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PILOT ACCEPTANCE, COMPLIANCE, AND PERFORMANCE WITH AN AIRBORNE CONFLICT MANAGEMENT TOOLSET

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A human-in-the-loop experiment was conducted at the NASA Ames and Langley Research Centers, investigating the En Route Free Maneuvering component of a future air traffic management concept termed Distributed Air/Ground Traffic Management (DAG-TM). NASA Langley test subject pilots used the Autonomous Operations Planner (AOP) airborne toolset to detect and resolve traffic conflicts, interacting with subject pilots and air traffic controllers at NASA Ames. Experimental results are presented, focusing on conflict resolution maneuver choices, AOP resolution guidance acceptability, and performance metrics. Based on these results, suggestions are made to further improve the AOP interface and functionality.

Introduction

In today's air transportation business environment, aircraft operators are increasingly looking for means to increase flight efficiency. However, with air travel demand once again rising to levels that exacerbate delays and challenge the capacity of the National Airspace System (FAA, 2004), large efficiency improvements may be difficult to realize under current operational conditions. As a result, it has been acknowledged that a transformational, rather than evolutionary, approach to air traffic management modernization is needed (DOT, 2004).

As part of the Advanced Air Transportation Technologies project, NASA has developed such a far-term, transformational concept, called Distributed Air/Ground Traffic Management (DAG-TM) (NASA, 1999). The goals of DAG-TM are to increase efficiency and maintain safety through a redistribution of decision-making authority among airborne and ground-based elements of the air transportation system. It is a gate-to-gate concept, addressing all flight phases from dispatch to arrival.

En Route Free Maneuvering

En Route Free Maneuvering is one component of DAG-TM, addressing the en route and terminal-transition phases of flight. In an En Route Free Maneuvering environment, trained crews of equipped aircraft assume responsibility for traffic separation. Such crews would be free to modify their flight path in real time, without approval from an air traffic controller, as long as basic flow management initiatives are complied with (e.g., crossing a terminal airspace entry point at a specified time). These flights would operate under a new set of flight rules called Autonomous Flight Rules (AFR). Except for busy terminal areas, where AFR operations would not be permitted, AFR traffic would be integrated with Instrument Flight Rules (IFR) traffic. AFR flight crews would be responsible for separation from both IFR and other AFR aircraft. Air traffic controllers would issue flow management constraints to all aircraft, and continue to provide separation among IFR aircraft, accommodating those operators who choose not to equip for AFR. By distributing separation assurance among multiple airborne and ground-based elements in this way, the National Airspace System may be able to absorb a higher increase in demand beyond what is possible with a centralized, ground-based approach.

Background

Previous Research

The work presented in this paper builds upon previous studies conducted at NASA as well as initial Free Flight research by organizations such as NLR in the Netherlands (Hoekstra et al., 2000). Past NASA experiments investigated such topics as AFR operations in confined airspace and the use of aircraft intent for decision making (Krishnamurthy et al., 2003).

The Autonomous Operations Planner

Central to AFR operations are the capabilities of airborne conflict prevention, detection, and resolution, as well as adherence to traffic flow management constraints. It is assumed that pilots cannot safely perform these functions without some form of decision support. As such, NASA Langley Research Center has developed a prototype airborne toolset called the Autonomous Operations Planner (AOP) (Barhydt & Krishnamurthy, 2004).

The prototype AOP interface is designed around a modern "glass cockpit" flight deck. It provides conflict alerts and resolution guidance via the navigation display, using state and intent data from the ownship and proximate traffic. To meet flow constraints, it also generates conflict-free paths that achieve Required Times of Arrival (RTAs) at waypoints. The AOP has been developed using a human-centered approach, with resolution guidance complementing the pilot's choice of control mode. For example, when the aircraft is being flown in a tactical mode (e.g., a selected heading or altitude) or when very near-term conflicts exist, resolution guidance is presented as a simple heading or vertical speed command. When the aircraft is flown in a strategic mode (i.e., coupled to the aircraft's flight management system (FMS)), resolution guidance is presented as an FMS route modification.

