A MULTI-MODAL APPROACH TO COMMUNICATION IN AVIATION

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As data-link communication makes its way into Air Traffic Control, some controllers fear that their job environment may change and potentially reduce safety. The present paper reports on a small scale real-time simulation that was performed to investigate whether voice and data-link communication can be combined to support each other. The results indicate that time delays are perceived more disturbing for voice than data-link communication and that proper feed-back is vital, especially for voice.

Air Traffic Control, Data-link communication, Multi-modality

1 Introduction

During the past decades, civil aviation has experienced a steady growth that is foreseen to continue. Because of the increase in traffic volume, the capacity limit of current Air Traffic Control is reached, which constitutes a cause of increasing delays in the traffic system. Currently, several technologies are introduced to improve capacity and to provide more optimal routes leading to less fuel consumption and emissions.

To maintain safety in the air traffic system air traffic controllers currently maintain continuous communication with the pilots in the system using VHF-radio technology. As controller-pilot voice communication constitute workload (Porterfield 1997; Manning et al. 2003) the induced voice communication resulting from increased traffic pushes current communication systems to their capacity limits, thus making data-link communication an attractive alternative. Present radio voice communication also suffers from shortcomings such as poor sound quality and language problems, which could have safety implications in that they reduce message throughput and increase the risk of misunderstandings.

Previous interviews have shown that data-link communication in aviation may potentially lead to a quieter and more boring working environment and may contribute to a feeling of reduced involvement and degradation of situational awareness (Barchéus and Mårtensson 2003; Trzmiel and Rognin 2006). Also, the shared radio frequency allows implicit knowledge sharing to surrounding aircraft, generally known as “party line information”, which may be important for issues such as turbulence or traffic density (Midkiff and Hansman 1993). Although data-link communication decreases voice frequency load, it may introduce delays in the system caused by transmission time (Pinska and Whiteley 2004) and pilot response time (Conroy et al. 2002).

The present research investigates operators’ subjective opinions of different combinations of voice and data-link communication .

2 Theory

If operators in a team are sufficiently close, e.g. pilots in a cockpit or adjacent air traffic controllers, coordination often occur in informal manners, and contain many cues that are implicit in nature (Rognin and Blanquart 2001; Garbis and Artman 2004). The use of informal communication usually combine a multitude of cues, such as gestures, tone of voice, and of course also incorporate the formal message. Such multitude of cues is also a base for learning and facilitation of communication in contexts where areas of work overlap between job functions (Hutchins 1990). In present Air Traffic Control, communication between controllers and pilots is performed using radar and radio in parallel, rather than combined. With the introduction of data-link communication into Air Traffic Control, combining the modalities audio and video is made possible, which would mimic the situation in close collaboration.

Bolic and colleagues (2005) introduced the metrics Physical utilization and Cognitive utilization of time, Physical utilization being the time used for actual occupancy of the radio frequency in ATC communication and Cognitive utilization being the time that a controller has to remain mentally focused on a particular transaction. A transaction may be described as a series of messages regarding one topic, while a message is defined as a single utterance by one operator (Barchéus 2006). Cognitive utilization thus equals transaction time whereas Physical utilization equals message time. As current data-link technology demands considerable time for transmission and the modalities used may increase operator handling time, data-link communication may lead to a situation where the Cognitive utilization far exceeds the Physical utilization.

Also, in current operations controllers and pilots often perform cognitive as well as physical work during the actual message delivery, which is made possible by the fact that the message is transmitted at the same time as it is received. In Figure 1 active work (i.e. actual speech) is grey and passive work (i.e. evaluating the instruction) is white.

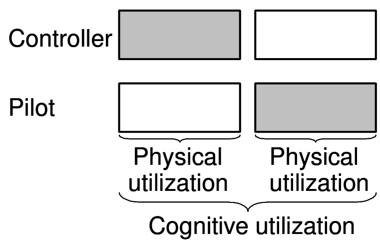

Figure 1: Physical and Cognitive utilization in voice communication

In data-link communication there is no Physical utilization present (defined as voice communication). On the other hand, because of the transmission delays caused by the data-link and the sequential manner in which messages are sent, Cognitive utilization may increase vastly as shown in Figure 2.

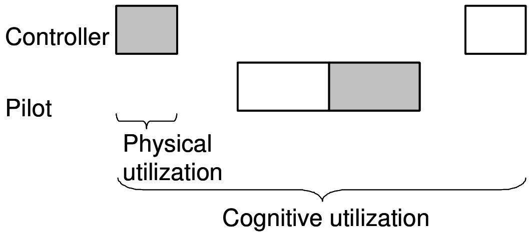

Figure 2: Physical and Cognitive utilization in data-link communication

Simulations of data-link communication have shown the presence of this fact, and propositions have been made to use the freed time between a controller sending a message and getting a reply to other tasks. However, controllers regarded this as being potentially confusing (Öze et al. 2003).

By using voice as attention getters there is a possibility that lags caused by use of data-link may be counteracted. Since detailed information, e.g. sector frequencies, may be transmitted the required phraseology in the data-link setting could be heavily reduced. In the present investigation, the hypothesis was that the voice message would prompt the controller and decrease response time, thereby decreasing cognitive utilisation of time.

3 Methods

3.1 Setup

To investigate the presented scenario a lap-top based simulation of air traffic control was designed. The interface is a simplified version of the Eurocat 2000 E systems in use at Stockholm and Malmö ATCC. Data-link transmissions were indicated by a frame around the appropriate field on the aircraft label (Öze et al. 2003) as shown in Figure 3.

