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The effect of automation on workload management and pilot role

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**The effect of automation on workload management and pilot
role**

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San Jose State University, 1994

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THE EFFECT OF AUTOMATION ON WORKLOAD MANAGEMENT AND
PILOT ROLE

A Thesis

Presented to
the Faculty of the Department of Psychology
San Jose State University

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts

by
Kimberly Jobe
May, 1994

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May 27, 1994

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ABSTRACT

THE EFFECTS OF AUTOMATION ON WORKLOAD MANAGEMENT AND PILOT ROLE

by Kimberly Jobe

Recent research suggests that advances in automated cockpit systems may have an impact on crew communication (Wiener, 1989; Segal, 1993; Veinott & Irwin, 1993). The present study explores the possibility that communication requirements may be different in the more automated cockpit, and that workload management and pilot role may be affected.

Level of automation was varied by comparing the DC-9 and its automated derivative, the MD-88. Videotapes of twenty air crews were coded for control actions performed on the cockpit systems, instrument sets/adjustments specific to navigation, and those involved in irregular procedures. Questions concerning cockpit systems, navigation changes, and irregular procedures were assessed, as was amount of total communication.

There were no differences in amount of communication between aircraft type. Captains (CAs) asked more questions than First Officers (FOs) regarding navigation. DC-9 CAs had the highest mean frequency of systems behaviors. MD-88 CAs had the highest mean frequency of navigation behaviors. Interpretations of these differences are discussed in terms of their impact on workload management and pilot role.

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The Effects of Automation on Workload Management and Pilot Role

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EFFECTS OF AUTOMATION

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Abstract

Recent research suggests that advances in automated cockpit systems may have an impact on crew communication (Wiener, 1989; Segal, 1993; Veinott & Irwin, 1993). The present study explores the possibility that communication requirements may be different in the more automated cockpit, and that workload management and pilot role may be affected. Level of automation was varied by comparing the DC-9 and its automated derivative, the MD-88. Videotapes of twenty air crews were coded for control actions performed on the cockpit systems, instrument sets/adjustments specific to navigation, and those involved in irregular procedures. Questions concerning cockpit systems, navigation changes, and irregular procedures were assessed, as was amount of total communication. There were no differences in amount of communication between aircraft type. Captains (CAs) asked more questions than First Officers (FOs) regarding navigation. DC-9 CAs had the highest mean frequency of systems behaviors. MD-88 CAs had the highest mean frequency of navigation behaviors. Interpretations of these differences are discussed in terms of their impact on workload management and pilot role.

The Effect of Automation on Workload Management and Pilot Role

Cooperative endeavors such as flying an aircraft require that crew members communicate and coordinate activities effectively in order to achieve their goals. Recent studies suggest that the introduction of automated cockpit systems may have an impact on these processes (Costley, Johnson, & Lawson, 1989; Veinott & Irwin, 1993; Wiener, 1985, 1989). These studies suggest that communication patterns may be different in highly automated aircraft. If so, what effect might automation have on crew coordination and workload management? This paper examines this impact, and whether the roles and duties of the pilots have been affected as well.

Crew Coordination

Past research indicates that there is a link between communication and crew coordination. For example, Cooper, White, and Lauber (1979) reviewed air crew accidents and incidents and suggested that failures in communication and crew coordination (including task delegation and workload management) were associated with many of the problem situations. Foushee, Lauber, Baetge, and Acomb (1986) investigated the effect of fatigue on air crew resource management in a full-mission simulation study. They reported that familiarity (i.e., the experience of pilots having recently flown together) was one factor which facilitated crew communication and coordination. Moreover, in this study it was a more important factor than fatigue in terms of crew performance.

As a result of these studies, human factors researchers began to focus on crew processes and Crew Resource Management (CRM), rather than on

individual factors or technical competence alone. Specifically, more recent research focuses on crew communication as a means of providing an indication of overall crew coordination (Kanki, Lozito, & Foushee, 1987).

Use of Cockpit Communication to Examine Crew Coordination

The role of verbal communication. Foushee and Manos (1981) established a relationship among communication patterns, resource management, and performance in another simulation study. They found that lower performing crews tended to communicate less overall. In particular, lower performing crews made fewer commands and acknowledgments. Commands were defined as "specific assignments of responsibility" and acknowledgments as "recognition of a command, inquiry, etc." (p. 65). This finding was interpreted to reflect poorer crew coordination in lower performing crews because these kinds of communications were meant to ensure that duties are effectively delegated.