Conflicts are displayed by highlighting the intruder aircraft and indicating the region of conflict along the active flight path with a colored "dog bone." The AOP also provides information to help pilots avoid inadvertently creating new conflicts while maneuvering. These conflict prevention tools take on two forms: Maneuver Restriction Bands and Provisional Conflict Alerts. Maneuver Restriction Bands are displayed as "no fly" heading and vertical speed ranges. Using a "dashed dog bone" symbology, Provisional Conflict Alerts show regions of conflict along *proposed* flight paths (e.g., a modified but unexecuted FMS route or a selected but unengaged heading). Figure 1 shows an example of AOP symbology on a Boeing 777-style navigation display.

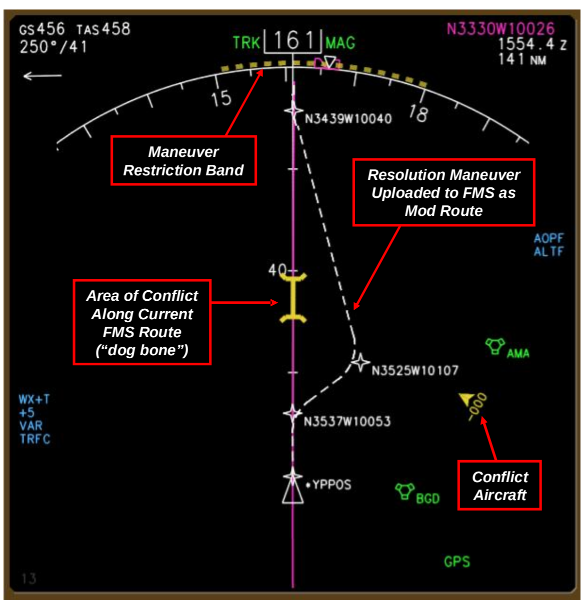

Figure 1. *AOP Interface with Strategic Resolution Experimental Approach*

In summer 2004, the NASA Ames and Langley Research Centers jointly conducted a human-in-the-loop simulation of En Route Free Maneuvering operations (Barhydt & Kopardekar, 2005). This experiment extended the previous research in several ways. A realistic, mixed AFR-IFR operating environment was simulated, including overflight aircraft as well as arrivals. The AOP was enhanced to provide vertical resolution guidance in addition to lateral guidance. In addition, interactions with ground-based air traffic controllers were studied.

This paper presents a subset of the En Route Free Maneuvering experimental results, focusing on conflict resolution maneuver choices, pilot-reported acceptability of AOP guidance, and performance metrics, including how pilot compliance with AOP affected resolution performance.

Participants

Test subjects included 12 pilots at NASA Langley as well as pilots and air traffic controllers at NASA Ames. The NASA Langley subject pilots were all Airline Transport Pilot rated with experience in Boeing glass cockpit aircraft. These pilots flew workstation-based flight simulators that emulated the displays of an AOP-equipped Boeing 777. Additional AFR and IFR background traffic was supplied with pseudo-pilot stations staffed by research personnel.

Figure 2 shows the experimental airspace. It consisted of simulated high- and low-altitude sectors of a portion of Fort Worth Center. The sectors were staffed at NASA Ames by five FAA-qualified air traffic controllers. They provided separation services between IFR aircraft and were given automated tools for conflict detection and resolution. In addition, researchers acted as pseudo-controllers in large "ghost" sectors surrounding the experimental sectors, providing limited services to flights entering and exiting the subject-controlled airspace.

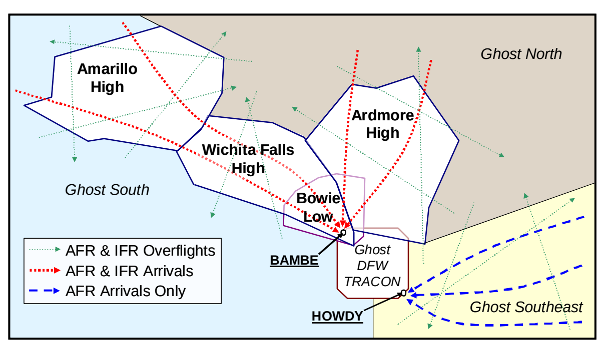

Figure 2. *Experimental Airspace*

Scenario Design

The experiment was designed in a within-subjects format, with 16 different scenarios. Four different traffic conditions were simulated, which varied the amount of traffic as well as the relative proportions of AFR and IFR overflight aircraft. Table 1 details the four traffic conditions.

