The Efficiency of New Audio Alerts in the COOPANS Eurocat System

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Abstract. The Air Traffic Control System in Ireland, known as COOPANS, has been developed in conjunction with an industry partner Thales Group, is deployed in five European countries – Austria, Croatia, Denmark, Ireland, Sweden, is unique as all countries operate the same software version and by 2020 will be responsible for 3,559,000 flights within European airspace. These systems are designed to detect and alert critical situations such as conflict between aircraft, between aircraft and terrain and between aircraft and areas where there is a risk to flight within that airspace. COOPANS provides three different safety alerts to warn Air Traffic Controllers of system safety events, including Short Term Conflict Alert (STCA) which indicates potential for a loss in either required lateral or vertical separation between aircraft; Minimum Safe Altitude Warning (MSAW) which indicates that an aircraft is operating at an altitude which may not be terrain safe; and Area Proximity Warning (APW) which indicates that an aircraft is projected to enter airspace which is segregated due to military or security operations. 77 participants out of a total Air Traffic Control cadre of 375 rated Air Traffic Controllers took part in the trial. 38 participants completed Trial A – traditional audio alert and 39 participants completed Trial B enhanced audio alert. The results demonstrate that the enhanced audio alert improved air traffic controller performance and efficiency across all three critical incident situations STCA, MSAW, APW regardless of air traffic controller experience. This improved performance resulted in faster response times by the air traffic controllers to the critical alerts presented. Training for air traffic controllers in the use of these new audio alert presentations can be harmonized and no distinctions need be made between experts and novices. This represents substantial benefit to air navigation service providers in avoiding increased costs in designing separate training programs for expert and novice air traffic controllers.

Keywords: Air traffic control · Area proximity warning · Minimum safe altitude warning · Short term conflict alert · Training

1 Introduction

Regardless of the field of interest, be it medicine, aviation, nuclear power plants, as technology has evolved, as systems have become more complex and as developers strive to automate more and more tasks, increased automation has had the impact of at

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times reducing the operator to a monitoring role. In aviation the role of the pilot has been described as that of a systems manager or monitor as aircraft systems now have the capability to navigate and control the aircraft through all phases of flight (Woods et al. 1997). A fundamental issue, clearly highlighted is that a poorly designed audio alert system has the potential to distract the operator, to disrupt the tasks that the operator is engaged in and to prevent the effectiveness of the prioritisation of information processing tasks by the operator (Woods et al. 1987). All of these have the potential to prevent the operator identifying, prioritizing and responding to abnormal conditions despite the presence of an alerting system designed to enhance safety and assist in retrieving a critical situation.

Even when the audio alerts used are distinctive and can be perceived among all the other signals in the work environment, even when the alert is capable of transmitting the nature of the situation being presented the overall alerting system can be undermined if the operators are presented with a high frequency of non-valid alerts (Sorkin 1988). Parasuraman et al. (1993) have proposed that operators can demonstrate signs of complacency and overreliance on automation and hence automation alerts when their workload is high and they are involved in concurrent tasks. This is of particular concern in an environment where a number of critical safety barriers are all presented in the same manner, visually and aurally. For instance in the COOPANS Air Traffic Control system the associated risk is that an alert presentation for a critical risk such as Short Term Conflict Alert (STCA) is misinterpreted as it is mistaken for a lesser alert such as Area Proximity Warning (APW). STCA alerts typically occur less frequently but signify a situation of graver concern than the APW alert. APW alerts can be generated in situations where aircraft are perceived by the COOPANS system to be entering an area where they are not permitted to enter, but to which they have the appropriate authorization and clearance to enter. Multiple APW activations as a result of aircraft legitimately entering a protected area (such as military aircraft) may subsequently mask the activation of an STCA alert where a rapid air traffic control response is required to resolve a critical separation issue. In this case multiple movements by such an aircraft will generate multiple APW alerts, within this period, should a concurrent STCA alert occur the risk is that complacency associated with the APW alert, masks an STCA event which subsequently occurs. The Air Traffic Controller response may be to simply silence the audio alert, not solve the separation risk and the risk is not identified and therefore a system safety barrier is weakened and airborne systems (TCAS) are required to resolve this conflict.

