Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Executive summary

Using Voice to Control the Civil Flightdeck

Problem area
Human Errors, slips or mistakes are often part of the cause of incidents and accidents in aviation. A significant number of those have as underlying cause high pilot mental workload.

Offering the pilot a means to give input to the aircraft by voice rather than having to look at a panel to identify a particular button or switch may help to reduce that pilot workload and as such to contribute to less incidents and accidents.

Description of work
In NLR's GRACE simulator a Direct Voice Input system was installed. This system allowed pilots to give input to the aircraft by voice.

An experiment was executed in which twelve pilots participated for evaluation of the Direct Voice Input system.

Results and conclusions
The hardware functioned fine but before installation in real aircraft the Direct Voice Input needs some improvements. Operation of Direct Voice Input takes more time than the current way of operation.

- The syntax must become simpler
- The recognition rate of the system must improve
- Response time of the system must decrease

All of these issues are of a technological nature and it seems feasible to solve these issues.

Applicability
In cockpits especially during emergencies where pilots have to operate the entire aircraft on their own a Direct Voice Input system seems very relevant. During other situations it seems interesting but at this moment not of crucial importance.

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This report is based on a presentation held at the HCI Aero, Seattle (U.S.A.), 20 - 22 September 2006.

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Summary

The current paper describes a part of the SafeSound[1)] project. The overall objective of that project was to investigate the possibilities of improving aviation safety for ground and flight operations by the application of enhanced audio functions in the civil cockpit. The current paper focuses on the evaluation of the Direct Voice Input system. This system, which was developed earlier in the project, allows pilots to control parts of the civil cockpit by giving voice commands. Together with other SafeSound features this system was evaluated in a full-scale simulator experiment. The experimental design and a number of results of that evaluation experiment are discussed in this paper. The main conclusion is that the system is quite promising. Technological improvements can enable full exploitation of all benefits of voice input features and would therefore enhance the system drastically.

[1)] The SafeSound project ran from May 2002 until November 2005 and was funded by the European communities as part of the Growth Project under contract number G4RD-CT-2002-00640. The project partners are: Thales Avionics (project coordinator) from France, NLR and TNO from the Netherlands, AKG from Austria, Risoe from Denmark, EUROCONTROL and Airbus from France, and Alitalia from Italia.

Contents

Abbreviations

Abbreviation	Meaning
3DS	3D Sound
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependent Surveillance Broadcast
AMS	IATA code for Amsterdam Airport Schiphol
ASR	Automatic Speech Recognition
ATC	Air Traffic Control
ATM	Air Traffic management
CAT	CATastrophic *or* CATegory
CDG	IATA code for Paris Airport Charles de Gaulle
CNS	Communication, Navigation and Surveillance
CPDLC	Controller Pilot DataLink Communication
DCDU	Data Communications Display Unit
DMM	Dialogue Management Module
DVI	Direct Voice Input
DVO	Direct Voice Output
EAS	Enhanced Audio System
EFIS	Electronic Flight Instrument System
ECAM	Electronic Centralized Aircraft Monitoring system
EFOB	Estimated Fuel On Board
FBW	Fly By Wire
FL	Flight Level
FMS	Flight Management System
ft	feet
GRACE	Generic Research Aircraft Cockpit Environment
HF	Human Factors *or* High Frequency
HMI	Human Machine Interface
IMC	Instrument Meteorological Conditions
LHR	IATA code for London Airport Heathrow
MEL	Minimum Equipment List
ND	Navigation Display
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium
NM	Nautical Mile(s)
NOTOC	Notification TO Captain

PF	Pilot Flying
PFD	Primary Flight Display
PNF	Pilot Not Flying
PTT	Push-To-Talk
RA	Resolution Advisory
RMP	Radio Management Panel
SA	Situation Awareness
SOP	Standard Operating Procedure
TA	Traffic Advisory
TCAS	Traffic alert and Collision Avoidance System
TOW	Take-Off Weight
TSA	Team Situation Awareness
VHF	Very High Frequency
WL	(Mental) WorkLoad
ZFW	Zero Fuel Weight

