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DIA-PHONEME RELATION OF THE ATC-PILOT RADIO COMMUNICATION PHRASEOLOGY PHONETIC CONFUSION

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ABSTRACT

Air Traffic Controller (ATCo)-Pilot communication may contain frequency misunderstandings. The radio communication has different types of disturbances including background noise, atmospheric disturbances and high-power RF (Radio Frequency) source interactions. In this study, general phraseology misunderstandings structure were analysed to reduce the radio communication failure rate. Pilotage and Air Traffic Control (ATC) trainees are examined with a real Yesilkoy Approach voice record between ATCo and pilots. Besides, a fill-form, to define their listening failures, was applied to the participants during the experiments. The fill-form results indicated that the common radio communication failures between ATCo and pilot are related with the similarity of NATO (North Atlantic Treaty Organization) phonetic letters and some numbers. To reduce the similar phonetic confusion, a dia-phoneme usage classification is proposed in order to avoid the spelling conflicts in this study.

INTRODUCTION

During ATCo trainings, two-way radio communication is generally used to simulate the real-life scenarios as they are. [Bardach et al., 2003; Miller and Greenspan, 2008]. The ATCo's control the aircraft by using the two-way communication systems such as a radio and the public switched telephone network (PSTN). This communication structure is applied usually with a proprietary circuit-switched network where the work stations of the air traffic controllers are connected via an electronic line exchange to the radio and the telephone network.

One of the essential principles of air traffic control is the clarity of the radio communication between ATCo and Pilot [Hopkin, 1995]. ATCo-Pilot communication is executed by two-way radio system usually and accessed through hardware such as on-ear, earbud headset and microphone etc. In order to ensure safety, neatness and rapidity, the communication circuit composes of a confirmation and correction process between the pilot and the ATCo (Airbus, 2004). Numerous incapability's are happened commonly during this kind of communication method. There are lots of pros and cons of this kind of communication method. The main insufficiency is to understand the person in front of the headset, due to background noise (sometimes called static), atmospheric disturbances such as electrical storms and rains, and high-power RF sources (such as radar equipment and broadcast equipment). Communication errors can be classified into two categories: errors caused by ATCo-Pilot communication and the errors caused by the communication between the ATCo's. These errors occur due to the incorrect read back, returning with a wrong call-sign, non-standard phraseology and clip of the call sign [Moon et. al., 2011].

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There are two main issues regarding classic radio communications. Channel congestion and the language – related problems can be accepted as classic radio communications. Geacăr has showed that according to their statistics almost 80% of all pilot radio communications contain one or more errors. However, the same statistics show that 30% of all incidents are caused, in the case of the air traffic controllers, among others, by communication errors and 23% of flight level intrusions are caused by communications errors (40% in the case of runway incursions) [Geacăr, 2010].

The Boeing Company proposed that the commercial aircraft accidents happened in the last 10 years, 55% of them were caused by pilot error, 17% by aircraft defect, 13% by weather condition, 5% by airport and ATC, 3% by maintenance and 7% by miscellaneous matters (Boeing, 2006). ATC caused accidents get the 5% of commercial aircraft accidents, which is relatively lower than the other factors. But it should not be overlooked that the 55% of the accidents due to the pilot error accounts, either directly or indirectly are related with ATCo, since the cooperation between a pilot and an ATCo takes a significant part of aircraft operation.

While the problem attracted the interest of Prinz et. al. and was identified as threat in a study by Eurocontrol, it has not really attracted the Air Navigation Service Providers (ANSPs) attention so far [Prinz et. al. 2005., Eurocontrol, 2002] However this ensues from not causing crucial damages up until now, on the contrary this is caused by the cautious policy of ANSPs. However, Emilio showed that there is a significant number of cyber-attacks and examples demonstrate that they induce a real danger for confusing conversations between air traffic controllers and pilots [Iasiello 2013; LiveATC, 2011; Chivers and Hird, 2013].

The voice communications were obtained from a set of exercises. However, they were analysed in the concepts of grammar and semantics, and later correlated with the information extracted from the structure, observing the controller works [Manning et. al., 2002; Manning and Pfleiderer, 2003]. Ability of interacting with the structure in terms of control commands understanding and pseudo-pilots text-to-speech were also provided by Cordero et.al. [Cordero et. al., 2012]. These controller works obtained from any of the two sources may feed different workload calculation models based on controller events.

