CARE Innovative Action

Cognitive Streaming Project

Report on Work Package 3: Prevention of Performance Impairment

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DOCUMENT REVIEW

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A	30 Sept 2003	First draft for comment	
1.0	14 Nov 2003	Version incorporating flight deck observation and suggestions from Management Group	Information on flight deck observation added (Section 8 & Appendix B); minor changes to Sections 5.1, 5.2, 7.2, 7.4, 9.8; Abstract, References, Glossary and Distribution List updated; Typographical errors corrected.

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GLOSSARY

ADS — B	Automatic Dependent Surveillance — Broadcast
AIM	Aeronautical Information Manual
AMTE	Aviation Multi-Tasking Environment
ASAS	Airborne Separation Assistance System
ASRS	Aviation Safety Reporting System
ATC	Air Traffic Control
ATSAT	Aviation Topics Speech Act Taxonomy
ATSAW	Air Traffic Situation Awareness Systems
CAA	Civil Aviation Authority
CARE	Co-operative Actions of R&D in EUROCONTROL
CDTI	Cockpit Display of Traffic Information
CRM	Crew Resource Management
CRT	Cathode Ray Tube
EICAS	Engine Indication and Crew Alerting System
eND	Experimental Navi gation Display
FAA	Federal Aviation Administration
FFAS	Free Flight Air Space
FMS	Flight Management System
ICAO	International Civil Aviation Organisation
ICBC	Insurance Corporation of British Columbia
IOE	Initial Operating Experience
ISE	Irrelevant Speech Effect
NASA	National Aeronautics & Space Administration
NLR	Nationaal Lucht en-Ruimtevaartlaboratorium (National Aerospace Laboratory)
NTSB	National Transportation Safety Board
PF	Pilot Flying
PNF	Pilot Not Flying
R/T	Radio/ Telephony

S	Seconds
SA	Situation(al) Awareness
SAE	Society of Automotive Engineers
SAPI	Speech Application Programming Interface
SELCAL	Selective Calling
SID	Standard Instrument Departure
STAR	Standard Terminal Arrival
SUI	Speech User Interface
TCAS	Traffic Collision Avoidance System
TiVO	[not an acronym, according to TiVO Inc.]
TLX	Task Load indeX
TNO	Nederlandse Organisatie voor **T**oegepast-**N**atuurwetenschappelijk **O**nderzoek
TSD	Traffic Situation Display
VDL	VHF Data Link
VHF	Very High Frequency
VINTHEC	Visual Interaction and Human Effectiveness in the Cockpit
VMC	Visual Meteorological Conditions
WP	Work Package

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ABSTRACT

This Eurocontrol CARE project aims to demonstrate how a new theoretical approach to understanding human information processing ? 'cognitive streaming' ? can be applied to problems facing aircrew and air traffic controllers. Experiments in Work Package (WP) 2 had shown that irrelevant sound disrupted many aviation-relevant tasks in the laboratory — only a psychomotor task (tracking) was unaffected. The aims of WP3, the subject of the present report, were to examine real flights to determine the typical incidence of party line communications, and to consult relevant bodies of literature to suggest ways in which interference could be reduced.

As expected, party line communication, a source of irrelevant sound on the flight deck, was relatively common during most phases of flight, even occurring during the cruise phase of short-haul flights. The streaming model suggests that the party line would disrupt most of the flight activities observed, and indeed disruption was clearly visible at several stages of the flight. This work was interpreted within the context of the growing body of recent literature suggesting that interruptions and distractions on the flight deck are a major cause for concern.

A fundamental principle of the streaming model is that processing of irrelevant sound is obligatory, presenting a serious challenge for any attempt to reduce its disruptive effect. *Moreover, similar disruption is found for sounds corresponding to a whisper or a shout, and individuals do not habituate ('get used') to irrelevant sounds over time*. However, a set of possible counter-measures was identified:

Simple techniques that could be applied with little cost or effort:

- Following the strategies outlined by Dismukes et al (1998) to reduce vulnerability to interruptions and distractions on the flight deck
- Encouragement of greater discipline in adherence to standard phraseology to reduce the amount of unnecessary party line activity
- Following the guidance given by Brown (2003) on methods of improving communication

Solutions that will become possible with the introduction of new aviation technology:

- ADS–B with a Cockpit Display of Traffic Information or a Traffic Situation Display, which would replicate aspects of the auditory party line without the potentially damaging effect of speech
- Airborne Separation Assistance System procedures, with greater delegation of responsibility to aircrew

New technology that could be developed:

- 'Time-shifting' of R/T messages that could store the messages during tasks most vulnerable to disruption. A promising development is an automotive system that includes a subsystem allowing control over the timing of speech-based messages.
- Voice-to-text systems to allow R/T messages to be recoded visually, providing a pseudo-datalink system that would circumvent the problem of irrelevant speech

Evidence from studies of task interruption that could form the basis of future counter-measures:

- A playback feature to manage interrupting auditory messages
- Development of task management aids sensitive to both interrupted and interrupting tasks
- Inclusion of interruption management strategies in training programmes

Possible selection and training interventions:

- It may be possible to develop tests of selective attention for airline pilots, extending the work of Gopher
- Evidence that skills of selective attention can be trained could be exploited to reduce disruption.