1 Introduction

Human errors, slips, or mistakes are often (about 70% depending on the criteria and definitions [3]) part of, the cause of incidents and accidents in aviation. A significant proportion of those can be attributed to pilots being involved in numerous, high workload, tasks.
Given the foreseen traffic growth in the near future it is quite likely, if no actions are taken, that the incident and accident rates will increase dramatically. The SafeSound project's aim is improving safety during ground and flight operations by means of enhanced audio functionalities [3]. This aim was executed by first identifying the requirements of these functionalities for current flight operations and then developing an audio interface that would reduce the number of human errors resulting from the above mentioned sources.
The SafeSound interface comprises three different systems Direct Voice Input (DVI), Direct Voice Output (DVO) and Three Dimensional Sound (3DS). In this article the emphasis will be on the Direct Voice Input (DVI) system. The focus of the current article will in particular be on the evaluation experiment and not on the design the DVI system or any other preceding steps in the SafeSound project.
The principle of applying voice input in the cockpit is not new. Especially in the domain of military cockpit research it was used more often. Points of interest where the SafeSound approach deviates from other approaches are:

- Two pilots in one cockpit are able to use the system;
- The boom mike but also an array microphone are both available as input devices;
- It is not necessary to train the system to get used to a particular pilot's voice. It responds well to the entire group of subjects without individual training.

In this article the focus is at the use of DVI in the cockpit as such. The starting point for the study is the DVI system that was developed earlier in the SafeSound project. For more details about that system, and how it was developed, the reader is referred to the SafeSound reports [1], [2], [3], [5], [6] and [7] as well as to other SafeSound reports that are mentioned in this paper. The subjective impressions of the pilots about DVI, as well as their reported workload and error rates will be described in order to provide an impression about the advisability of pursuing the implementation of DVI in the cockpit, and as such are the core of this paper. The link with safer aviation in the future is an important SafeSound aim, but is beyond the scope of this article.

1.1 Direct Voice Input

One of the features that is created for the SafeSound project is a DVI system. DVI is an interface whereby the pilot gives instructions to the aircraft by voice, which is considered to be more intuitive and less distracting compared to current interfaces. As a result pilots will have more and better opportunities to focus on their piloting task and human error will be reduced. Eventually that will result in an even safer aviation than we currently have.

For operation of the DVI system the pilot uses either the headset or a microphone array, which is mounted on the glare shield of their cockpit. A dedicated syntax is used to give specific commands. In the current implementation the pilots can give commands concerning the following aircraft applications:

- Radio frequency change;
- Navigation Display (ND) layout change;
- Primary Flight Display (PFD) layout change;
- Flight Management System (FMS) input;
    - Runway (RWY) change.

1.2 How to give voice commands

In general one can say that giving DVI commands is always done in a fixed pattern.

1. The pilot (either left or right seat) who wants to give a command activates the DVI system by pressing the Push-To-Talk (PTT) button at the side stick next to the autopilot disconnect button.
2. The pilots wait until the DVI feed back display (which is located just above the navigation display (ND) turns white, as a sign that the system in ready to receive his command.
3. The pilot addresses the system that he wants to command by saying the name of that system (i.e. navigation display, or flight management system) and releases the PTT button.
4. The DVI feedback display shows the DVI’s interpretation of the system that the pilot wanted to address.
5. The pilot pushes the PTT again until the DVI feed back display turns white and says aloud the command that he wants to give the system that was addressed after which he releases the PTT button.
6. Then the command will be executed automatically, unless it is a command that was considered to have such an impact on the flight that requires a confirmation (which is a double click on the PTT button) from the pilot.

For more details about the operation of the DVI and the complete DVI-syntax the reader is referred to the SafeSound documentation in general and the briefing guide for the pilots [1] in particular. The above mentioned DVI hardware components can be seen in Figure 1.

2 Methodology

2.1 Environment

The SafeSound full-scale evaluation experiment was conducted in NLR's research flight simulator Generic Research Aircraft Cockpit Environment (GRACE) in Amsterdam, The Netherlands. GRACE can simulate a number of different cockpits ranging from the Boeing 747-400 and Airbus family environments to Fokker 70/100 cockpits. For the SafeSound evaluation experiments a generic Airbus configuration was selected. A high fidelity simulator like GRACE allows researchers to perform realistic experiments in a fully controlled environment, but including the opportunity of installing new equipment, like SafeSound's DVI in the cockpit. A photograph of the DVI hardware that was built in the GRACE cockpit may be found in Figure 1.

