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Datalink in air traffic management: Human factors issues in communications

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Abstract

This paper examines issues underpinning the potential move in aviation away from real speech radiotelephony (R/T) communications towards datalink communications involving text and synthetic speech communications. Using a novel air traffic control (ATC) task, two experiments are reported. Experiment 1 compared the use of speech and text while Experiment 2 compared the use of real and synthetic speech communications. Results indicated that generally there were no significant differences between speech and text communications and that either type could be used without any main effects on performance. However, a number of specific differences were observed across the different phases of the scenarios indicating that workload levels may be more varied when speech communications are used. Experiment 2 illustrated that participants placed a greater level of trust in real speech than synthetic speech, and trusted true communications more than false communications (regardless of whether they were real or synthetic voices). The findings are considered in terms of datalink initiatives for future air traffic management, the importance placed on real speech R/T communications, and the need to develop more natural synthetic speech in this application area.

Keywords: Datalink; Air traffic management; Flightdeck of the future; Air traffic control; Speech; Text; Communications

1. Air traffic management

The management and control of air traffic comprises a complex problem and with aircraft levels set to double in the next 15 years, some degree of automation will be needed to enable such desired safe increases in air traffic capacity (Siemieniuch and Sinclair, 2001; Kirwan and Rothaug, 2001). The modern flightdeck–air traffic control (FD–ATC) system encompasses the integration of other aircrew, air traffic control operators (ATCOs), ground crew, and auxillary agencies (such as airline companies and service staff) and their related practices and procedures (Stedmon et al., 2003). For example, during a typical flight, a pilot will be in constant communication with other members of the flightcrew and different ATCOs; the pilot will receive information from FD instruments and displays; and may develop an awareness of other activities occurring in nearby airspace by 'eavesdropping' on radio communications between other aircraft and ATCOs (Cox et al., 2006). These sources of information contribute to FD crew and ATCO attention demands, mental workload and situation awareness (SA) and will affect subsequent communications and/or behaviour within the FD–ATC system.

Aircraft safety during flight is highly dependent on information exchanges via radiotelephony (R/T) between the ATCOs and pilots (Navarro and Sikorski, 1999). Since R/T communication bottlenecks and delays frequently occur, there is a need to investigate alternative modes of communication such as datalink (Wickens et al., 1997). It is estimated that 37% of current communication failures could be prevented if datalink replaced all standard verbal controller–pilot communications, and if additional systems were devised to check that pilot understanding matched a controller message, this would provide an additional 30%

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improvement (Gibson et al., 2001). Datalink is designed to relay communications between ATCOs and pilots, using text-based digital information rather than conventional R/T communication channels (Kerns, 1991). However, datalink may also incorporate other digital formats such as automated synthetic speech output.

To examine underlying human factors issues of potential datalink initiatives, two experiments were conducted using an ATC task and different modes of presenting information to users. The experiments were based on the same paradigm so that the first experiment provided a basis for the second experiment. Each experiment was independent and investigated separate issues associated with datalink. Experiment 1 examined the use of speech and text-based communications while Experiment 2 examined the use of real and synthetic speech. Both experiments also considered SA, performance and attention variables and, when considered together, offer a comprehensive examination of datalink information presentation.

2. Experiment 1: speech and text in ATC

This experiment investigated issues associated with speech and text communications in an ATC-based task. With datalink systems delivering information in the visual modality rather than the traditional auditory modality, there is a need to address the circumstances under which operators could miss critical information, or become habituated to visual stimuli (see Thorley et al., 2001). Consideration of the wider implications of workload and SA in datalink communications was required since the impact of any task re-distribution was expected to contribute to safety in enabling controllers and pilots to maintain an up-to-date picture of the relevant situation (Rognin et al., 2001).

2.1. Method

2.1.1. Design of Experiment 1

The independent variable was mode of information presentation (plain text, coloured text, real speech, and synthetic speech). A between-participant' design was used with participants undergoing two of four scenarios (i.e. one speech and one text condition). To minimise any order effects conditions were counterbalanced between-participants. Dependent variable measures were workload (NASA-TLX and continuous ratings); performance (response times (RTs) to rate continuous workload); attention (percentage of workload cues attended to and beacons recognised); vigilance (number of aircraft deviations noticed); communications (number of comments by participants); SA (memory test scores); and preference for mode of communication.

2.1.2. Participants

Thirty-two participants (16 males, 16 females) were recruited for the study from an opportunistic sample. Their age ranged from 18 to 55 years (mean = 25 years). All participants spoke English as their first language and had normal, or corrected to normal, vision and no prior ATC experience.

2.1.3. Apparatus and materials: development of the ATC interface

A dynamic ATC task was required that was realistic enough to be ecologically valid but not so complex that naïve participants would find it too difficult. A Microsoft Powerpoint interface was developed based on field visits to ATC centres. A series of 260 'slides' were presented as an animated sequence so that the ATC task followed a precise script which progressed at a pre-determined rate. In this way, each participant conducted the task over the same length of time, using the same information. An example of the interface (reproduced in black and white) is given in Fig. 1.

The interface represented a fictional ATC sector within which participants were responsible for monitoring the aircraft. The aircraft moved through the sector as part of the animation with the screen refreshing every 6 s. At various stages throughout the scenario and unknown to the participants, three SA tests were triggered where the screen went blank and participants had to remember as much information from the previous slide as possible. The SA tests provided the opportunity to split the main scenario into four phases: low, medium, and high aircraft activity, and high with a near miss situation.

On other occasions, icons appeared which represented navigation beacons and participants were requested to state which beacon was nearest to an aircraft in their sector. The ATC task was presented with plain green text and icons on a black background.

The ATC task was run as a Microsoft Powerpoint presentation on a 700 MHz PC and monitor. Standard computer speakers were used to relay speech communica-

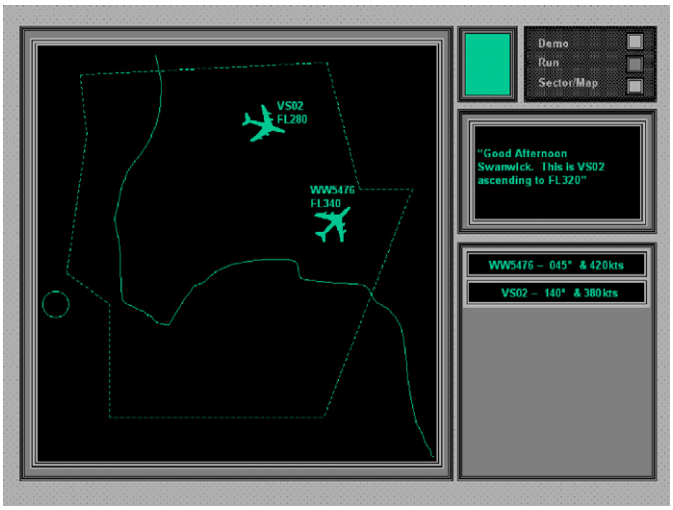

Fig. 1. The ATC interface.