6 types of communication errors are proposed by Moon et. al. (Table 1.). Radio communication disruption can cause these errors such as call sign truncation, incorrect read back and clipped call etc.

Table 1: Communication Error Classification [Moon et. al., 2011]

Communication Error	
Difficulties in communicative interaction or aeronautical operations	Incorrect readback not challenged
	Wrong callsign used
	Non-standard phraseology
	Callsign omission/truncation
	Missed call
	Clipped call

During this study, the mistakes during the two-way radio communication between ATC and pilotage trainees will be classified. A questionnaire is applied during listening of the two-way radio communication instructions. It shows that the mistakes are caused due to the incorrect assumptions regarding the letters or numbers that were half-heard or guessed improperly.

RESULTS AND DISCUSSION

The experimental two-way communications were recorded from real ATCo-Pilot conversations in Istanbul Ataturk Airport Approach Control Position. Since these recordings were collected from the HF radio data links, they have lots of noise and disturbances.

The instructions in the recordings were selected according to their call signs which have common misunderstood letter pairs (Table 2.). During the experiments, the 20 applicants were listened with 15 conversations. Through these conversations, they tried to catch and write

down the call signs. The statistics of the applicants according to the valid and missing answers are shown in Table 3.

Table 2: Call signs used in the conversations

Conversation Number	Call Sign
1	THY6DT
2	THY7WU
3	THY7JT
4	KAC153
5	THY7JT
6	THY8DP
7	THY5220
8	KAC153
9	THY7WU
10	THY6DT
11	THY8MY
12	THY831
13	THY9PE
14	THY10Z
15	THY22R

Although some of the conversations have the same call signs, they were misunderstood. Because, the voice recordings have different disturbances and noises. Main misunderstood alphanumeric alphabets are as shown:

Letter “J” is understood as number “8”,
Number “2” is understood as letter “Z”,
Letter “Z” is understood as number “2”,
Letter “Z” is understood as number “0”
Number “0” is understood as letter “Z”
Letter “E” is understood as letter “K”,
Letter “M” is understood as number “9”.

This experiment showed that the letters and numbers that were misunderstood mostly due to the HF noise and disturbance were “J, Z, E, K, M” and “8, 2, 9”.

Table 3: Applicant Statistics

Applicant #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Valid Answer Amount	8	4	6	11	6	7	8	8	9	6	12	4	15	13	9	8	9	12	10	8
Missing Answer Amount	7	11	9	4	9	8	7	7	6	9	3	11	0	2	6	7	6	3	5	7

In Table 3, first ten applicants are air traffic control students, remaining are pilot training students. ATCo students are more prone to get the voice recordings. Because their simulator studies are applied with pseudo pilot radio communications. They have at least 3 hours of simulation in a week, while pilot training students have less than 2 hours of simulation without radio communications and flight. According to the results, air traffic control students were more experienced for voice recordings. In Table 4, the average, standard deviation, maximum and minimum of the missing and valid answer amount is presented.

Table 4: Valid and Missing Answer Comparison

	Average	**Max**	**Min**	**Std. Dev.**
Valid Answer	8,65	15	4	2,82
Missing Answer	6,35	11	0	2,82

Average valid answer is 8.65 which means 57.66 percent of the total conversations. Air traffic controller and pilots increase this amount by predicting the conversation in front of their frequency. This brings lots of misunderstanding problems.

To reduce the misunderstandings during radio communication, some similar spelling letters and numbers should be controlled during the assignment of the call sign assignments. These similar letter and number pairs are shown in Table 5.

Table 5: During radio conversation, misunderstood letter and number pairs

Similar Spelling Letter and Number Pairs	
juliet	eight
mike	nine
two	zulu
zulu	zero
echo	kilo

Usage of these letter and numbers shown in Table 5 must be in control. To emphasize the pronunciation of these letters and number, a rule-based method can be adopted to the call sign assignment. This method provides the use of dia-phoneme classification shown in Table 6. Dia-phoneme is a nonconcrete phonological unit that classifies a correspondence between related sounds of two or more diversities of a language or language cluster.