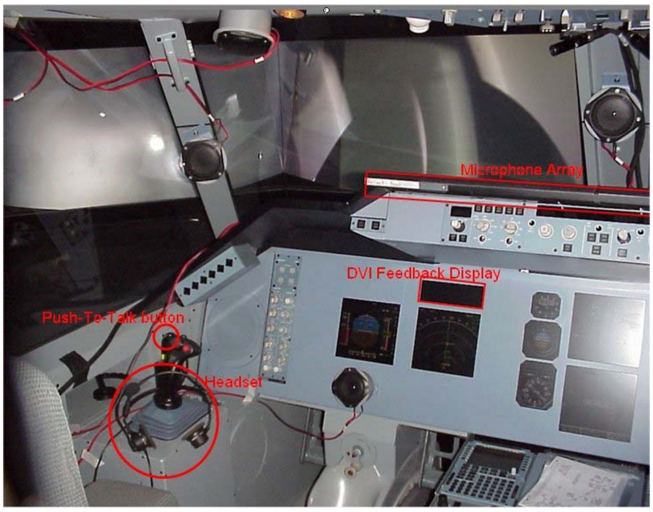

Figure 1: Interior of NLR's GRACE cockpit with SafeSound's DVI related hardware (microphone array, DVI feedback display and the PTT button) that was used by the pilots during the experimental flights.

More information about GRACE is provided in [2]. The modifications that were made to GRACE in order to make this SafeSound evaluation experiment possible are described in [6].

2.2 Subjects

Six crews of experienced Alitalia A320 pilots participated in the experiment. Each crew comprised a captain and a first officer so that the pilots could function as much like in their normal daily routine.

2.3 Training and schedule

Prior to participation in the experiment the crews were trained. The first step of this training was a briefing guide that was sent to all participants. In this guide details about the simulator itself

and the SafeSound functionality (in particular the DVI hardware and the complete DVI syntax) and the procedures that would be followed were provided.
Further there were two full day training sessions scheduled at Alitalia in which the crews participated. Here the pilots received detailed instructions and where able to verify, in desktop settings, whether they mastered the DVI syntax.
Then the pilots arrived crew after crew at the NLR for two day sessions. During such a period each crew familiarised with the GRACE and the SafeSound equipment in one morning. In the afternoon that followed they performed two evaluation flights, the next morning they performed another two evaluation flights, and in the last afternoon the entire experiment was debriefed and evaluated.

2.4 Experimental design

A within subjects and between flights experimental design was used. The above mentioned flights were two return flights between Amsterdam (Schiphol) and London (Heathrow). During half of the flights the SafeSound functionality was switched on and half of them the functionality of these tools was switched off. Note that not just DVI but also direct voice output and three dimensional sound features were evaluated during these flights. Further the captain was pilot flying (PF) during half of the flights and the first officer was PF during the other two flights.
This approach allowed each pilot to make comparisons between the situation with and without SafeSound functionality in both the pilot flying and pilot not-flying role. As such the approach gave optimal opportunities for evaluation of the added value of the SafeSound tools.
During the simulated flights the pilots used both their headsets and a so called microphone array as input devices. For reasons of comparison between flight the crews were asked to use their headsets below flight level (FL) 180 and use the microphone array when they were flying altitudes higher than FL180.
In the experiment the background noise level was slightly lower than in the real Airbus aircraft. The scenarios themselves contained a number of micro experiments / events (see also Figure 2) which formed together the moments of the flights that the researchers focussed upon during the analysis of the experiment. During these micro experiments, events happened that would demonstrate the added value of the SafeSound functionality.

The different kinds of flights and the events were randomised as good as possible, in order to eliminate order or learning effects from the data analysis.