Foushee et al. (1986) established a link between crew communication patterns and crew coordination as well. They found that commands and acknowledgments were more prevalent in crews that had recently flown together, and that this pattern was associated with better crew coordination and performance as well.

The role of non-verbal information in cockpit communication.

Aviation research has primarily focused on verbal communication as a means of assessing crew coordination. However, we know from research on non-verbal communication that non-verbal cues are an important source of information in human communication. Segal (1990) was the first to

emphasize that the non-verbal aspect of crew communication may play an important role in crew coordination. Specifically, Segal advanced the view that pilots obtain additional information by observing each other as they interact with cockpit systems.

This type of communication would appear to be an important source of task-related information, especially during periods of heavy workload. During a missed approach, for example, one pilot may be unable to acknowledge verbally the fact that the gear has been retracted because an out-of-cockpit communication was required at that moment. The information would be conveyed nonetheless if the second pilot was able to observe the action.

An underlying premise of this paper is that increased automation often replaces separate and distinct instruments with multi-function displays. As a result, many of the non-verbal cues obtained by simply observing other crew members perform tasks are lost in the more automated cockpit. Research regarding this loss is critical given the introduction of new technology to cockpit systems.

Automation: Available New Technology, Safety, Workload Reduction

Advances in microprocessor technology in the 1970's led to the introduction of flight deck microcomputers designed to increase flight safety and efficiency by assuming some of the duties of the pilots and flight engineer. However, Curry (1985) and Wiener (1985, 1989) found that pilots of highly-automated aircraft reported that automation increased their workload during periods where the workload was already high, and decreased it during

periods of low workload.

Weiner, Chidester, Kanki, Palmer, Curry, and Gregorich (1991) reported differences in subjective workload ratings as well. There was a tendency for crews of the more automated MD-88 aircraft to rate their workload as higher than crews in the less automated DC-9 aircraft. When these data were analyzed separately for pilot position, there were significant differences for First Officers (FO) only, "indicating that MD-88 FOs attributed a higher workload to their cockpit duties than those assigned to the DC-9s" (p. 36).

Automation, Role Structure, and Workload Management

Task allocation and crew member responsibilities in the cockpit are heavily dependent on pilot role assignment; i.e., whether he or she is the pilot flying (PF). The primary responsibility of the PF is control of the aircraft. The pilot not flying (PNF) generally takes care of out-of-cockpit communications, checklists, and navigation. Weiner (1989) has suggested that automation may bring about a change in the way tasks are delegated, creating a less clear picture of roles and responsibilities than those occurring in conventional cockpits.

In related research, Segal (1993) investigated the effects of automation design on crew coordination and concluded that there is a link between the physical design of the cockpit systems and pilot interaction. He found that the level of non-verbal control activity increased significantly in cockpits where electronic manual and electronic automatic checklists were used when compared to those in which standard paper checklists were used.

Interestingly, the increase in activity in the more automated cockpits

was not accompanied by differences in amount of verbal communication between conditions. The researcher concluded that 1) workload was not reduced by automation in this case, and that 2) verbal communication alone may not be sensitive enough to pick up differences between conditions.

More importantly in terms of pilot role and workload management, the distribution of workload was very different in the more automated cockpits. The pilot not flying was much more active than the PNF in the standard checklist cockpits. This is consistent with the Wiener et. al. finding of higher subjective workload ratings reported by MD-88 FOs who tended to be the PNF. Furthermore, the PF in the more automated cockpit tended to monitor PNF activity, acquiring what Segal has termed unintentional or "consequential" communication.

The research outlined above suggests that both verbal and non-verbal communication patterns should be examined for effects on workload management and pilot role that may be present as a result of increased cockpit automation.

Rationale for the Present Study

Wiener et al. (1991) conducted a full-mission simulation study investigating the impact of automation on crew performance, coordination, and communication. They reported no significant differences in performance between aircraft type, but there were differences in subjective workload reports and communication patterns that have not been fully examined. As mentioned above, MD-88 crews rated their workload as higher compared to DC-9 crews. Also, Veinott and Irwin (1993) reported differences between

aircraft type in overall communication using data obtained from the Wiener et al. study. MD-88 crews talked more than DC-9 crews, and MD-88 Captains (CAs) asked their FOs more questions than CAs in the DC-9.

These differences in overall communication and questions suggest that there may be different communication requirements in the more automated cockpit. Perhaps it is more difficult to determine what tasks have been performed because much of the information normally obtained by observing the actions of another pilot is not readily available in the more automated cockpit. Segal (1990, 1993) has argued that in order to coordinate their activities, crew members make use of both verbal communication and the non-verbal communication inherent in observing other crew members as they perform tasks and interact with the cockpit systems.

