of Transcribed Corpus: Application to Errors and Corrections Study

In a previous study (Bouraoui et al., 2003), we presented a complete study on this topic[4]. It is not the main subject of the present article. Consequently, we will only give the most outstanding results. Indeed, our aim is to illustrate the interest of this kind of work for the study of interaction between controllers and pilots. First, we present the categorizations we made, and conclude by giving the main results and comments.

Errors typology

After several viewings of the corpus, we noted that, whatever the error is, it's not the whole utterance (simple or complex, as definedabove) that is wrong, but only a part of it, or the way it is constructed. Due to this observation, we defined the following classes of errors:

- On an attribute: we mean by "attribute" an alphanumeric data that can be considered as an argument of a command. It can be for example a plane call sign ("Britair 452"), a position ("9 0"), a town ("Paris"), etc;
- On a command: a term (most often corresponding to an order, such as "climb", "request", etc.) is substituted to another;
- On utterance structure: a word or a group of words is not at its correct position in the utterance. For example "Air France 41 82 good morning climb level identify climb level 140": here, the speaker realized that he began to give the order "climb level 140" before the order "identify". Consequently, he corrects himself. The phraseology imposes the respect of the structure;
- On the language used: the speaker notice (or is being noticed) that he does not speak in the correct language (French instead of English or vice versa). For example, in the following dialog, the pseudo-pilot reminds to the controller that he must talk to him in English: Controller: "November 9 O O euh Fox Roméo contact ENAC 123 décimale 8" – Pseudo-Pilot: "in English please". This category is totally dependant of the ATC domain. Indeed, it is due to the fact that the controller has to speak one language according to the pilot he addresses to.

When an error is noticed, whether it is by the speaker or his interlocutor, it gives rise to various strategies of correction and self-correction, which we describe below.

Correction and Self-correction Strategies

We'll make a distinction between three main strategies of correction: self-correction of an element of the utterance being produced (either attribute or order), self-correction of a previous utterance, or correction coming from the interlocutor. The distinctive features of these categories are based on the person who does the correction (speaker or interlocutor) and the moment when it occurs. Indeed, we think that these different kinds of corrections can occur in distinct ways, and consequently be characterized by specific markers. Some studies on others oral corpora (notably (O'Shaughnessy, 1992), (Nakatani & Hirschberg, 1994), (Bousquet, 2002)) also revealed the existence of a phenomenon called "false-start" It occurs when the speaker begins a word, and stops producing it before the end. We considered it like an other category of self-correction.

Here follow examples of each of these categories, taken from our corpus (we set the element being corrected in italics):

- Self-correction: "KLM er 2 1 5 climb level 1 9 0 contact ENAC 120 contact ENAC er *1 2 6 decimal 8 5*.". The controller asks to pilot to go to level 190, and to contact ENAC on frequency 126.85. He makes a correction on the frequency to use. A particular kind of self-correction is false-start. For example: "Fox Golf Hotel Mike November ENAC good morning (…) speed minim er 200 Knots *minimum*.". The speaker begins to utter the word "minimum", and stops himself before ending it for he noticed that he did not give the speed;
- Correction of a previous utterance: here is a short dialog between a controller and a pseudo-pilot: Controller: "er Fox Kilo Charlie maintain level 1 7 0."-Pseudo-Pilot:"to level 1 7 0 Kilo Charlie." - Controller: "er Fox Kilo Charlie correction maintain level *1 9 0*." The controller first gives a position to which the pseudo-pilot must go. The pseudo-pilot confirms, but afterward, the controller

[4] Based on the two thirds of our corpus that were processed at that time. The present study is based on the whole corpus.

corrects his previous order, that was giving wrong coordinates;

- Correction from the interlocutor: here again, a dialog between a controller and a pseudo-pilot: Controller: "euh TAT 289 Mike Lima (…) join Poitiers" - Pseudo-Pilot: "Lacan Amboise Poitiers it's TAT Mike *India*.". In this example, the controller made a mistake on a part of the call sign of his interlocutor. Consequently, this one corrects him.

Markers

This part will be subdivided in two: we will first make general remarks about the different markers picked out, and then focus on the case of lexical ones, which present some interesting features.

General remarks. Two questions rise when one speaks about makers of a given phenomenon: what is the length of the scope around the phenomenon where something can be considered as marker, and which are the kinds of markers searched. Here are the principles we observed after viewing the corpus:

- We fixed the scope to 3 words before and after the correction phenomenon itself; this value results from empirical observations, as well as from the fact that some three "words" sequences form in fact the call signs; for more details on that point, see (Dourmap & Truillet, 2003);
- Three classes of markers were used: lexical, accentual and finally spontaneous speech phenomena. The two last ones results from the oral nature of the corpus: we employ the term "accentual" to designate the emphasis put on a word by the means of a variation of prosodic features (intensity for example). Thus, when a speaker corrects a wrong element within a call sign, it arrives that the element being corrected is pronounced with a particular accent. Let's take for example "Lacan Amboise Poitiers it's the TAT Mike *India*" (previously mentioned). The element in italics, that corrects a wrong value previously given, has been accentuated by the speaker, The class of "spontaneous speech phenomena" puts together various phenomena such as hesitations, repetitions (contrary to (Shin et al., 2002), we didn't put them in a specific category), or pauses. We call pause a non-speech period during more than half a second. We formulated the hypothesis that a silence during such a length is revealing of an enunciation problem such as the thought time necessary to find the correct word to say.