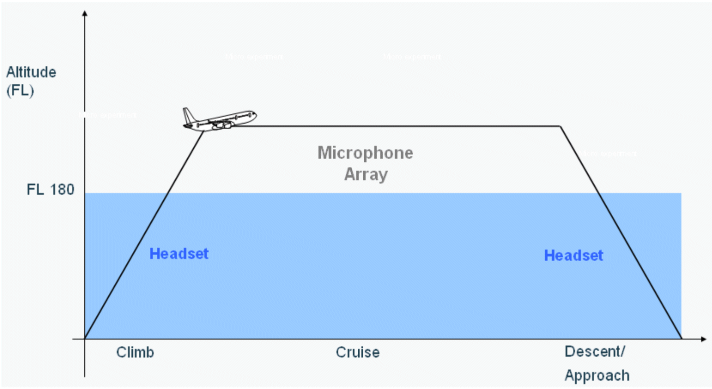

Figure 2: Visualisation of a simulated flight during the SafeSound full-scale simulation experiments. Below FL180 the pilots used their headsets, above the flight level they took their headsets off and used the microphone array.

2.5 DVI Related Features Micro Experiments

Changing the Radio Frequency

During the flight the crew was asked, by Air Traffic Control (ATC) to change their frequency a number of times. Pilots could do that by using DVI. Since ATC was part of the experiment management the request to change the radio frequency could be given at the same moment of the flight for all crews.

Changing Primary Flight Display settings

It was up to the pilots' own discretion to decide if and when to change the layout of their Primary Flight Display (PFD). They could switch the flight director bars on and off and they could change the ILS settings.

Changing Navigation Display settings

It was up to the pilots' own discretion to decide if and when to change the layout of their Navigation Display (ND). They could change the range as well as the mode of the ND.

Reprogramming the Flight Management System for a Runway Change

The commands necessary to change the selected landing runway (RWY) in the Flight Managements System (FMS) were made available by voice. At a moment during cruise, when there was a relatively low workload situation, the crews were asked by ATC to change the RWY. Due to the fact that the nature of this task was definitely not a routine task, this task was given at this relatively quiet moment of the flight. It allowed the crews to steadily perform this task and to take their time for it.

2.6 Data Logging

Prior to starting the experiments it was established which data would be recorded. One data stream that was recorded was coming from NLR's GRACE simulator. These data comprised numerous inputs that the crew made to the cockpit. It further contained a number of 'flight data recorder like' aircraft parameters. Other data that were captured were all DVI inputs, video (there were three camera's in the cockpit) and audio of the pilots. After each flight and at the end of all sessions, but never during flight, questionnaires were filled in and an over all debriefing session took place. Questionnaire provided information mental workload, situational awareness, as well as pilot opinions regarding efficiency, safety, convenience and acceptability. The pilots were also asked to give suggestions for improvement and other application areas. The complete data recording process and all questions that were asked are described in SafeSound deliverable [4].

2.7 Analysis

Eventually the researchers were able to compare numerous parameters between the flights with and without SafeSound which allowed them to denote the advantages and disadvantages of the SafeSound system.
For more details regarding the methodology of this experiment the reader is referred to [4].

3 Results

Figure 3 shows the percentage of pilot errors in their operation of the DVI system. As can be seen out-of-syntax errors in which the DVI did not respond correctly and errors in which the PTT button was not operated correctly, are the most common. The PTT errors are mostly errors where the pilots pressed the PTT button and either released the button without saying anything or mistakenly used the button for ATC communication.

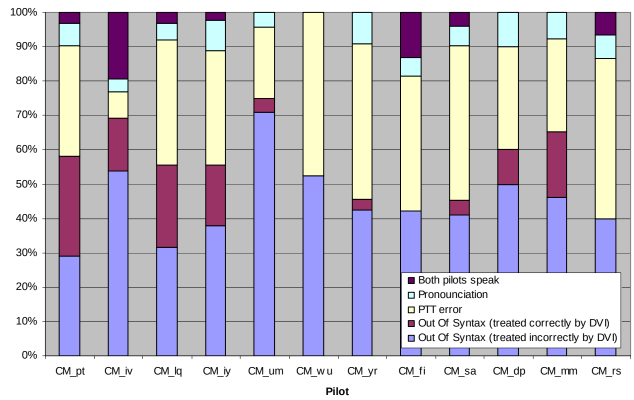

Figure 3: Each bar represents one pilot while each colour represents one type of error that was made by the pilots. The total number of errors that was made per pilot was of course 100%

Figure 4 shows that the system achieves nearly the same performance regarding recognition rate for the array microphone as for the boom microphone that is part of the headset. It further shows that the pilot failure rate depends on the speaker, as was the case with the recognition rate. The correlation quotient between the pilot error rate and the recognition rate is for the headset –0.74 and for the array microphone –0.1.