Table 1. *Traffic Conditions Tested*

Condition	Avg. Traffic Density	% IFR	% AFR
C1	slightly above current Monitor Alert parameter	100%	0%
C2	equal to C1 density	75%	25%
C3	≈1.5 × C1 density	50%	50%
C4	≈2 × C1 density	35%	65%

At each of the four traffic conditions, pilots flew two overflight profiles and two arrival profiles. Except for C1 scenarios (in which all flights were IFR), subject pilots were responsible for resolving scripted and unscripted traffic conflicts. AOP alerted pilots to conflicts up to 10 minutes prior to predicted Loss of Separation (LOS). Pilots were trained to use AOP strategic resolution guidance, tactical resolution guidance, and (in the case of manual maneuvers) conflict prevention information as appropriate to the situation. They were also instructed to operate the aircraft as they would during line operations. Although hand-flying was not available, pilots were allowed to use any desired autopilot modes, including both FMS-coupled modes and tactical modes.

Results & Discussion

The NASA Langley subject pilots encountered a total of 500 traffic conflicts throughout the 12 AFR scenarios (C2, C3, and C4). For 332 of these conflicts, the subject pilot performed a resolution maneuver. The analyses presented below show results for these conflicts, without distinguishing between traffic conditions. The effects of traffic density on resolution performance are treated in a separate publication (Doble, Barhydt, & Hitt, 2005).

AOP Compliance

To examine the effects of AOP resolution maneuver compliance on resolution performance, resolution maneuvers were divided into six categories, based upon whether the maneuver was strategic or tactical and whether or not the pilot followed AOP guidance. These categories are summarized in Table 2. Two different performance metrics were then used to evaluate the maneuvers: induced conflicts and conflicts requiring multiple resolution maneuvers.

Table 2. *Resolution Compliance Categories*

Category	Description	Count
Strategic Comply	Pilot implements AOP-recommended route modification without modifications	141
Strategic Noncomply	Pilot edits waypoints before implementing AOP-recommended route modification	0
Strategic Manual	Pilot ignores or does not seek AOP resolution, and manually edits waypoints, altitudes, etc. of FMS active route	15
Tactical Comply	Pilot maneuvers in direction of AOP-recommended heading or vertical speed	118
Tactical Noncomply	Pilot maneuvers away from AOP-recommended heading or vertical speed	15
Tactical Manual	AOP tactical guidance not available, pilot implements own lateral or vertical maneuver via autopilot mode control panel	43

Induced Conflicts. The frequency of induced conflicts is a measure of the ability of pilots and AOP to account for aircraft other than the intruder when calculating a resolution maneuver. An induced conflict was defined as a new conflict arising within one minute of a previous resolution maneuver and directly caused by that maneuver. Figure 3 shows the percentage of resolutions inducing a conflict in each of the six compliance categories. Results from χ^2 tests indicate no significant differences in the frequency of induced conflicts across the three tactical categories ($\chi^2(2, N = 176) = 0.27, p > 0.05$), but a significantly higher frequency of induced conflicts for Strategic Manual maneuvers vs. Strategic Comply maneuvers ($\chi^2(1, N = 156) = 32.2, p < 0.05$).

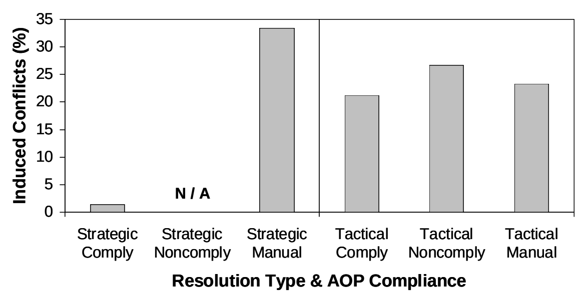

Figure 3. *Induced Conflicts vs. AOP Compliance*

The lowest induced conflict rates occurred when pilots followed AOP guidance. This highlights the advantage of decision support when resolving conflicts involving multiple proximate aircraft. It is conjectured that the relatively high rate of induced conflicts among tactical maneuvers was due primarily to two factors: the time to predicted LOS when the maneuvers were executed, and the characteristics of the AOP tactical resolution algorithm. During the experiment, tactical resolution maneuvers were generally initiated closer to predicted