The final Work Package in this project will examine the effects of irrelevant sound during a realistic simulation exercise. This WP will permit more definitive conclusions concerning the extent to which performance is disrupted by the party line.

General Introduction

1. INTRODUCTION

1.1. Background

A pilot study was conducted as part of the Eurocontrol CARE programme (Jones & Farmer, 2001) to demonstrate how a new theoretical approach to understanding human information processing ? 'cognitive streaming' ? could be applied to problems facing aircrew and air traffic controllers as traffic density increases. Cognitive streaming (e.g., Jones et al, 1997; Macken et al, 2003) is a theoretical framework for human information processing when auditory and visual information is combined. It was developed to understand the adverse effects of irrelevant background sound on a variety of tasks, particularly those that involve the retention of order in short-term memory. This approach postulates that interference between tasks occurs when they draw upon the same mental process (such as keeping track of order). It therefore differs from multiple resource theory (Wickens, 1992), which assumes that specialised 'resources', each with its own capacity limitation, can be distinguished.

1.2. Structure of the Work Programme

The programme described here is being conducted by QinetiQ, Cardiff University, and NLR Amsterdam. This report describes Work Package (WP) 3 of the main study on cognitive streaming that follows on from the preliminary work summarised above. The work is divided into four WPs.

WP1: Possible usefulness of irrelevant sound. The results of the pilot study confirmed that irrelevant sound will be registered, and have a damaging effect on task performance. The objective of the studies in this work package was to determine whether the information registered is useful to the individual.

WP2: Range of tasks affected by irrelevant sound. The objective was to determine the extent to which the effects found in the pilot study generalise to other tasks. The results are summarised briefly in Section 3 of this report.

WP3: Prevention of performance impairment. The objective of this WP (reported here) was to determine how the disruptive effects of irrelevant sound could be avoided. Methods of reducing the disruption would have an important role in promoting flight safety.

WP4: Real-world effects. The objective of this WP will be to examine the extent to which the effects can be demonstrated in realistic aviation tasks. To date, the study of the Irrelevant Sound Effect (ISE) has taken place almost entirely in the context of simple laboratory tasks. WP4 provides an opportunity to assess the disruptive influence of irrelevant sound in an applied setting.

1.3. Aims of Work Package 3

WP3 is the only non-experimental phase of the current programme. Its aims were a) to examine real flights to determine the typical incidence of party line communications, and b) to consult relevant bodies of literature to suggest ways in which interference could be reduced. These aims were addressed in separate work-elements, described below.

1.3.1. WP3.1: Data collection

This work-element was based upon direct observation and analysis of video-recordings of pilot activity and R/T traffic during short- and long-haul flights. Of interest were (i) the incidence of party line R/T, and (ii) the type of task being undertaken during the transmission. This analysis was intended to reveal those stages of flight most likely to be disrupted by irrelevant sound.

1.3.2. WP3.2: Counter-measures

The data-collection phase was followed by consideration of the ways in which disruptive party line effects could be prevented.

The conventional aviation human factors literature was insufficient in isolation, since most authors have assumed that the party line is a source of benefit (such as situation awareness) that may be lost on the introduction of datalink. Only a few papers have hinted at possible detrimental effects of the party line, as discussed in later sections.

The literature review was extensive, and included:

- pilot-ATC communication and its analysis (e.g., Prinzo's Aviation Topics Speech Act Taxonomy [ATSAT])
- party line and aircrew errors
- technologies claimed to address loss of the party line (e.g., Automatic Dependent Surveillance – Broadcast [ADS-B] with cockpit display), which might give clues to the extent to which R/T information could be modified
- strategies for coping with speech/noise in open-plan offices
- non-aviation domains, particularly automotive studies (e.g., speech-based e-mail; use of hands-free mobile phones)
- evidence from the selective attention literature
- evidence from the recent human–computer interaction literature, particularly that on the distracting effects of incoming Instant Messaging and other interruptions

1.4. Structure of the report

Key findings concerning selective attention are described in Section 2, and WP2 studies on the irrelevant sound effect are summarised in Section 3. There follows a consideration of flight deck communication issues (Section 4), and discussion of relevant findings concerning the party line and datalink (Sections 5 and 6). Evidence from non-aviation domains is presented in Section 7.