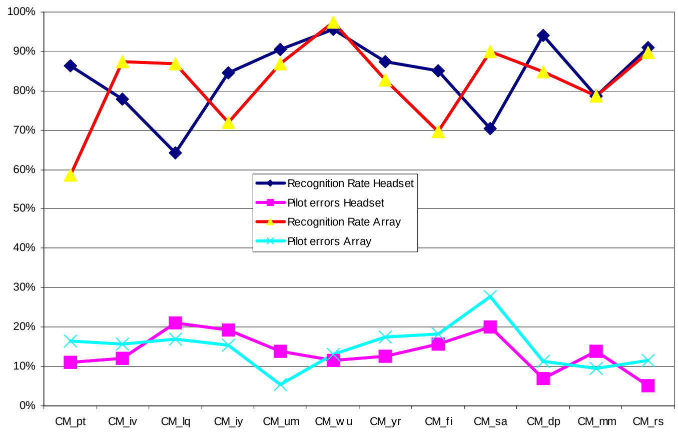

Figure 4: On the horizontal axis are letter-codes that represent the pilots who have participated in the experiment anonymously. On the vertical axis are the recognition rates expressed in percentages

3.1 Pilot Mental Workload (NASA-TLX Ratings)

The workload was reported regarding a complete flight and not separate for each of the micro experiments that were performed during flight. The complete - weighted - version of the NASA-TLX was used for workload rating. The mental workload turned out to be very different for captains and first officers as well as for pilots flying (PFs) as pilots not-flying (PNFs), therefore the workload is reported for each of those cockpit-roles.

Figure 5 shows that the workload during the experimental runs that the SafeSound system was switched on, is reported higher ($F(1, 47) = 43.111$, $p < 0.0005$) [4] compared to the experimental runs when the SafeSound system was switched off. Note that this calculation is over 6 crews (each comprising 2 pilots) and that all of these pilots have performed flights with DVI switched on as well as baseline flights (with no DVI) in both the pilot flying and the pilot not-flying role. Further it was found that captains in general rated their workload higher ($F(1, 47) = 7.855$, $p < 0.010$) [4] than first officers. This is true for both the SafeSound on and off conditions and regardless whether the pilot acted as PF or PNF.

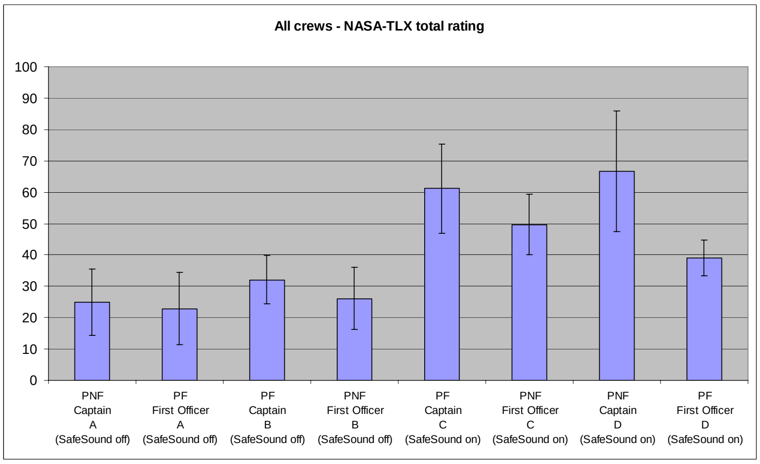

Figure 5: On the vertical axis the pilot mental workload is expressed. On the horizontal axis captains and first officers acting as PF as well as PNF during all different flights have their own bar

3.2 Pilot Opinions / Open Questions and Debriefing

Below the most striking results from questionnaires and debriefing sessions are be summarised. For a complete listing of all results the reader is referred to [7].

Main Advantages

The pilots who have participated in the experiment have summed up the main advantages of DVI in their cockpits.

Pilots have reported that the current recognition of DVI may be a bit too unpredictable for high workload situations. However they appreciated the principle of the tool and as such they consider the current configuration convenient for those situations that there is time, not during high workload situations

However, when DVI is more reliable, then it would be a useful tool for emergencies, for example for single pilot operations, when the pilot has to fly the aircraft on his / her own. Under such circumstances all tools that may assist the pilot to focus on the aviation task itself, and remain head up as much as possible, will be highly appreciated.