LOS than strategic maneuvers. In such situations, especially in the high-density airspace simulated in this experiment, some induced conflicts may be inherently unavoidable, as the first priority is usually to resolve the most critical conflict in a timely manner. In addition, for very near-term conflicts (under 2 minutes to LOS), the AOP tactical resolution algorithm did not take other aircraft into account when calculating resolution guidance. This algorithm was chosen for its ability to successfully resolve complicated conflict situations without the need for maneuver coordination between aircraft (Eby, 1994). Ongoing research will investigate the integration of this algorithm with the AOP conflict prevention tools in order to further reduce induced conflicts.

While the significant increase in induced conflicts for Strategic Manual resolutions is cause for concern, it should be noted that three of these five induced conflicts were caused by the same pilot during the same scenario. Nevertheless, pilot training and the AOP conflict prevention symbology may warrant further attention as these subject pilots all implemented route modifications despite being shown Provisional Conflict Alerts.

Multiple Resolutions. The frequency of multiple resolutions is a measure of the ability of pilots and AOP to resolve a conflict and remain out of conflict. If a subject pilot was in conflict with the same intruder multiple times and implemented more than one resolution maneuver, this was noted as a multiple resolution conflict. Figure 4 shows the percentage of conflicts requiring multiple resolutions in each compliance category. Results from χ^2 tests indicate no significant differences in the frequency of multiple resolutions across the strategic categories ($\chi^2(1, N = 156) = 1.67$, $p > 0.05$). The differences among tactical categories were significant ($\chi^2(2, N = 176) = 6.04$, $p < 0.05$).

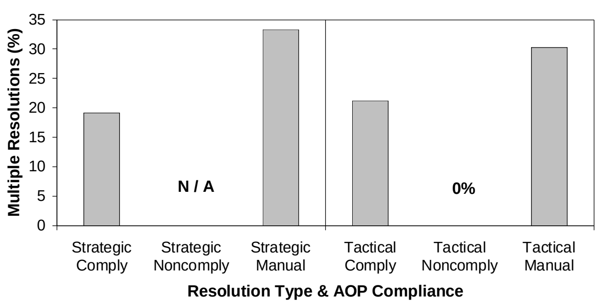

Figure 4. *Multiple Resolutions vs. AOP Compliance*

The lower multiple resolution rate for maneuvers that complied with AOP guidance (vs. manual maneuvers) shows the benefits of decision support when resolving conflicts between aircraft flying complex, four-dimensional trajectories. While the lowest multiple resolution rate occurred when pilots did not follow AOP guidance (Tactical Noncomply), this is not seen as a cause for concern. Compliance only accounted for 3% of the variance in multiple resolutions, and this category of maneuvers had a relatively small sample size. In addition, there may have been a performance tradeoff, with these maneuvers effectively avoiding the intruder aircraft at the expense of additional induced conflicts.

Choice of Maneuver Axis

To judge the relative effectiveness of lateral and vertical AOP guidance, the maneuvers categorized above as Strategic Comply and Tactical Comply were further separated into Strategic Lateral, Strategic Vertical, Tactical Lateral, and Tactical Vertical categories.

Induced Conflicts. Figure 5 shows the percentage of induced conflicts that occurred for each of the four axis categories. Results from χ^2 tests indicate no significant differences between either the strategic categories ($\chi^2(1, N = 141) = 0.46$, $p > 0.05$) or the tactical categories ($\chi^2(1, N = 118) = 0.37$, $p > 0.05$). For the reasons mentioned above, it is not surprising that strategic resolutions resulted in fewer induced conflicts than tactical resolutions, but within the strategic and tactical categories, the choice of maneuver axis appears to have had little effect.