Lexical Markers. Among the lexical markers, we made the following classification, from what we observed:

- Deictic: word referencing to other word, such as "it's" (or "c'est" in French). The most frequent configuration is the following: "it's *CS*" (where *CS* is a call sign; for instance: "it's Alpha Mike Lima 753"). One should note that this usage of deictics are also quite frequently used in other contexts, especially by pilots to introduce themselves;
- Excuse: for example, "sorry", "excuse me", etc.;
- Negation: any words used in order to negate something, the most common one being "no";
- Correction: the word "correction". Its usage is explicitly asked by the phraseology for marking the correction of an utterance. It is also mentioned that the correction must be followed by the element corrected. Due to its status in phraseology, we put it in specific category.
-

Results and Comments

We'll display our statistics according to the classification presented above: firstly errors, then correction and self-correction strategies, to conclude with their markers.

Errors

On table 1, the reader will find the number of occurrences and the percentage (calculated in comparison with the total number of errors) of each category.

	Number	Percentage
Attribute	132	51,36%
Command	93	36,19%
Utterance structure	11	4,28%
Language	21	8,17%

Table 1: *Number and percentage of errors categories*

There's the same number of noticed errors that of corrections. (see also table 2). This is normal: any error has to be corrected at a moment or another, the sooner being the best. Most of the errors concern what we called "attribute", along with "commands". It is not surprising. Nearly all utterances contain at least one reference to a call sign, a speed, etc. The same reasoning can be applied to "commands". However, there is 1.5 times less errors committed on "commands" than on "attributes". This can be explained by the fact that "attributes", especially call signs and positions, are quite complex sequences of numbers and letters. Furthermore, they are only used in ATC context. Consequently, they certainly require handling an important cognitive load, thus leading to more errors. The cognitive load is all the more high since the apprentice controllers are in formation. This also explains the lesser number of errors of command utterances (nearly two times less occurrences than for “attributes”) and of structure (more than six times less occurrences than for “attributes”).

Corrections and Self-corrections

In table 3, we display the number of occurrences of the different kinds of correction found in the corpus. We also give their percentage in comparison with the number of speech turns. This last result must be tempered. Indeed, there are sometimes several corrections occurrences for one speech turn. In spite of this, it gives a good idea of the global proportion of this phenomenon through the corpus.

	Number	Percentag e
Self-Correction	232	90,27%
Self-Correction of a previous utterance	16	6,23%
Correction by interlocutor	9	3,50%

Table 2: *Number and percentage of corrections strategies*

It appears that the most frequent kind of correction is the first one: the speaker corrects himself, during his current utterance. We now compare this result with those obtained a corpus of train reservations (Kurdi, 2003). The author count 241 self-corrections, on a total of 5300 speech turns[5]. In proportion to our corpus size, that makes a lot more self-correction occurrences in this corpus than in our. Lets examine this from a psycholinguistic point of view. It is admitted by most of authors (notably (Reason, 1990, p. 156 sq.) or (Levelt, 1999)) that, in the end of the speech production process, the locutor proceed to a “control” of what he actually said, in comparison to what he intended to say. In controllers’ production, this “control” is obviously more efficient that for people who does a “daily” task. Here again, we think that the responsibilities that the controllers does have enhance their attention to what they said.

Conclusions and Perspectives

We have studied a corpus of spontaneous speech dialogues, consisting of interactions between air controllers in formation and “pseudo-pilots”.
We shown, first, that the transcription and annotation of this kind of corpus is a very complex task. Its realization depends on the exploitation planned. Then, we detailed the methodology we applied. We chose it in order to constitute a structured data base in XML format.

In a second time, we sought to present the interest of corpus based works to study different sides of the ATC interactions. As a concrete illustration, we gave the main results of a previous study on errors and corrections in our corpus. It appears that the most frequent kinds of errors concerns what we called “attribute”, such as callsigns. We linked this to the fact that memorizing values need an important cognitive load, especially for novice controllers.

More generally, we saw that phraseology plays an important role for some of the errors that occur. For example, it is the case when the cause is a deviation regarding to the organization of the utterance.

In order to further explore this analysis, we plan to follow the two main ways we presented in this article. On one hand, setting up an enhanced methodology of transcription and annotation, sufficiently robust to be implemented into an automatic or semi-automated system, for example thanks to CACAO system (Bousquet, 2002). On the other hand, continuing our study on management of errors and their corrections. We could do this by leading cognitive studies on the notion of “attribute” and its cognitive load. A comparison between the apprenticeship dialogs we have with real ATC situations ones could also be done. This would benefit to one of the goals of VOICE projects, i.e. the implementation of communicating agents that would help pseudo-pilots and more generally to all researches concerning speech in ATC.

Acknowledgments

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5 (Kurdi, 2003, p. 74-75).

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