A task analysis undertaken for WP3 is reported in Section 8, and Section 9 presents ideas for countermeasures. The key points of the study are discussed in Section 10.

2. SELECTIVE ATTENTION

2.1. Classic studies: The Cocktail Party Phenomenon

The pioneering work on selective attention in the 1950s was in fact inspired largely by air traffic control issues. Messages from pilots were broadcast in the control room, and controllers had some difficulty in attending to specific messages among several being played over the same loudspeaker (Kantowitz & Sorkin, 1983; Arons, 1992).

The work of Cherry (1953) elucidated the factors that determine the ease with which humans can attend selectively to particular sources of auditory information — much like attending to a single voice at a cocktail party in which a multitude of voices can be heard simultaneously, hence the term 'cocktail party effect' (Figure 1). Under some experimental conditions, such as two completely separate messages, each with a clear narrative thread and presented one to each ear, it is relatively easy to shadow (repeat aloud) one message while ignoring the other. Moreover, the individual does not appear to have much awareness of the information presented to the unattended ear. Gross physical changes, such as that from a male to a female voice, might be detected, but the individual might not notice that the message has changed from English to German or from forward to reversed speech (which retains general speech-like properties).

Findings such as these led Broadbent (1958) to propose a Filter Theory in which unattended information could be filtered out very early in processing, before its meaning had been derived. Hence, only its gross physical characteristics were accessible. The Filter Theory was a 'straw man' approach erected to stimulate empirical research. It quickly became apparent that the notion of complete early filtering was untenable. For example, in a shadowing task information meaningful to the subject presented on the unattended channel — such as his or her own name — was likely to be recognised. Thus, there must be semantic processing on this channel. Later modifications of the approach included the idea of attenuation of information on unattended channels analogous to lowering the gain on a channel in an audio system (Triesman, 1964), and rejection of the notion of a filter in favour of the idea that recognition is a function of the intensity and pertinence of the information (Deutsch & Deutsch, 1963). The anecdotal observation that a mother may sleep through a loud thunderstorm but be awoken by the sound of her baby crying in another room illustrates the postulated role of pertinence.

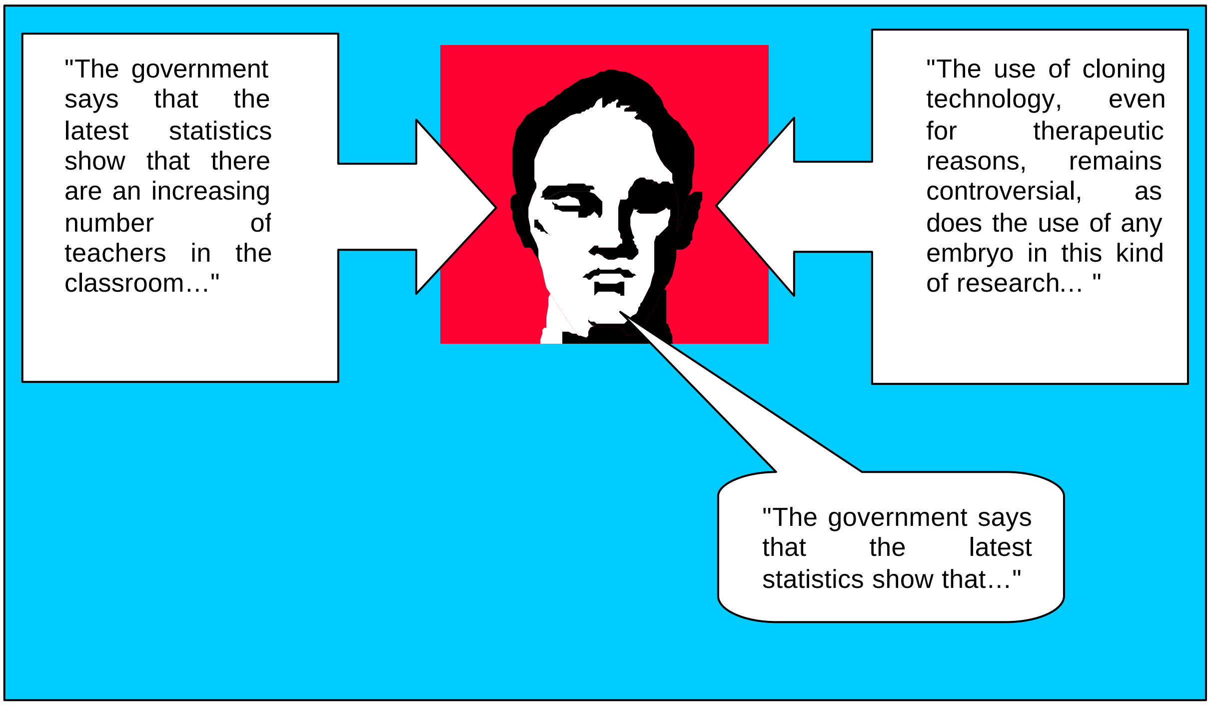

Figure 1. An individual shadowing the message to one ear while trying to ignore another message