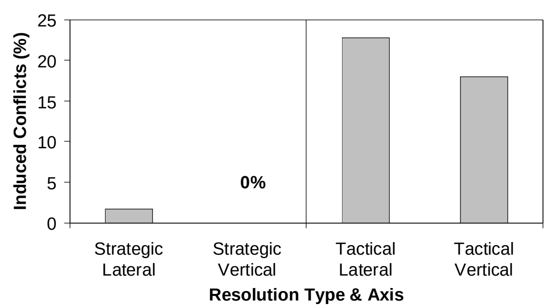

Figure 5. *Induced Conflicts vs. Maneuver Axis (When AOP Complied With)*

Multiple Resolutions. Figure 6 shows the percentage of multiple resolutions that occurred for each of the four maneuver axis categories. Results from χ^2 tests indicate no significant differences between either the two strategic categories ($\chi^2(1, N = 141) = 1.24$, $p > 0.05$) or the two tactical categories ($\chi^2(1, N = 118) = 0.02$, $p > 0.05$). This shows that lateral and vertical maneuvers were similarly effective in preventing multiple resolutions. However, the slightly higher incidence of multiple resolutions for Strategic Vertical maneuvers is worth noting. These maneuvers required pilots to adjust the autopilot altitude value in addition to uploading an FMS route modification. There were cases when the altitude value was not properly adjusted and the aircraft failed to follow the resolution maneuver. Compounding this was the difficulty of displaying vertical path changes on a horizontal situation display. Ongoing research will investigate other options for presenting vertical maneuver information, including the use of vertical situation displays.

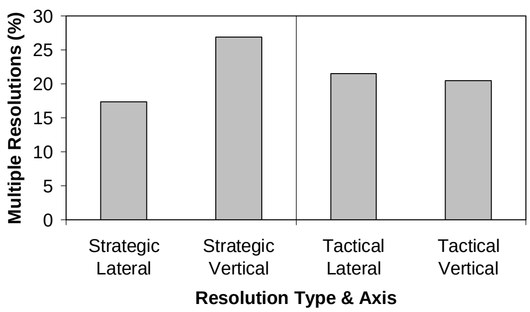

Figure 6. *Multiple Resolutions vs. Maneuver Axis (When AOP Complied With)*

Acceptability of AOP Resolution Guidance

To examine factors that affect pilot perception of the acceptability of AOP resolution guidance, subject pilots were asked after each scenario to rate, on a 1 to 7 scale, the acceptability of a) the first AOP strategic resolution in the scenario, and b) AOP tactical resolutions in general during the scenario. A series of correlations was then performed to determine if relationships existed between resolution acceptability and four other factors: conflict duration, maneuver axis (lateral or vertical), multiple resolutions, and induced conflicts. These results are presented in Table 3. Overall resolution acceptability was high for both strategic resolutions (M = 6.31, SD = 1.28) and tactical resolutions (M = 5.12, SD = 1.60).

Table 3. *Resolution Acceptability*

Attribute	Acceptability Correlation		Test
	Strategic Resolutions (N = 109)	Tactical Resolutions (N = 135)	
Conflict Duration	-0.24*	0.02	Pearson
Maneuver Axis	-0.18	0.10	Point-biserial
Multiple Resolution	-0.39*	0.14	Point-biserial
Induced Conflict	-0.02	-0.17*	Point-biserial

* = significant correlation at $p < 0.05$ level

The acceptability of AOP strategic resolution maneuvers was significantly correlated with conflict duration and multiple resolutions. The significance of conflict duration agrees with comments provided during debrief sessions, which indicated that pilots were frustrated by AOP computation delays and the options available when AOP was unable to calculate a solution. While the AOP strategic resolution algorithm (a genetic algorithm) normally converged on a solution within one second, insufficient feedback may have been provided to pilots when computation times were longer, creating the appearance that AOP had “frozen up.” The significant correlation with multiple resolutions is also reasonable, as one of the primary benefits of intent-based, strategic decision support is that the necessity for multiple resolution maneuvers should be reduced by accounting for trajectory changes that would be unknown to a solely state-based system.

The acceptability of AOP tactical resolutions was only significantly correlated with whether or not the resolution induced a conflict. As mentioned above, depending on the time to predicted LOS, the AOP tactical guidance may or may not have accounted for aircraft other than the intruder. As such, there were cases when the tactical guidance disagreed with Maneuver Restriction Bands. Although this behavior was explained to subject pilots during training exercises, this is recognized as a significant human factors issue. Research is underway to modify the AOP near-term tactical resolution logic so that conflicting information is not presented to pilots.