Previous researches identified a number of on-going issues of safety concerns within FAA air traffic control centers such as no uniqueness of alarms, many false alarms, alarms being counter intuitive, alarms being loud and annoying and startle the air traffic controllers, also revealed that automated tools within a system can also contribute to an increase in workload (Ahlstrom 1999; Newman and Allendofer, 2000; Wolfman et al. 1996). This occurs as the operator is in fact presented with additional tasks – consider the advice of the system and compare the solutions provided by the systems with their own concept of resolution (Selcon 1990; Kirlik 1993). These decision aids may counter intuitively, force an additional task upon an operator. In the highly automated environment of the modern cockpit or air traffic controller working position the pilot or air traffic controller has in some respects been reduced to a monitor of the system and flow of traffic (Hilburn et al. 1995). Wiener and Curry (1980) demonstrated a link between this increased monitoring workload for pilots and an increase in cognitive workload. Sarter (1996) highlighted the fact that workload had only really been redistributed within the cockpit leading to the potential for a new kind of error. Diagnosis of the situation being presented is a crucial element of the air traffic control process, an incorrect diagnosis of the situation will likely lead to an incorrect decision and ultimately an incorrect action to resolve the situation. Diagnosis of situations following the activation of a safety alert means that the air traffic controller is often attempting to resolve a situation during a time of stress. Dorner (1993) outlined a number of impacts of stress on decision making, such as, reduced decision time, increase in the speed of information processing, enhance the tendency to switch from proactive monitoring and control to reactive behaviour such as checking – diagnosis. This is especially important as Dorner's (1993) research suggests that not only is it possible that the response to the critical situation may be impaired but that the air traffic controllers ability to continue to monitor the progress of other traffic within the sector can be adversely affected due to the switch from proactive monitoring to reactive controlling. Research by Janis and Mann (1977) support the work of Dorner (1993) suggesting that in situations with a limited time there is a tendency for operators to reach non-optimal decisions.

Under time pressure, individuals sampled less of their environment, used less inputs when making their decisions, the quality of the judgments made deteriorated, persistence with the chosen course of action occurs and the ability to create other problem solving strategies diminishes (Keinan 1987; Edland and Svenson 1993; Benson and Beach 1996) also found that time pressure interfered with an individual's problem identification process making this process more random. In the context of the COOPANS Air Traffic Management System where all three critical situation alerts are signaled in the same manner, this may delay the problem identification phase and consequently delay or disrupt the resolution of the critical event. Therefore, current research is aiming to conduct an investigation into the effectiveness of the current alerting system within the COOPANS Eurocat Air Traffic control system and to design better warning systems for Air Traffic Controllers within safety critical environments.

2 Method

2.1 Participants

All participants were qualified Air Traffic Controllers and had been recruited directly into the organization and trained from AB-Initio stage to rated controller stage at the Irish Aviation Authority Training Centre. There were seventy seven participants in the study. All participants were currently rated Air Traffic Controllers with Air Traffic Control Licenses issued by the Personnel Licensing Department of The National Supervisory Authority of Ireland. There were fifty eight male participants and nineteen female participants.

2.2 Apparatus

Training Simulator: The Irish Aviation Authority's Contingency and validation platform was used to develop the training exercises in order to develop the scenarios for Short Term Conflict Alert (STCA), Minimum Safe Altitude Alert (MSAW) and Area Proximity Warning (APW). This contingency/Training platform is an exact copy of the main COOPANS Air Traffic Management System.

Hardware: The Contingency/training platform is an exact replica of the main COOPANS system controller working positions. The platform was supplied by THALES Air Traffic Management Systems as part of the COOPANS programme. Each controller working position consists of: 2 k × 2 k display screen – displaying the radar air situation display. A Single chain of Sun X4150 network servers which are rack mounted and Sun workstations which drive the displays.

Software: The Air Traffic Management software used on the contingency and training platform is the software that is being used on the main COOPANS Air Traffic Management system. In the case of this study the software version used was known as THALES software build B2.1.

Current COOPANS Air Traffic Management System Audio Alert: No adjustment was made to the configuration of audio alert presentation within the COOPANS Air Traffic Management system, this audio alert is referred to as the COOPANS Traditional Audio Alert.

New Audio Alert Presentation: A text to speech programme was used to convert the specific alert name to spoken word. AT & T Natural Voices™ is a text to voice synthesis programme which is freely available on the internet; this software allows the user to type text into a dialog box, which the software programme converts into spoken word. In this trial a female voice, "Crystal", in United States English was used as the computer voice for all alerts.