2.2. Contemporary approaches to selective attention

There is continued interest in human ability to attend to the relevant and ignore the irrelevant (Allport, 1989, 1993; Pashler, 1998; Styles, 1997; Hughes & Jones, 2003). The following is a summary of the account given by Hughes and Jones (2003; reproduced with permission of the authors). The selection process requires that sensory information be partitioned according to the different objects in the environment, and that 'crosstalk' from other candidate objects be minimised. As hinted at by early studies, it is now clear that information that is being 'ignored' is in fact processed and organised by the perceptual system. There is thus a distinction between processing that is attentive (deliberate and goal-directed), and processing that is 'preattentive' (perhaps only at a physical level, and without awareness); the latter will tend to compete for the control of action. Hughes and Jones argued that processing-of-the-unattended has several functional roles:

- The organism has some knowledge of 'what is out there', allowing efficient re-allocation of the focus of selective attention where appropriate (e.g., Houghton & Tipper, 1994).
- Obligatory processing of unattended information allows the organism to learn implicitly about statistical regularities in its environment, and hence to anticipate events.
- Attention can be automatically captured by important events even if attention is not initially directed at them.

The impact of preattentive processing is particularly high in the auditory modality since it is difficult to prevent this information reaching the brain. Studies of the irrelevant sound effect (Colle & Welsh, 1976; Hughes & Jones, 2001; Jones, 1993, 1999; Salame & Baddeley, 1989) have confirmed that unattended sound is organised into temporally-extended objects (streams). The disruptive impact of sound on performance is robust, and the decrement may be as high as 30–50% (Ellermeier & Zimmer, 1997). The key property of sound that produces disruption is the presence of acoustical variation (Jones, Madden & Miles, 1992). Properties such as semantic and phonological content play little if any role in this effect (Buchner, Irmen, & Erdfelder, 1996; Jones & Macken, 1995b; LeCompte & Shaibe, 1997), and the intensity of the sound is similarly not an influential factor (Colle, 1980; Tremblay & Jones, 1999). The effects can be understood by assuming a conflict between two seriation processes (maintaining serial order): the 'changing-state' account posits that the deliberate process of retaining the order of the to-be-remembered items in a serial recall task (i.e., rote rehearsal) is corrupted by the obligatory processing of the order of the changing tokens in the irrelevant sequence.

Since seriation is involved to some extent in most mental tasks, Jones and his colleagues have argued that performance in many applied settings will be disrupted by irrelevant changing-state sound (Hughes & Jones, 2001), including open-plan offices (Banbury & Berry, 1997, 1998), call centres, the air traffic control tower (Hughes & Jones, 2001), and the cockpit (Banbury & Jones, 2000).

In the present context, there are two key issues:

- The irrelevant sound effect is independent of the intensity level of the irrelevant sequence (Colle, 1980; Tremblay & Jones, 1999). The practical implications of this fact are immense: the sound must either be below the threshold of audibility, or be masked in such a way as not to reveal the acoustic changes that are the basis of the 'changing state effect'. The former is expensive and complex; the latter may cause losses in efficiency through masking of sounds that may on some occasions be relevant to the individual.
- The disruptive effect of irrelevant changing-state sound is resistant to the process of habituation, and will not diminish with repeated exposure.

Thus, simply exposing aircrew to party line communication during training may not help them to ignore it when they are trying to attend fully to a challenging flight deck task, and attenuating the volume of the party line transmissions is similarly unlikely to be effective.

2.3. Facilitating selective attention

Although the streaming model has convincingly demonstrated that it is not possible to ignore irrelevant speech, findings from the general selective attention literature suggest that the intrusive effects might at least be reduced under certain conditions. Cherry enumerated some of the factors that might facilitate the separation of relevant and irrelevant messages:

- messages coming from different directions
- lip-reading, gestures, and so on
- different voices, pitches, sex, etc
- different accents
- transitional probabilities in the messages (a factor that features strongly in the cognitive streaming approach)

Unfortunately, these interventions could not easily be applied to the flight deck. Although the party line encompasses a variety of speakers, it is not spatially separated from relevant messages and it contains information that is highly meaningful to aircrew. These conditions therefore suggest that the party line will be difficult to ignore. This problem is compounded by the belief of many aircrew that the party line is a source of useful information that should not in any case be ignored.

The work of Gopher has shown that there are substantial individual differences in the voluntary control of attention, and that training can enhance attention management skills. A test of individual differences in selective attention has been used as part of the pilot selection process in Israel and elsewhere (see Gopher, 1982), and a computer game-based trainer has been developed to improve the skill of attention control (Gopher et al, 1994). There is thus a possibility that the effects of irrelevant sound could be reduced by selection and training.