The fundamental premise of this paper is that the design and configuration of the more automated MD-88 cockpit may reduce the ability to make use of this non-verbal component of communication. The layout of the MD-88 cockpit is depicted in Figure 1. When in an upright position, the throttle obstructs the view of a portion of the lower front panel for each pilot. As a result, it may be more difficult for the PF to observe the actions of the PNF, especially if this involves entering data into the control display unit (CDU) . If much of the information needed to perform cockpit duties must be extracted from the CDU, crew members may have to communicate more and ask more questions in order to determine what has been accomplished, coordinate tasks, and manage the workload. There may also be some confusion over the roles and duties, and tasks may be allocated differently in

Figure 1. MD-88 Cockpit

the more automated aircraft. This seems plausible given the increase in overall communication and questions in the CA to FO direction in the MD-88 cockpit reported by Veinott and Irwin (1993). Consequently, unlike DC-9 CAs who tend to "fly the aircraft" while their FOs take care of navigation, irregular procedures, and out-of-cockpit communications, MD-88 CAs may be more likely to share some of these duties with their FOs .

Previous work found that differences between traditional and automated cockpits are more pronounced in high workload periods. The present study has therefore focused on a portion of an abnormal phase of flight. If there are differences in the way in which crews of the more automated aircraft manage their workload, and if these differences are driven by different communication requirements in the more automated cockpit, the following results would be expected:

- (1) More verbal communication during higher workload periods in the MD-88 cockpit compared to the DC-9.
- (2) More questions in the CA to FO direction in the MD-88 than in the DC-9 concerning cockpit systems, navigation, and irregular procedures.
- (3) Differences in task allocation between aircraft type during the high workload period.

The focus of this study was to examine communication and activity patterns in each type of cockpit, and to examine the role that any observed differences have in workload management and pilot role.

Method

Subjects

Eighty-six line pilots from a U.S. airline volunteered for the study. (For a more detailed description of subjects, see Wiener, et al., 1991). Because selection was based on schedule compatibility, 48 of the original 86 pilots (24 crews) flew the experimental simulator session. Two of the MD-88 runs were discarded due to instructor inconsistencies.

Scenario

Videotapes and data from the Wiener et al. (1991) full-mission simulation study were utilized for the present study. As defined in Wiener et al., the Line Oriented Flight Training (LOFT) scenario was designed by the study team and associated airline DC-9 and MD-88 simulator instructors to be equally difficult for both types of aircraft. It included periods of high workload produced by a system failure, bad weather, and complicated Air Traffic Control (ATC) clearances in order to address the following areas: systems management, flight guidance and navigation, and crew coordination. Automation was varied by selecting two aircraft of the same family, one representing a low level of automation, the DC-9, and its derivative representing a higher level of automation, the MD-88.

The flight scenario was adapted from a regularly scheduled flight from Atlanta to Columbia, SC. The flight went as expected until the approach into Columbia, at which point one of the constant speed drives (CSD), which transfers power to a generator, began to overheat. The temperature leveled off in the caution range, requiring the completion of a generator low light

message checklist. The temperature then had to be monitored while the crews continued the approach to Columbia.

The crews had to make a missed approach due to poor weather at Columbia. They were then issued an unpublished missed approach procedure and holding pattern because a "no-radio" aircraft had conducted a missed approach immediately ahead of them and could not be reached by ATC. At this point, the CSD temperature began to climb into the emergency range. If this event went unnoticed before entering the holding pattern, the CSD failed and caused a generator to shut down.

This was a period of very heavy workload in that the crews had to copy their clearance and plan an entry into a different holding pattern than they had expected. They then had to enter and maintain this holding pattern, deal with the failed CSD and generator, get the current weather reports, talk with the company dispatcher, and decide on an alternate landing airport.

Given the findings of Wiener (1985, 1989), Wiener et al. (1991), and Segal (1990, 1993) that communication, workload management, and crew coordination appear to be different in the more automated cockpit and more pronounced in high workload periods, and because of the heavy workload involved between missed approach and leaving holding, this segment was examined for differences between aircraft type. On average this segment lasted 10 minutes, and this did not differ significantly between aircraft type.