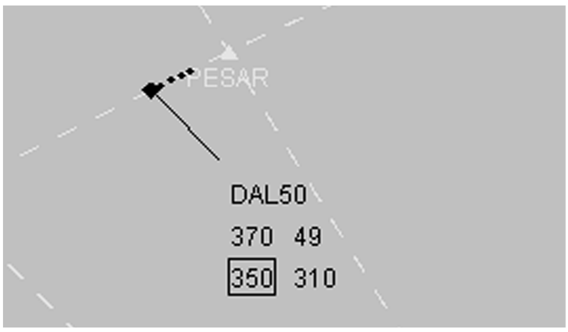

Figure 3: Data-link transmissions were indicated by a frame. The controller has issued flight level 350 and is waiting for a response.

Three scenarios were investigated;

- voice only, all communication was managed by voice. This scenario was considered base-line as it represents current procedures. Pilot messages were pre-recorded sentences that were played promptly on the test leader's call.
- separate voice/data-link communication, communication was managed by voice or data-link exclusively meaning that controllers and (simulated) pilots could choose one medium at own discretion. Subjects were instructed to reply using the same medium as the call.

- simultaneous voice/data-link communication, communication was prompted by voice but messages were shorter since some information was transmitted via data-link.

In cases where data-link transmission was simulated, transmission time of the data-link was simulated randomly according to a Poisson distribution with a mean-value of six seconds in each direction (Pinska and Whiteley 2004). When data-link was chosen in the separate voice/data-link scenario, pilot implementation time was simulated using a Poisson distribution with a mean-value of twenty seconds (McGann et al. 1998). In the simultaneous voice/data-link scenario voice was used as a priming message for the pilots/test-leader. Therefore, pilot handling time was controlled by the test-leader. When a message arrived, the assumption was that the pilots only have to check the consistency with the previously sent voice message. Since the message is readily available on flight deck even after a transaction, the read-backs that constitute current procedures would not be needed. The read-backs are used to serve as a safety net because pilots' short term memory is heavily loaded. Because of this, the pilot response would not have to be a complete read-back in the data-link scenario, but only a voice response that a proper data-link message has arrived. The pilot response in the simulation was therefore set to "Roger" followed by the aircraft callsign. Also, transferring an aircraft to another sector would not have to include the frequency of the sector.

3.2 Subjects and procedure

Eight operational air traffic controllers from Stockholm ATCC were used as test subjects. Their age varied between 26 and 41 years and their operational experience varied between three and 17 years. Participation was voluntary and the subjects were not reimbursed for their participation.

Each test run begun with a short description of the simulation and the simulation objectives. Then the subject conducted a training exercise to get familiar with the simulation environment and procedures. After training, three simulation exercises were conducted. Each simulation exercise was preceded by a short training run to familiarise the subject to the special circumstances in the exercise i.e. the different procedures regarding voice/data link. The two data-link scenarios were shifted between the test subjects to eliminate learning effects.

After each run the subject were instructed to give comments regarding the factors affecting communication. Spontaneous comments during the simulation runs were recorded and in some cases followed-up for clarification after the run.

4 Results

The subjects generally expressed favourable opinions about the simulation platform, indicating sufficient face validity. Negative comments included; minor problems with mouse input, unfamiliarity with the area and the traffic, and absence of conflict detection tools.

Choosing between simultaneous and separate voice/data-link communication, the subjects favoured the scenario where voice and data-link were separated. Though the time delay caused by data-link did increase workload, as reported by the subjects, it was considered functional for non-critical communication. As sector transfers are non-critical and also add considerably to total voice communication (Barchéus 2006), data-linked sector transfer was a very much appreciated application.

Using voice as attention getters in the simultaneous condition was discharged as unviable, mostly because of the time delays. However, some kind of audio signal was wanted for data-link messages originating from aircraft. Also, using the term "roger" to indicate reception of a data-link message was not considered functional. The subjects wanted proper read-backs to ensure that the pilot had understood the clearance. Many of the subjects that accepted the simultaneous voice/data-link setting tended to focus on the use of data-link, rather than the change of voice communication.

Several subjects affirmed that introduction of data-link communication could render the job more silent, and acknowleged that voice communication with pilots is a positive factor in their work. Some comments also indicated increased feeling of detachment when using data-link communication, e.g.; "Feels even more like a game when you don't talk", "Then you could sit and click away without talking […] [you could] click without having control over the effect it has on conflicts."

5 Discussion

Each run was limited to a period of ten minutes which may be a too short time to experience the task as silent. However, the comments indicate that the preference of voice or data-link is connected to the individual preference for the activity of speaking to pilots and to the general level of trust in automation. Similar results were previously found by Barchéus and Mårtensson (2003; 2006).

In the simultaneous condition, the use of "roger" rather than a complete read-back was discouraged, and some subjects expressed concerns about the pilot side of communication. While recognising the advantages of visual communication, they remarked that they would like to be assured that the clearance sent by the controller is the one implemented in the aircraft. This was suggested to be assured by being implemented in the aircraft from the clearance input by the controller rather than being input by the pilot. Such implementation would correspond to a higher level of automation regarding the pilots' work, which must be properly attended.

As this initial simulation was concerned with normal procedures in different scenarios, no measurements have been performed on error rate etc. In other words, all communication was considered perfect and no erroneous inputs or misunderstandings were assumed. To be conclusive, further measurements must be performed to assess possible errors or factors affecting workload such as erroneous inputs, confusion between aircraft callsigns or interactions between several clearances.

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