3. COGNITIVE STREAMING IN AVIATION: THE IRRELEVANT SPEECH EFFECT

3.1. Nature of the effect

To reiterate, processing of sound has been found to conform to the following principles (see Jones & Farmer, 2001, and Hughes & Jones, 2003, for overviews):

- *Processing of sound is obligatory.* Sound is registered even when it is irrelevant, when attention is directed elsewhere, and, for example, when the primary short-term memory task is visual.
- *Unattended sound is organised in the same way as attended sound.* The auditory system organises both attended and unattended sounds into temporal 'streams'.
- *Unattended sound does not habituate.* In other words, the effect does not decline with repeated exposure.
- *The irrelevant speech effect is not dependent upon intensity:* it is the same for a whisper as for a shout.
- *Disruption is not affected by the similarity of irrelevant and relevant material.* Counter-intuitively, a person trying to remember sequences of digits is no more adversely affected by irrelevant digits than by irrelevant letters.

3.2. Findings in WP2

The Aviation Multi-Tasking Environment (AMTE) battery was developed for this research programme (Pope, Houghton, Jones, & Parmentier, 2003). It comprised four tasks: air traffic conflict, tracking, visual monitoring, and communication (see Figure 2).

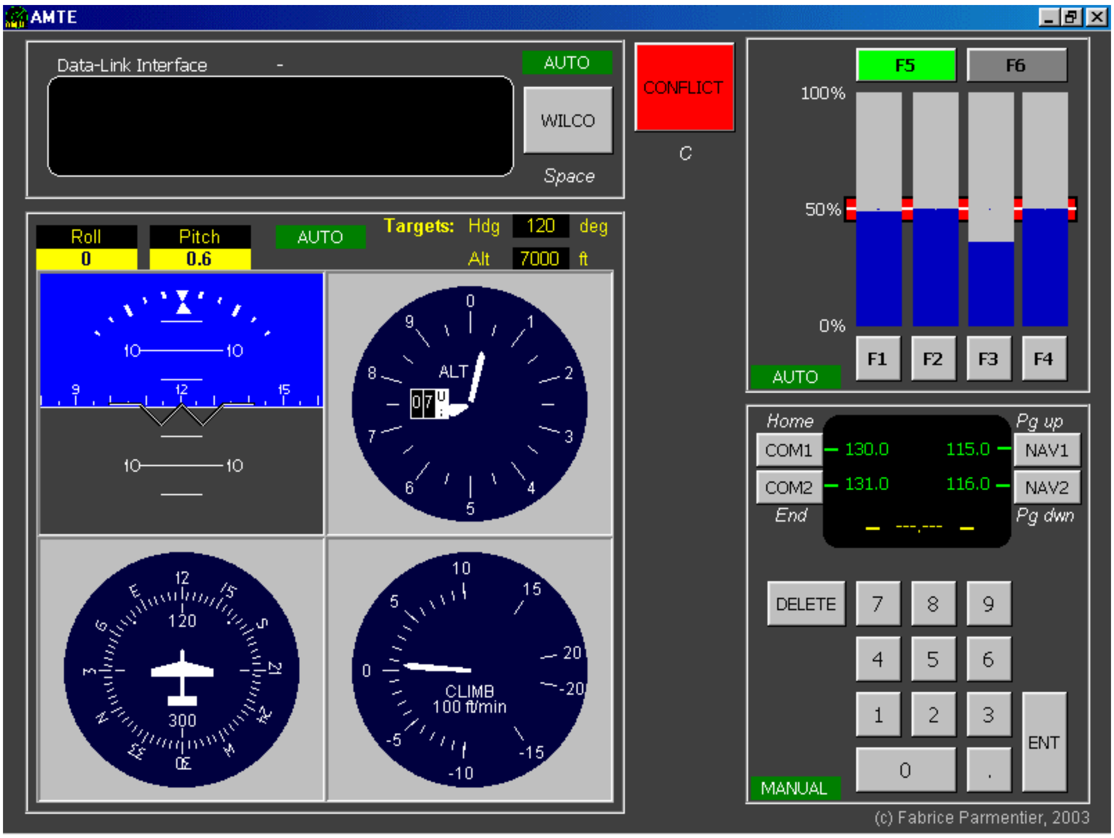

Figure 2. The AMTE display

The effect of irrelevant sound (normal and reversed speech) on these tasks was determined. The main findings were:

- Conflict detection: a general trend toward higher hit rates and lower false alarm rates in the quiet condition than in the two irrelevant sound conditions; correct response times were also longer with irrelevant sound
- Communication: accuracy was lower in both irrelevant sound conditions than in the quiet condition
- Visual monitoring: irrelevant sound increased reaction times to the monitoring events, particularly in the irrelevant speech condition
- Tracking: no significant effects of irrelevant sound on tracking performance

These results suggest that most flight deck activities will be liable to disruption by irrelevant speech. Only strictly psychomotor activity (the tracking task) was unaffected. In the modern glass cockpit, psychomotor control has largely been replaced by systems management and monitoring tasks. In WP2, even visual monitoring was affected by irrelevant speech, indicating that the effect of speech is not modality-specific.