Practice Effects

The En Route Free Maneuvering experiment lasted a total of eight days, with three days devoted to training, four days for data collection, and one day for debriefing. Each data collection day included four scenarios, with one at each traffic condition, and with the order of conditions varying across days.

To identify any learning or practice effects, conflicts were sorted by day and evaluated with the same performance metrics presented above. Figure 7 shows the frequency of induced conflicts and multiple resolutions across days. χ^2 tests indicate that no significant differences in the frequency of induced conflicts ($\chi^2(3, N = 332) = 1.37$, $p > 0.05$) or in the frequency of multiple resolutions ($\chi^2(3, N = 332) =$ 4.78, p > 0.05) existed across the four days.

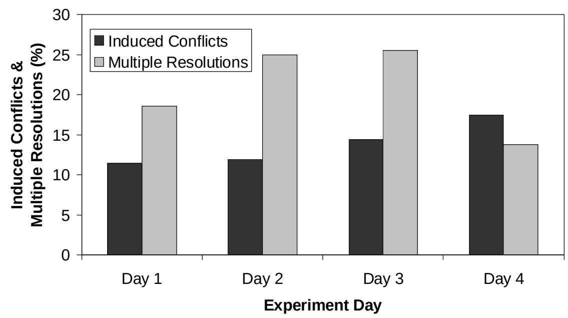

Figure 7. *Resolution Performance by Day*

While no significant practice effects were found, it is interesting to compare the performance by day with the resolution maneuvers chosen. Figure 8 shows the percentage of maneuver types chosen each day. Notionally, resolution performance appears to degrade with increases in manual and non-complying maneuvers over the first three days of the experiment, then improve on Day 4 with an increase in Strategic Comply maneuvers.

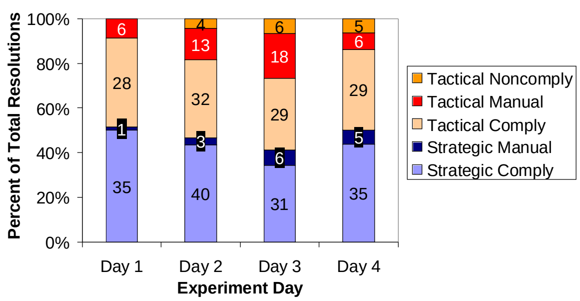

Figure 8. *Resolution Maneuver Compliance by Day*

Conclusions

Through the above analysis of conflict resolution maneuvers, several conclusions can be drawn about the performance of pilots during AOP-equipped AFR operations. First, the choice of maneuver axis (lateral or vertical) had little effect on resolution performance, indicating that resolution maneuvers can be well-executed in either axis. Second, resolution performance was shown to generally improve when pilots complied with AOP-recommended resolution maneuvers. Finally, although pilot acceptability of AOP guidance was high overall, possible ways to further increase acceptability and performance were identified. These methods include better integration of AOP near-term tactical resolution logic with conflict prevention information, improved feedback when AOP cannot converge on a strategic solution, and the potential inclusion of a vertical situation display. Along with previous findings, these results further support the feasibility of the En Route Free Maneuvering concept while highlighting areas for future research.

Acknowledgements

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SAFETY ATTITUDES IN THE AVIATION SYSTEM: INFLUENCES OF A HIGHLY REGULATED ENVIRONMENT

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Although safety is considered paramount in the aviation industry, very few studies have explored the influence that such a highly regulated environment may have on safety attitudes. This paper explores how perceptions and attitudes may be influenced by context characteristics and analyses how a highly regulated context, such as the aviation industry, compares with other industries. Results suggest that the aviation industry seems to be centered on individual behaviors and attitudes towards safety; in contrast other industries highlight safety at the organizational level. Implications of these results and repercussions of national safety campaigns to promote safety at the workplace are considered.