One characteristic of the missed approach to leave holding segment was that Captains were required to be the pilot flying because the approach was a Category II approach. A Category I approach allows the pilot to

approach to a height of 200 feet above touchdown, with a runway visual range (RVR) of at least 1800 feet. In contrast, a Category II approach allows the pilot to approach to a height of 100 feet, with an RVR of at least 1200 feet (Jeppesen Airway Manual, 1994). The Category II approach requires special authorization and training. Because of the cost of training Category II PF duties, FOs did not have this training.

Another characteristic was that CAs tended to retain control of the aircraft for this entire segment. This was true for all but 2 crews, which were discarded. Consequently, the remaining ten MD-88 and ten DC-9 crews were used in the present study. Based on the requirement that the CAs fly this segment, the terms CA/PF and FO/PNF will be used interchangeably.

Apparatus

The LOFT flights were videotaped by cameras which recorded 1) a panoramic view of the cockpit and 2) part of the instrument panel. Audio was recorded from three microphones, one worn by each pilot, and a third behind them.

Procedure

Videotapes were transcribed and coded for amount of communication and communicative function in a previous study (Wiener et al. 1991). Amount of communication was defined as number of speech acts (e.g., number of initiation-response pairs). Communicative function categories included commands, questions, replies, and acknowledgments (Veinott & Irwin, 1993). In addition, questions were categorized into those regarding systems, navigation, and irregular procedures. Amount of communication

(number of speech acts) and questions concerning the three categories occurring during the missed approach to leave holding segment were used for analysis in the present study.

In addition to the data obtained from previous studies utilizing this data base, the present study required that the videotapes be coded for relevant control actions and behaviors. These included control actions or behaviors performed on the cockpit systems, instrument sets and adjustments specific to changes in navigation, and those involved in irregular procedures.

Systems. Behaviors in this category were those having to do with changing the aerodynamic configuration and/or speed of the aircraft, or CDU manipulation (which is one element of the Flight Management System).

They included the following:

1. setting the flaps
2. setting the gear
3. changing the speed
4. entering data into the CDU
5. adjusting rudder trim.

Navigation. Behaviors in the navigation category were those having to do with utilizing appropriate navigation aids as a reference in order to follow a prescribed route. They included the following:

1. tuning in navigation radios
2. changing the heading
3. changing course
4. changing the altitude

5. changing the flight director mode.

Irregular procedures. Behaviors in the irregular procedures category were those having to do with accomplishing the checklist for the CSD problem. They included the following:

1. resetting and/or disconnecting the CSD
2. attempting to start the APU
3. turning off air conditioning pack
4. turning off the galley power
5. disconnecting the APU bus switches.

Two coders were trained on videotapes excluded from the present study. Coders established an overall inter-rater reliability of 85% agreement on behaviors, with 87% reliability for systems behaviors, 80% for navigation behaviors, and 80% for irregular procedure behaviors.

Coding was then completed by one coder. Discrepancies or coding questions were resolved by committee with the second coder. An intra-rater reliability was assessed half way through the coding procedure, resulting in 92% agreement, and again at the completion of coding, with a 94% agreement.

Results

Speech Acts

Frequency of speech acts during the missed approach to leave holding segment were subjected to a 2 (aircraft type) $\times$ 2 (pilot position) between subjects analysis of variance. The first hypothesis, stating that MD-88 crews were expected to communicate more overall, was not supported. As can be seen in Figure 2, there were no significant differences in number of speech

Figure 2. Mean frequency of speech acts as a function of aircraft type and speaker.

acts between aircraft type. DC-9 crews had a mean frequency of 46.30 speech acts, while the mean frequency for MD-88 crews was 49.45. There were differences between pilot position, with CAs generating more speech (Mean = 53.30) than FOs (Mean = 42.45), but the difference did not reach significance.

Questions

In order to determine whether MD-88 CAs asked more questions of their FOs concerning cockpit systems, navigation, and irregular procedures, the frequencies of each kind of question were submitted to a 3 (category of question) $\times$ 2 (aircraft type) $\times$ 2 (pilot position) mixed analysis of variance. Category of question was a within-subjects variable.

The second hypothesis, stating that more questions would be expected from the MD-88 CAs was only partially supported. Although MD-88 CAs asked more questions overall, the difference (depicted in Figure 3) did not reach significance. However, there was a significant pilot by category interaction [$F(2, 72) = 9.78, p < .001$]. The pattern of the interaction indicated that Captains asked more than twice as many questions than First Officers regarding navigation (Figure 4). There were no differences in frequency of questions regarding systems or irregular procedures. Means and Standard Deviations for the question data are presented in Table 1.