Regarding radio frequency change different opinions where heard. On the one hand pilots stated that especially during taxiing two pairs of eyes that can look outside are really helpful. So these pilots appreciate the radio frequency change by DVI. On the other hand there were pilots who stated that monitoring whether the DVI has ‘understood them right’ (e.g. captured the right frequency) takes time as well, and possibly more time then entering the right frequency directly into the radio management panel (RMP).This latter group of pilots added that when a new frequency is provided by Air Traffic Control (ATC) the pilot can immediately start entering it in the RMP, while performing the same task by DVI requires to read that frequency back first, await ATC’s reply, and then repeat the frequency for the DVI. Remembering the frequency all that time included the potential risk of mixing up some of the digits that together form the new frequency.

Hard and Software

As a means to prevent from accidentally executing unintended tasks the system was designed in such a way that pilots had to double click the PTT-button for the more critical tasks. Pilots reported that too many tasks were considered critical by the SafeSound researchers, and that the number of times that they had to double click to confirm were too many.

Regarding the DVI feedback display there were also differences of opinion. These differences concerned:

- Its location
- The use colour on the display
- The number of lines on the display

About the location there were pilots who felt that the current location allowed them to include the DVI feedback display in their normal eye scanning pattern, the so called “basic T”. These pilots were in favour of the current location. The majority of the pilots wanted the display to be closer near the window, so that the DVI system would give them even more head up time. This group of pilots suggested to either include the DVI feed back display in a HUD or include it in the glare shield close near the caution and warning lights.

The letters on the display where all white in a standard font that is used more often on Airbus displays. Some of the pilots have reported that they would have appreciated the use of colour. However, there was not one common opinion about the colour coding that should have been used.

In the current version there was room for five lines of text on the DVI feedback display. Some pilots stated that fewer lines would be sufficient because they actually only wanted to read back the last command that they had given, and one single command always fits on one line.

In the current implementation the PTT button was mounted very close near the autopilot (AP) disconnect button (see also Figure 1) pilots were concerned that such an implementation may increase the likelihood of mixing up PTT with AP-disconnect button. Mounting the button somewhere on the side of the side stick was an often heard suggestion.

Pushing the PTT button takes, according to the pilots, too much ‘force’. Pushing the button should be as swift as pushing a computer mouse button, especially when double clicks to confirm have to be made.

Pilots were asked to speak in the direction of the microphone array, which was mounted on the glare shield (see alsoFigure 1) when giving a DVI command via that input device. Pilots have reported that it was no problem to speak in that direction. It felt natural to do that and enabled them normally to monitor the outside view as well as most of the relevant displays.

Having a microphone in front of the pilots without the need to wear a headset or to hold the microphone by hand, as communication device with ATC, or possibly with the cabin crew, was appreciated as well.

Giving input via the microphone array normally requires speaking louder than to the boom microphone on the headset or speaking to the other crew member. This raising ones voice when speaking was considered inconvenient for speaker as well as other pilot. That is especially true for those moments of flights that both pilots normally are silent (i.e. during climb). Pilots reported to be were distracted by the other pilot when he / she started to talk to the DVI system during those quiet moments.

Suggestions for Improvement
The DVI system interprets the command given by the pilot by trying to find the best possible match between what the pilot has said and the possible commands that are allowed by the syntax at that time. Sometimes this results in an interpretation that is not correct. That is especially so when the pilots give an out-of-syntax command. The pilots have suggested making the system print “not understood” more often on the DVI feedback display, rather providing the wrong interpretation.

Pilots want the syntax to be adjusted in such a way that recognition rate improves and response time becomes quicker. It would be most appreciated when the system could understand the pilot as a third crewmember would. But if a simpler syntax would provide a better recognition rate most pilots would be happy with that as well.

Besides suggestions for other positions for the PTT button the ultimate solution seems to be a DVI system without buttons, which can be addressed by saying a particular word (call sign).

As a solution to the above mentioned issue of having to raise ones voice when speaking to the array microphone it was suggested to develop a more sensitive array microphone. Such an array would allow the pilots to speak softer than in the current implementation. And in that same context it was suggested to develop a boom microphone that is so sensitive that allows pilots to whisper rather than speak when entering commands in the DVI system.