2.3 Procedure

Simulated traffic scenarios were developed using the COOPANS training simulator in order to provide a high fidelity radar screen representation. The training exercises were faithful to normal COOPANS configuration, all systems were shown to be operating normally, there was no degradation of weather conditions, and all of the aircraft operated to the performance characteristics of the specific aircraft type. Three specific training exercises were selected on the basis that each individual exercise produced one occurrence of either STCA, MSAW or APW. Once the system safety alert activated, the exercise was paused and a screenshot of the Radar screen, with the system safety alert clearly displayed, was taken. This process was repeated for each system safety alert – STCA, MSAW and APW. These three screen shots were then printed onto A3 paper and laminated so that they could be marked with a non-permanent marker.

The audio alert presented to the Air Traffic Controllers in the control group is the audio alert that is available within the COOPANS system – two tone continuous alert.

(Beep Beep Beep Beep) – Trial A. The audio alert presented to the experimental Group consisted of a new audio alert design. This audio alert is structured as follows (Beep Conflict Conflict Beep) – Trial B. Trials were conducted within the operational rooms at both the Air Traffic Control centres at Dublin and Shannon, ensuring normal background noise of an Air Traffic Control centre. Participants were presented with a total of three radar screen shots from the COOPANS air traffic control system.

The appropriate audio sound (Current COOPANS Audio alert (Trial A) sound or enhanced Audio Alert sound (Trial B)) was activated on A Toshiba Portege R830-138 laptop. On hearing the audio alerting sound participants marked on the radar screen shot the aircraft or aircrafts that were creating the alerting event. The time taken by the Air Traffic Controller to indicate the alerting event was noted using a stopwatch. Activation of the stopwatch was synchronized with the activation of the audio alert and the stopwatch was stopped upon correct identification of the alert.

3 Results

There are 77 of Air Traffic Controllers including 58males and 19 females participated in current research within the Irish Aviation Authority. Thirty eight participants conducted the trial using the current COOPANS Traditional Audio alert, and thirty nine participants completed the simulations using the Enhanced Audio Alert. The working experience were between 1 and 40 years ($M = 11.71$, $SD = 8.58$). Thirty five participants in the study had worked as Air Traffic Controllers for less than ten years and were therefore classed as Novices. Forty Two participants in the study had worked as Air Traffic Controllers for ten years or more and were therefore classed as Experts. The ages of the participants in the study ranged from twenty years of age to sixty two years of age ($M = 36.69$, $SD = 8.79$).

3.1 Air Traffic Controller Response Times to Critical Alerts Between the Enhanced Audio Alert System and the Traditional Audio Alerting System

There was a significant difference in air traffic controllers' response time to all critical alerts (STCA, MSAW and APW) whilst using the enhanced audio alerting scheme, in all cases the response time is improved resulting in faster reaction times to the critical event being displayed compared to the traditional COOPANS (Table 1). STCA $F(1, 75) = 5.63$, $p = 0.02$; MSAW $F(1, 75) = 4.12$, $p = 0.05$.; APW $F(1, 75) = 4.66$, $p = 0.03$.

3.2 Expert and Novice Performance Between the Enhanced Audio Alert System and the Traditional Audio Alerting System

No significant difference is revealed between the response time of experienced and non-experienced Air Traffic Controllers across STCA, MSAW and APW Warnings, by using the Enhanced Audio Alerting Scheme and traditional COOPANS (Table 2).

Table 1. Mean and standard deviation of ATC response time across scenarios of STCA, APW & MSAW between control group and experimental group

Groups		STCA	APW	MSAW
Control group (n = 38)	Mean	3.46	3.09	3.71
	SD	2.22	0.92	2.70
Experimental group (n = 39)	Mean	2.57	2.68	2.78
	SD	0.70	0.76	0.96

Table 2. Mean and standard deviation of ATC response time across scenarios of STCA, APW & MSAW between experienced and non-experienced group

Groups		STCA	APW	MSAW
Non-experienced (n = 35)	Mean	2.72	2.84	2.81
	SD	0.70	0.84	0.96
Experienced (n = 42)	Mean	3.25	2.91	3.59
	SD	2.18	0.89	2.60

STCA $F(1, 75) = 1.92$, $p = 0.20$; MSAW $F(1, 75) = 2.81$, $p = 0.10$; APW $F(1, 75) = 0.12$, $p = 0.73$.