Introduction

Workplace safety and, in particular, the analysis of occupational accidents have emphasized the importance and interrelationship of two main contributors: The technical component which involves physical working conditions, machinery, equipment and work instruments and the Human component comprising job incumbents, teams, supervisors and top managers (e.g., Oliver, Cheyne, Tomás & Cox, 2002; Sarkus, 2001). The development of a positive safety culture and constructive attitudes towards safety are considered as an important and effective strategy to promote and maintain a safe workplace. In many instances, attitude surveying is recommended as a quick and helpful way of conducting a safety diagnostic.

The literature on safety attitudes presents a variety of dimensions and a plethora of instruments (e.g., Cox and Cox, 1991; Díaz & Cabrera, 1997; Glendon, Staton & Harrison, 1994; Zohar, 1980). A renaming and grouping exercise on the existent measures is considered necessary (Guldenmund, 2000; Sorensen, 2002) with possible identification of core dimensions and clear explanations on the issue of dimensionality. These efforts led to the development of a measure to evaluate attitudes towards safety that can be used in various contexts (D'Oliveira, 2004). A methodology similar to the one adopted by Williamson, Feyer, Cairns and Biancotti (1997) was used and a measure considering eight scales was put together. Safety areas considered were: Organizational objectives, organizational practices and safety, information on safety issues, management and supervisors' attitudes, personal attitudes to safety, risk perceptions and relationships with co-workers.

Safety is paramount in the aviation system and efforts have considered both the technical component (e.g., by fostering safer machinery) and human interventions (e.g., through improved training like CRM). The industry investments in standards and practices led to an outstanding safety record (ICAO, 2004).

Context characteristics such as the activities performed, the hazards involved and the degree of regulation imposed by the industry may play an important role when discussing safety attitudes and safety culture. These characteristics have yet to be considered in the literature on safety culture/climate. Very few studies have considered safety attitudes in different industries (e.g., Diaz & Cabrera, 1997). This paper addresses these issues and explores how perceptions and attitudes may be influenced by context characteristics and analyses how a highly regulated context, such as the aviation industry, compares with other industries.

Method

Participants

A total of 346 participants, 60.4% men and 396 females, from various industries (aviation, health, car industry, metal industry, etc.) were invited to participate in this study. Table 1 presents sample's main characteristics.

Table 1. *Participants' main characteristics*

Age	M = 36.71, SD=10.09
Qualifications	M = 9.9 years
Contract	Full time permanent = 84.3 %
Position	Supervisor = 19.1%
Industry	Aviation = 25.4%; Non Aviation = 74.6% Pilots, Cabin crew, Maintenance

Instrument

A measure was developed using a methodology similar to the one adopted by Williamson, Feyer, Cairns and Biancotti (1997) was used in this study. Specifically, a review of the literature was conducted in order to identify potential measures of attitudes towards workplace safety. All potential measures were then considered as a full set and items were assembled according to their content. This procedure led to the identification of seven dimensions: organizational objectives, organizational practices and safety, information on safety issues, management and supervisors' attitudes, you and safety issues, personal appreciation of risk and relationships with coworkers. A detailed definition of each dimension (Table 2) was then produced and eight items were selected to represent each safety attitude dimension. The final measure was composed of 56 items, each item being responded in a 5 point rating scale.

Table 2. *Safety attitude dimensions (Cronbach's values for each dimension).*

Sub-Scale Definition
A – Organizational Objectives This dimension considers how the Organization values safety issues. The potential conflict between safety and productivity, the Organization openness to discuss issues related to safety and proposals by the employees are some of the issues considered in the literature (α = .725).
B- Organizational Practices & Safety This dimension addresses how organizational practices such as training, performance evaluation, promotion, accident/incident investigation may be related with safety (α = .850).
C - Information on Safety Issues This dimension tries to evaluate how the Organization stimulates the diffusion of information related with safety by creating safety awards, safety bonus, how workers might present suggestions or report their safety concerns, etc (α = .720).
D- Management & Supervisors Attitudes In this dimension, supervisors and top managers' behavior is considered by assessing workers perceptions of their technical knowledge on safety issues, proactive or reactive safety attitude and their support to workers safety concerns (α = .806).
E – Yourself & Safety This dimension considers the knowledge and satisfaction of workers in relation to safety and their awareness of the consequences of their behavior to safety in general (α = .776).
F – Risk Perceptions In this dimension workers' perceptions of the risks involved in their activities are considered along with their estimative of how probable it is to be involved in an accident (α = .717).
G – Relationships with coworkers This dimension considers workers perceptions of their colleagues' knowledge and behaviors related to safety. It also includes the perception of being part of a group and how this characteristic influences personal behavior (α = .808).