Non-verbal Control Actions/Behaviors

In order to determine whether there were any differences in task allocation between aircraft type across systems, navigation, and irregular procedure behaviors, frequencies of each action or behavior were submitted to a 3 (category of behavior) $\times$ 2 (aircraft type) $\times$ 2 (pilot position) mixed

Figure 3. Mean frequency of question as a function of type and speaker.

Figure 4. Mean frequency of question as a function of type and speaker.

Table 1

Means and Standard Deviations for each Type of Question.

Type of Question				
	DC-9		MD-88	
	CA	FO	CA	FO
Systems	1.10	1.10	1.10	1.00
	(1.91)	(0.99)	(1.28)	(1.05)
Navigation	3.80	1.10	4.80	2.10
	(2.48)	(0.99)	(2.93)	(2.10)
Irregular procedures	0.70	0.40	0.00	0.00
	(0.67)	(0.96)	(0.00)	(0.00)

analysis of variance. As depicted in Figure 5, the third hypothesis stating that differences in task allocation between aircraft type would be expected, was supported. The aircraft by pilot by category interaction was significant [$F(2, 72) = 41.46, p < .001$]. However, as depicted in Table 2, the mean and standard deviation for MD-88 CA irregular procedure behaviors was zero. Because the absence of variance in this cell could be responsible for the three way interaction, a 2 (category of behavior) $\times$ 2 (aircraft type) by 2 (pilot position) ANOVA was performed. The interaction was still highly significant [$F(1, 36) = 51.660, p < .001$]. Therefore, each category of behavior was analyzed by a 2 (aircraft) $\times$ 2 (pilot) between subjects analysis of variance.

There was an aircraft by pilot interaction for the systems category of behavior, with DC-9 CAs having the highest mean frequency of these kinds of behaviors, followed by MD-88 CAs and FOs, then DC-9 FOs [$F(1, 36) = 36.072, p < .001$]. Further, DC-9 CAs had a mean frequency more than seven times greater than their FOs, while the mean frequency for MD-88 CAs was only slightly higher than their FOs (Figure 6).

The aircraft by pilot interaction was reversed for the navigation category of behavior (Figure 7). MD-88 CAs had the highest mean frequency of navigation behaviors, followed by DC-9 FOs, MD-88 FOs, and DC-9 CAs respectively [$F(1, 36) = 11.922, p = .001$].

There was a main effect for pilot in the irregular procedure category of behavior [$F(1, 36) = 9.807, p = .003$], with FOs performing the majority of these behaviors (Figure 8).

Figure 5. Mean frequency of behavior as a function of type and pilot.

Table 2

Means and Standard Deviations for each Type of Action Behavior.

Type of Action Behavior	DC-9		MD-88	
	CA	FO	CA	FO
Systems	42.60	5.10	15.90	9.00
	(12.86)	(2.69)	(8.48)	(3.89)
Navigation	5.90	7.90	10.50	6.10
	(1.79)	(2.56)	(4.69)	(1.59)
Irregular procedures	0.60	1.70	0.00	1.60
	(1.27)	(1.42)	(0.00)	(1.96)

Figure 6. Mean frequency of system behavior as a function of aircraft type and pilot.

Figure 7. Mean frequency of navigation behavior as a function of aircraft type and pilot.

Figure 8. Mean frequency of irregular procedure behavior as a function of type and pilot.

Discussion

There were three notable findings from the present study. First, no difference between aircraft in amount of overall communication type was observed. This was surprising given that past research found such differences with this database overall, and given that other researchers found differences in communication patterns to be more prevalent during high workload periods. Second, although there were no significant differences between aircraft type in number or type of questions asked, a significant pilot by category interaction associated with navigation questions was observed. Finally, a highly significant three-way aircraft by pilot by category interaction was observed for mean frequency of behavior. The observed significant differences will be discussed in turn.

Navigation Questions

Captains in both types of aircraft asked twice as many navigation questions as their FOs. This is consistent with traditional roles mentioned previously. If the FO assumes most of these duties, it seems reasonable that the CA would ask about them. However, MD-88 CAs asked the highest proportion of these questions, followed by the DC-9 CA, MD-88 FO, and DC-9 FO respectively. Although the differences were not significant, the trend is in the predicted direction. This is somewhat consistent with the Veinott and Irwin (1993) finding that MD-88 CAs had the highest proportion of questions overall.