4 Discussion

The improvement in air traffic controller performance and efficiency is as a result of the improved method of presented informing the air traffic controller of the critical situation. The traditional COOPANS Audio alert requires the air traffic controller to find the cause of the critical situation, identify exactly what alert is being presented and then apply a resolution strategy; this presents a risk that an incorrect judgment of the type of alert being signaled could be made resulting in the application of an inappropriate resolution strategy. In any case this process takes additional time, in an already time critical situation reducing the time available for effective resolution and restoration of safety. Previous research by Li and Harris (2008) has shown that judgment or decision errors may be contributing up to 69 % of all aircraft accidents. Also, Wood et al. (1987) demonstrated the impact of a poorly designed audio alert system was more wide ranging than simply distracting the operator when the poorly designed alert activates. Distraction following alert activation, subsequent continuous signaling by the alarm can disrupt not only the resolution of the critical situation but also the ability of the operator to continue to manage other workload (Banbury et al. 2001).

The enhanced audio alert format provides the air traffic controller with an initial BEEP to signal "I have an important message for you", then provides the nature of the alert i.e. CONFLICT, the air traffic controller can no longer be startled by the activation of the audio alert, which according to Thackray and Touchstone (1970) can cause a decrease in performance immediately after the startle has occurred and lasting between 2 and 10 s. As the alert is now more semantically rich and is informing the air traffic controller of precisely the nature of the critical situation, no further consideration of the nature of the critical situation is required and the air traffic controller can immediately begin to develop resolution strategies, thereby providing crucial extra time in a time critical situation. As the enhanced audio alert has demonstrated improved response time stemming from a more salient alert, which provides the air traffic controller with knowledge of the situation to be resolved the air traffic controller can more effectively and efficiently respond to the situation and then return to ensuring the rest of the aircraft under his/her control continue to be managed in a safe and efficient way.

The effectiveness of any alerting system is determined by how the system supports the system operator in resolving critical situations. In most cases this requires the system to provide knowledge of the alert being signaled so that the operator is supported in a prompt response often in circumstances which are time critical so that safety is maintained. Previous researches found that individuals under time pressure sampled less of their environment, used less inputs when making their decisions, the quality of the judgments made deteriorated, persistence with the chosen course of action occurs and the ability to create other problem solving strategies diminishes (Keinan 1987; Edland and Svenson 1993; Benson and Beach 1996). Therefore any mechanism which can make the air traffic controllers response more efficient will result in more time being available for the air traffic controller to sample their environment before making a judgment or decision in respect of a resolution strategy. This contributes to better decision making and improved air traffic controller response in critical situations.

The response to the new audio alert of both novices and expert air traffic controllers was equally improved contrary to the work of Roth and Woods (1988) and Wickens (1992). This improvement is related to alerts which provide the air traffic controller with knowledge of the critical situation which is occurring, this is achieved by ensuring that the alert is sufficiently salient so that the attentional mechanism and perception process is engaged and the requirement to revert to working memory is reduced as there is no requirement to interpret the alert cause. Diagnosis of the critical situation is simplified which provides more time for the Air Traffic controller to engage in decision making which ultimately will permit the deployment of more effective decisions to resolve the critical situation which correspond with previous research (Dorner 1993). In turn this means that the air traffic controller can continue the process of proactive monitoring of all air traffic within their sector rather than to reactive controlling to resolve the critical alert situation providing equal benefits regardless of expertise level.

5 Conclusion

The use of semantically rich audio alerts as part of the COOPANS Air Traffic Management system reduced Air Traffic Controller response times to critical system events as the alerts now inform the air traffic controller of precisely the nature of the critical situation, therefore no further consideration of the nature of the critical situation is required and the air traffic controller can immediately begin to develop resolution strategies, thereby providing crucial extra time in a time critical situation. The findings of current research suggests training for air traffic controllers in the use of new audio alert presentations can be harmonised and no distinctions require to be made between expert and novice air traffic controllers. This represents significant benefit to the air navigation service provider to avoid increased costs as no requirement exists to design separate training programmes for expert and novice air traffic controllers. Civil Aviation Authorities, Air Navigation Service Providers and Air Traffic Management system providers consider the findings of this research with a view to ensuring that Air Traffic Controllers are provided with the most optimal audio alerting schemes.

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