4. FLIGHT DECK COMMUNICATION ISSUES

4.1. Introduction

In 1930, Cleveland Municipal Airport became the first in the United States to have a radio-equipped control tower (Prinzo & Britton, 1993). Voice radio communications remain a major component of air traffic control, although new technologies such as datalink will supplement and perhaps eventually supplant this means of communication.

4.2. Amount and complexity of communication

Morrow and Rodvold (1993) analysed over 40 hours of air traffic communications from 12 ground-control facilities in the US. The 23,224 transmissions comprised:

- Controller–pilot: 10,208
- Pilot–controller: 12,221
- Controller–ground vehicle: 403
- Ground vehicle–controller: 392

Controller instructions were found to be relatively complex. For example, over 35 percent contained four or more elements (such as taxiways). Only about one third of taxi instructions were followed by a full readback, and the probability of a full readback declined as instructions became more complex.

Pilots requested full or partial repeats for about 1 percent of taxi instructions, and the incidence of such requests increased with complexity. Errors in readback also increased as a function of complexity.

4.3. Types of controller–aircrew communication

The communication between controller and pilot typically has four components (Prinzo & Britton, 1993):

- Controller sends message
- Pilot actively listens to the message
- Pilot repeats the message back to the controller
- Controller actively listens to check that the readback is correct

Prinzo (1998) summarised content analysis of data on the communication between aircrew and controllers (Cardosi, 1993; Bürki-Cohen, 1995; Morrow, Lee, & Rodvold, 1993; Cardosi, Brett, & Han, 1996; Prinzo, 1996; Helmreich, 1994; Predmore, 1991). Clearances and instructions formed the largest proportion of such communication. Prinzo et al (1995) developed the Aviation Topics Speech Acts Taxonomy (ATSAT), which comprised five speech act categories: Address, Instruction, Advisory, Request, and Courtesy, with a sixth category ('Non-codable'), for communication elements that could not be categorised. Table 1 shows data reported by Prinzo (1998) for the occurrence on each type of speech act. It can be seen that the data from field studies and from simulations are roughly comparable.

Table 1. Occurrence of Speech Acts within each ATSAC Category (adapted from Prinzo, 1998)

Speech Act Category	Field Data	Simulation Data
Address	36%	47%
Instruction	36%	43%
Advisory	16%	9%
Request	2%	1%
Courtesy	5%	0%
Non-codable	4%	0%

An analysis of pilot–controller interactions focusing on shared situation awareness (SA) was reported by Hansman and Davison (2000). These authors noted that the need for shared information was particularly important when it was necessary to amend a clearance owing to a conflict involving weather, traffic or airspace. Since controllers have access to limited weather information on their displays, they rely upon pilot reports of factors such as icing and turbulence to construct a mental picture of weather patterns in their sector. In an empirical study, Barhydt and Hansman (1999) asked *en route* controllers to draw their mental map of weather conditions after they had controlled traffic around convective weather for about 20 minutes. They were able to identify the major convective areas, albeit with gaps in their awareness. This finding provides modest evidence that voice communications may be of benefit to the controller as well as the pilot. Hansman and Davison suggested that "a collective mental representation of the turbulent regions is built up through informal Pilots' Reports. Access to turbulence information is generally through the Controller's mental representation but is also sometimes obtained through "Party Line" communications". The authors also suggested that, in the absence of TCAS, aircrew knowledge of traffic depends entirely upon the party line. Moreover, they pointed to the importance of shared intent information, and the limitations of datalink in providing information to indicate the rationale for requests and commands. A further possible problem associated with the transition from voice to data was the failure to communicate affective information (e.g., emotional state, workload and urgency), which is currently apparent through factors such as prosodic content and the rate of verbal communication.

4.4. Processing voice messages

A study of errors in copying ATC clearances was conducted by Rantanen and Kokayeff (2002). Experienced pilots listened to taped clearances and copied them down on paper. The authors noted the "astonishingly poor performance" of their experienced pilot subjects. Errors of commission were much more frequent than errors of omission. The errors appeared to be strongly influenced by habit and past experience. Common errors were 'victor-airways' copied as 'jet-airways', and low altitudes and speeds copied as much higher.