4 Discussion

Note that during the above described experiment other SafeSound features were evaluated as well. The DVO and 3DS system had their own requirements concerning micro experiments as part of the scenarios that were simulated. It is possible that these different SafeSound features and accompanying micro experiments have interfered to a certain extent with the DVI evaluation.

The environmental sound that was simulated in the cockpit was about 6 dB(A) lower than in real flight. Therefore implantation of the DVI system in a real cockpit may give a slightly different performance compared to the results that were found in the current study.

With future, faster computers the response time of the system may be faster, while the system will also be possible to handle a more complex syntax. That is a technological development that will make future versions of a DVI quicker and less error prone. As such that technological development will solve a number of the problems that were identified in the current evaluation.

Note that all pilots who participated in the experiment were native Italian speakers, while the commands to the DVI system were given in English. So the Italian accent of the pilots may have contributed to a poorer performance of the system compared to for example native English speaking pilots would have produced.

The fact that there are moments during flight that crews normally don't speak, or that DVI commands are given through other communications either within the crew or between one crewmember and ATC, is experienced as disturbing. Creating more sensitive microphones, thereby allowing crewmembers to speak softer to the DVI system, is a technological solution to that problem. Another solution may be creating new procedures about how when to use DVI. Possibly it is just like with mobile telephones; it may be so that an 'etiquette' about how to operate DVI needs to develop over time.

Given the fact that most DVI related errors that were identified are related to pilot error makes that a more intuitive interface (i.e. improved syntax), possibly in combination with more training, is needed.

The NASA-TLX results indicate that the pilot workload is higher when DVI is switched on compared to the baseline condition. Based upon the pilot reactions that were given in the questionnaires and debriefing this difference in workload rating is interpreted as that the current version of DVI is not mature enough. Solutions need to be found for a number of side effects of the system that are either sources of errors in DVI operation or interfering with normal cockpit procedures.

5 Conclusion

The microphone array (as a stand alone feature) functions intuitively. There was no negative feedback at all regarding that array. No significant differences in recognition rate were found between use of headsets and array microphone.
Before installation in real aircraft the DVI needs some improvements. Operation of DVI takes more time than the current way of operation.

- The syntax must become simpler (third crewmember)
- The recognition rate of the system must improve
- Response time of the system must decrease

Solutions are needed to deal with the fact that using DVI in a (two seater) cockpit interferes with other communication (e.g. ATC, cabin crew), or with an expected silent cockpit during certain moments of the flight.

The major sources of errors with DVI are related to out-of-syntax errors and errors related to erroneous operation of the PTT buttons.
DVI is definitely interesting for further development because most of the problems identified have a technological basis, that may be fixed in the future, and the underlying principle of DVI sounds promising to the pilots.

References

[1] Abma, H.J. & Zon, G.D.R. (2005). *"Pilot Briefing Guide"* NLR-CR-2005-117, NLR, Amsterdam, 2005.

[2] Egter van Wissekerke, R.F. (2004). *GRACE - Generic Research Aircraft Cockpit Environment.* NLR-Memorandum ATTH-2004-014, Amsterdam, 2004.

[3] SafeSound (2002). *Annex 1 "Description of Work"*. Safety Improvement by Means of Sound.

[4] Statsoft (2005). *The statistics homepage.* URL: http://www.statsoft.com/textbook/stathome.html

[5] Zon, G.D.R., Roerdink, M.I., Joosse, M. & Bonnee, W.J.A. (2005). - SafeSound Deliverable 5.1 tome 1: *"Report on Scenarios Design"*. NLR-CR-2005-429. NLR, Amsterdam, 2005.

[6] Zon, G.D.R., Keuning, M.F.R., Kessens, J., Verhave, J., Opitz, M., & Albert, B. (2005). - SafeSound Deliverable 5.2: *"Report on integration of the mock-up in the simulator"*. NLR-CR-2005-655. NLR, Amsterdam, 2005.

[7] Zon, G.D.R., Roerdink, M.I., Weber, S., & Paulsen, J.L. (2005). - SafeSound Deliverable 5.3: *"Report on tests and analysis"*. NLR-CR-2005-651. NLR, Amsterdam, 2005.