Non-verbal Control Actions/Behaviors

Systems. DC-9 CAs had the highest mean frequency of systems

behaviors (more than seven times greater than their FOs), while the mean frequency for MD-88 CAs was only slightly higher than their FOs. This pattern of the DC-9 CAs performing a much greater proportion of the system behaviors is consistent with traditional roles and duties whereby the CA tends to fly the aircraft, while his FO handles navigation, communications, and irregular procedures.

Conversely, it appears that MD-88 FOs may be assuming some of these duties for their CAs as they enter data into the CDU. Although many CAs did enter data into their own CDU, they may again be deferring many of these duties to their FOs during this period of heavy workload in order to avoid getting behind the aircraft. Problems seemed to arise when one or the other pilot had to ask what had or had not been accomplished. For example:

CA "15 mile [legs], we can put that in the machine"

FO "15 miles, uh you did put it in?"

And: CA "Give me slats, I'm sorry. You got slats?"

FO "Yeah, I got the slats, I already took 'em up. I should have told you. Sorry about that."

One way to circumvent this type of problem in the more automated cockpit where standardization of task assignment seems to have disappeared would be to incorporate a strategy of using 1) a statement of intent, and 2) acknowledgment before anything is done either manually or via CDU entry which would change the speed, configuration, heading, course, or altitude of the aircraft. Such a strategy, which would reduce any confusion over what has or has not been accomplished, would be especially helpful

during periods of high workload.

Navigation. Another interesting pattern of behavior was observed for navigation behaviors. CAs in the MD-88 cockpit had the highest mean frequency of navigation behaviors, while DC-9 CAs had the lowest. The pattern in the DC-9 cockpit is again consistent with the traditional cockpit roles.

On the other hand, CAs in the MD-88 seem to be assuming some of these duties for their FOs. For example, the MD-88 CA was more likely to tune in his own navigation radio, compared to the DC-9 CA whose FO performed this behavior in all cases. The MD-88 CA was also more likely to dial in a new heading or altitude than the DC-9 CA.

One possible explanation for these differences in task allocation between aircraft type is that high workload in the MD-88 cockpit is induced by the FO programming the unpublished holding procedure into the CDU. This may require the MD-88 CA to share in the navigation duties in order to re-allocate the workload more efficiently.

Irregular procedures. The main effect for pilot in this category, with FOs performing the majority of these kinds of behaviors, is consistent with the traditional pattern of roles and duties. It is not surprising that the FO, or PNF in this case, assumed the majority of these responsibilities.

In sum, it appears that during periods of high workload when automation should help reduce some of the work, MD-88 CAs are having to share some of the duties normally assumed by their FOs in order to keep up and not get behind their aircraft.

Implications for Training

One suggestion for improving training was outlined above.

Implementation of a strategy of using statements of intent and acknowledgment would help to keep both pilots informed of who has done what, and which tasks still need to be accomplished during high workload.

Another would be to improve training by improving the crew members' awareness of possible differences in pilot role in the more automated cockpits, especially during periods of high workload.

Future Research

In terms of differences in task allocation, it would be interesting to determine whether CA commands are acknowledged and carried out in the MD-88 cockpit for this segment. It may be that the CA, noticing that the FO is busy with CDU entry, simply does the requested action. If so, a statement of intent would again be helpful in keeping the other pilot informed of the situation.

Future research might also look at the navigation question category more closely. Those having to do with vectors, headings, weather, altitude, alternates, and flight route were included in this study. However, any of these topics may have had to do with what the PNF was entering into the computer at that moment. Consequently, the questions in this category may not have served the purpose of the present study.

Finally, future research should attempt to validate these findings using a different scenario and aircraft type in order to generalize the results.

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Appendix A. Signed Approval Form

Office of the Academic Vice President • Associate Academic Vice President • Graduate Studies and Research
One Washington Square • San Jose, California 95192-0025 • 408/924-2480

TO: Kimberly Jobe
737 Layton Court
Santa Clara, CA 95051

FROM: Serena W. Stanford *Serena W. Stanford*
AAVP, Graduate Studies and Research

DATE: March 3, 1994

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"The Effects of Automation on Workload Management
and Pilot Role"

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The Board's approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Dr. Serena Stanford immediately. Injury includes but is not limited to bodily harm, psychological trauma and release of potentially damaging personal information.

Please also be advised that each subject needs to be fully informed and aware that their participation in your research projects is voluntary, and that he or she may withdraw from the project at anytime. Further, a subject's participation, refusal to participate or withdrawal will not affect any services the subject is receiving or will receive at the institution in which the research is being conducted. If you have questions, please contact me at (408) 924-2480.