In a part-task simulation study (Morrow & Rodvold, 1993), pilots flew a simulation that required intensive communication with the air traffic controller, and performed a secondary visual monitoring task. Longer message lengths appeared to overload the pilot's working memory, producing more incorrect or partial readbacks and more requests to repeat the message. A second message also interfered with processing of the first message when the interval between the two was short. Communication reduced accuracy on the secondary monitoring task, suggesting that these tasks competed for resources.

4.5. Communication errors

Problems associated with pilot–controller communication are the most common topics of reports to the Aviation Safety Reporting System (ASRS). For example, 70% of reports submitted in a period spanning 1978–79 involved problems of vocal communication between controllers and aircrew (Grayson & Billings, 1981). Some of the common types of error are summarised in Table 2 (see Spence, 1992; Prinzo & Britton, 1993).

Table 2. Common communication errors by controllers and pilots

Controller errors	Pilot errors
Information delivered too rapidly	Use of non-standard phraseology
Failure to detect incorrect readbacks	Truncation of readback
Failure to verify readbacks	Failure to issue readback
	Failure to request clarification when appropriate

Readback errors are a prominent feature of analyses of communications. Golaszewski (1989) identified six types of readback error:

- Uncorrected pilot readback of an ATC clearance
- Uncorrected controller readback of a pilot communication
- Pilot readback of a clearance intended for another aircraft
- ATC instructions given to the wrong aircraft
- Non-compliance by the pilot with ATC instructions
- Uncorrected controller readback of information from another controller

Clearly, some of these errors — particularly confusion over clearances given to another aircraft — are related to the presence of the party line. Other issues associated with the party line are discussed in the next section.

5. THE PARTY LINE

5.1. Advantages and Disadvantages

The party line is often cited, at least anecdotally, as a source of situation awareness (e.g., Rehmann, 1995a; Rognin & Blanquart, 2001; Hansman et al., 1997), although aircrew are unlikely to act only on the basis of this information (Midkiff & Hansman, 1992). The SAE G-10W Free Flight Subcommittee has classified as 'serious' the issue of *compensation for the loss of situation awareness resulting from the withdrawal of the party line*. In a similar vein, Corwin (2003) identified four crew-related issues relevant to the certification of flight deck concepts: workload, situation awareness, training, and procedures. For datalink technology, one of the certification issues was reduced SA due to loss of the party line. Other evidence for the perceived importance of this issue is that French pilots are being encouraged to speak English primarily to maximise the benefits of the party line (*Air Safety Week*, April 3, 2000).

Although subjective data must be interpreted with care, the perceptions reported by aircrew support the notion that the party line serves an important function. For example, Pritchett and Hansman (1995) reported a survey to determine party line use by pilots of different operation types, flight experience, aircraft types and geographic regions. Overall, party line information was rated as very important (for example, a rating of 'critical' was assigned in 42% of responses). The highest ratings were given to the phases of flight nearest airports, especially Terminal Area and Final Approach; the lowest ratings were given in Cruise. Specific weather and traffic elements were assigned importance ratings following a similar pattern (e.g., higher ratings in the Terminal Area and Final Approach) but weather elements such as thunderstorm buildups and icing conditions were considered important in all phases of flight. Examination of operational type showed that General Aviation pilots rated the party line as important in all phases of flight, in contrast to the more general pattern described above. Ratings of availability and accuracy were lower than those of importance, suggesting that the conventional party line is not as informative or reliable as aircrew would like.

The party line may be a source of more than flight-related information. A further possible advantage of voice communication over datalink is that speech can convey cues to emotional state. For example, Griffin and Williams (1987) reported that people under emotional stress or increased task complexity have a higher voice pitch and tend to talk more loudly and more quickly.

Although it is generally assumed that the party line is a useful source of situation awareness, problems of the party line have been described by several authors (e.g., Sage & Johnson, 2002; U.S. Congress, Office of Technology Assessment, 1988; Hooey & Foyle, 2001). For example, pilots may respond to messages meant for other aircraft, or misunderstand instructions that differ from those anticipated on the basis of the party line. Deutsch (1997) noted that party-line communications are frequent interruptions to ongoing activities on the flight deck. In his performance modelling work, he assumed that radio communications to other aircraft in the sector are attended to and may interrupt verbal communication intended to co-ordinate flight deck activities.

The relevance of the party line is to some extent determined by the roles assigned to crew members: PF (Pilot Flying) or PNF (Pilot Not Flying). Among the duties of the PNF is handling of radio communications. Hence, provided that good Crew Resource Management (CRM) communication practices are followed between the crew members, the PF is not required to attend to the flow of R/T communications, which can truly be considered irrelevant sound. The PNF, on the other hand, must process the information much more fully to determine its importance.