Procedure

A general instruction was given to every participant as to how they should fill in the questionnaire: volunteers should give a description of their own company regarding safety issues. The objective of the study was to gather information that could help companies to improve their safety policies and results.

Results

A total of seven MANOVAS were conduct in order to explore potential differences between aviation and non aviation participants. Table 3 summarizes main results obtained in these analyses.

Table 3. *Differences between aviation and non-aviation participants in each subscale*

Sub-Scale	Results
Organizational Objectives	Pillai's Trace= .163, F= 7,990; p<.000 Non aviation has higher means
Organizational Practices & Safety	Pillai's Trace= .108, F= 4,958; p<.000
Information on Safety Issues	Pillai's Trace= .135, F= 6,374; p<.000 Non aviation has higher means (ns differences)
Management & Supervisors Attitudes	Pillai's Trace= .141, F= 6,859; p<.000
Yourself & Safety	Pillai's Trace= .266, F= 15,149; p<.000 Aviation has higher means
Risk Perceptions	Pillai's Trace= .105, F= 4,751; p<.000 Non aviation has higher means
Relationships with coworkers	Pillai's Trace= .189, F=9,675; p<.000

Discussion

Results obtained suggest differences between aviation and non-aviation participants in every dimension. In what concerns organizational objectives, information on safety issues and risk perceptions, non-aviation systematically has higher means.

Non-aviation participants compose a positive depiction of their companies: safety goals are clearly stated, safety procedures work well and are followed, there seems to be more information available on safety issues but it is recognized that sometimes there is a conflict between productivity and safety, something mentioned in the literature.

In what concerns aviation participants, they seem to have a personal relation with safety issues that appears to be more positive (receive safety information, understand safety rules, know training needed) and there is a proactive attitude towards safety (recognize that their personal intervention may avoid potential hazards), and attitudes and behaviors associated with an appreciation of risks involved in their jobs.

Organizational practices and procedures towards safety, management and supervisor's behaviors and attitudes and relationship with colleagues although presenting mixed results provide support to the differences previously identified. In the aviation context, safety is part of performance appraisal, supervisors are aware of what safety training each worker has, and participants report reliable safety behaviors in their colleagues. Non-aviation participants report that their work procedures are accurate and a reflection of what they actually do in their jobs, characteristics probably associated with a lesser degree of complexity in their jobs.

All in all, results suggest the presence of two different safety systems. Aviation safety systems seem to have at their centre individual safety qualifications: a greater risk in the activities performed is associated with the requirements for specific and formal safety training. Such qualifications are quite relevant in this context; not only are they included in the performance appraisal but also management and supervisors are aware of each worker qualifications. In the aviation context, if you do not have the necessary safety training, you will not be able to work.

In contrast, non-aviation industries seem to centre on the company safety records as a whole: company goals are emphasized, general information on safety is available, supervisors encourage involvement in safety issues and are perceived to know safety inspections' results. This analysis is further supported by non-aviation better results in "we are recognized and rewarded for working together".

In this sense it would be appropriate to say that aviation safety systems are individualistic by nature and non-aviation safety systems are much more collectivistic. Such perspectives can also be associated with an "organizational locus of control or accountability".

Results from non-aviation organizations may be related with recent government investments in workplace safety. Portugal has one of the worst work accident rates in the European Community. Support for safety training, safety programs, safety prizes, safety inspections and media campaigns have been created to address this problem. The problem is depicted as a national problem (national statistics may involve anyone) or an organizational problem (fines for companies that do not follow safety recommendations) and an issue that needs every person's contribution. Such perspective helps to depart from an individualistic approach of work accidents or the bad apple theory (Dekker, 2002) that hinders organizational safety learning. Advantages of this viewpoint should be considered by aviation safety systems as it may complement the existing perspective.

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