Table 6. Dia-phoneme and examples of some English words [IPA, 1999]

Dia-Phoneme	Phones	Examples
p	pʰ, p	**p**en, s**p**in, ti**p, pap**a
b	b, b̥	**b**ut, we**b, b**ravo
t	tʰ, t, ɾ, ʔ	**t**wo, s**t**ing, be**t,** fox**tr**o**t**
d	d, d̥, ɾ	**d**o, da**dd**y, o**dd, d**elta
t͡ʃ	t͡ʃʰ, t͡ʃ	**ch**air, na**t**ure, tea**ch, ch**arlie
d͡ʒ	d͡ʒ, d̥ʒ̊	**g**in, **j**oy, e**dge**
k	kʰ, k	**c**at, **k**ill, s**k**in, **q**ueen, uni**que**, thi**ck, k**ilo, e**ch**o
g	g, g̊	**g**o, **g**et, be**g, g**olf
f	F	**f**ool, enou**gh**, lea**f**, o**ff**, **ph**oto, **f**oxtrot
v	v, v̥	**v**oice, ha**ve**, o**f**
θ	θ, t̪	**th**ing, tee**th**
ð	ð, ð̥, d̪	**th**is, brea**the**, fa**th**er**, th**ree
s	S	**s**ee, **c**ity, pa**ss, s**ierra
z	z, z̥	**z**oo, ro**s**e, **z**ulu
ʃ	ʃ	**sh**e, **s**ure, se**ssi**on, emo**ti**on, lea**sh**
ʒ	ʒ, ʒ̊	**g**enre, plea**su**re, bei**ge**, equa**ti**on, sei**zu**re
h	h, ɦ, ç	**h**am, **h**ue, **h**otel
m	m, ɱ	**m**an, ha**m**
n	N	**n**o, ti**n**
ŋ	ɲ	ringer, sing, finger, drink, seve**n**
l	l, ɬ, l̥, ɬ̥, ɤ, w, o, ʊ	**l**eft, be**ll**, sab**le**, p**l**ease
r	ɹʷ, ɹ, ɾ, ɻ, ɹ̥ʷ, ɹ̥, ɾ̥, ɻ̊, ʊ	**r**un, ve**r**y, **pr**obably, novembe**r,** oscar**,**
w	w, w̥	**w**e, q**u**een, **w**hiskey,
j	j	**y**es, n**y**ala, **y**ankee
hw	ʍ, w	**wh**at

This table, which shows the symbols for the dia-phonemes given in bold and followed by their most common phonetic values, provides a partial system of dia-phonemes for English. For the vowels, a separate phonetic value is given for each major dialect, and words used to name corresponding lexical sets are also given in Table 6. The dia-phonemes and lexical sets are based on Received Pronunciation (Standard in the United Kingdom) and General American; they are insufficient to express all of the distinctions found in other dialects, such as Australian English.

CONCLUSIONS

The aim of the study is to find out the confused letters and numbers during the radio communication between ATCo and pilots due to the HF noise and disturbances and to create a correlation between the dia-phonemes of these letters and numbers and the mistakes. The survey indicated that the mistakes are the result of false assumptions caused by the words or numbers that were half-heard or guessed wrongfully. But the main reason of these mistakes are similar dia-phoneme classification of the letters and numbers.

The analysis shows that the mistakes happen mostly with the letters of J, Z, E, K and M and with the numbers of 8, 2, 9 etc. in the alphanumeric alphabet. These similarities show that the

NATO phonetic alphabet and numbers - also known as ICAO radiotelephonic, phonetic and spelling alphabet [ICAO, 2016]- cause some misunderstandings in some letter and number pairs such as “Zulu- Zero”, “Mike-Nine”, etc. The reason of the misunderstandings due to these pairs are the dia-phoneme classification of the letters in these words.

To enhance the voice communication Correct Understanding Rate (CUR) between ATCo and Pilot, some researches focused on the improvement of the RF communication network. the German Aerospace Center (DLR) is developing a prototype to support air traffic controllers (ATCO) in detecting intrusions into the air ground voice system and therefore allow subsequent mitigating actions to be conducted with the GAMMA (Global ATM Security Management) project [Stelkens-Kobsch et.al. 2015]. Besides this a prototype is developed to perform this Automated Speech Recognition and controllers event detection, as well as the methodology used to reach it [Cordero et. al. 2012].

Further studies regarding to this paper will focus on to improve the voice recognition CUR according to the dia-phoneme classification. As a consequence, an ATCo and Pilot supporting system, containing voice communication which will match the frequency communications and the instructions applied to the boards and Flight Management System (FMS), will be proposed.

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