5.2. The work of Rehmann

The analysis of ASRS reports by Rehmann (1995a) indicated the types of information conveyed by the party line:

- Runway/landing intentions: 27%
- Position report: 25%
- Weather information/conditions: 18%

- Traffic reports: 12%
- Go-around intentions: 9%
- Other: 9%

The incidents examined were coded according to whether the contribution of the party line was positive (e.g., evasive action) or negative (e.g., altitude deviation based upon clearance issued to another aircraft). The results, shown in Table 3, suggest that the party line is less beneficial than is sometimes supposed.

Table 3. Positive and negative consequences of party line information (adapted from Rehmann, 1995a)

Incident resulting from party line information			
Positive outcome	**%**	**Negative Outcome**	**%**
Conflict Avoidance/Air	22	Ground Conflict	12
Conflict Avoidance/Ground	17	Air Conflict	9
Weather Avoidance/Awareness	5	Near Mid-Air Collision	8
		Runway Transgression	7
		Altitude Deviation	5
		Heading Deviation	3
		Unauthorised Takeoff	2
		Other	2
		Track Deviation N 1	1
(Undetermined: 7%)			

Two types of error were apparent: incorrect transmission of party line information (14 per cent error rate), and errors involving aircrew actions/decisions based on the party line information (26 per cent error rate). Almost half of the latter took the form of executing unauthorised clearances based on call sign confusion. Consistent with Pritchett and Hansman's findings, most reports related to incidents near airports or on the ground, and it is apparent that the party line was used to obtain useful information about landing/departing aircraft, runway/taxi instructions and weather conditions.

5.3. The party line in aviation training

In a survey of airline training programmes, Longridge, Bürki-Cohen, Go, & Kendra (2001) found that only 38 percent of respondents reported simulating any communications to/from other aircraft or vehicles, mainly on the airport surface. Thus, pilots receive little formal training in use of the party line. Damos and Tabachnick (2001), in a study of the effect of interruptions on flight crew performance, recommended that simulator instructors interrupt ongoing tasks with ATC communications. Current practice appears to be to delay communications and other distractions until important tasks have been completed, thus denying the trainee an opportunity to develop skills to deal with distractions. The authors also recommended that checklists should be started from the beginning after an interruption.

6. DATALINK

6.1. Possible advantages of datalink

Rehmann (1995b) noted problems of dependence upon Radio Telephony (R/T):
- poor signal-to-noise ratio
- congested frequencies
- overloading of aircrew short-term memory

He suggested that datalink could solve such problems:
- there would be no problem of signal-to-noise ratio
- datalink messages would be sent selectively to aircraft
- display of messages would reduce short-term memory load

Further possible advantages include user-friendly display of weather information, direct download of instructions to the Flight Management System (FMS), and constant availability of a communication line.

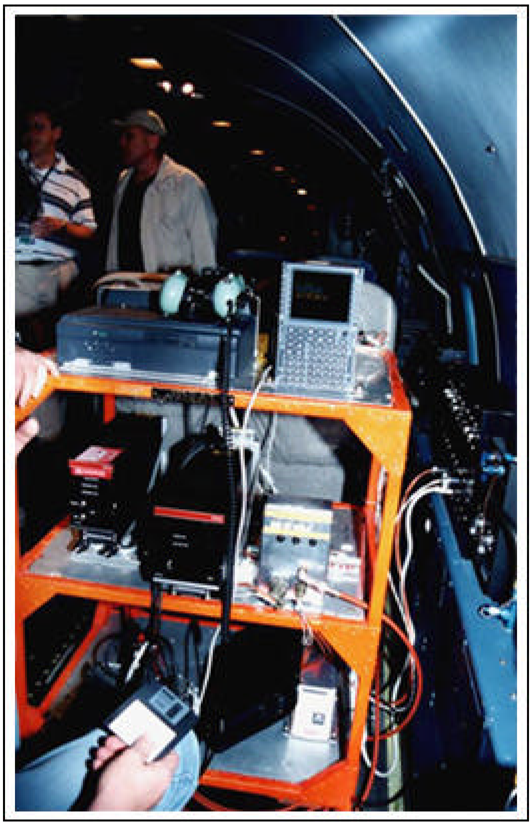

Figure 3. Datalink test avionics in the FAA Convair 580
(photo credit: public information available at http://ffp1.faa.gov/tools/tools_cpdlc.asp)

In a recent study, Wickens (2000) examined three simulated datalink interfaces to convey instructions while aircrew monitored for traffic. The attentional demands of current ATC were simulated using a synthesised voice display, and a redundant (text plus voice) display was designed to address the limitations of each display type (memory demands imposed by the auditory display and head-down requirements of the visual display). Readback errors were higher for the auditory-only display, and for messages of greater length. The visual text display did not interfere with detection of traffic, since the participants did not have to write clearances on a clipboard, which was necessary in the auditory-only condition, and flight path tracking was best in the visual-only data condition. The redundant condition did not improve performance on any task, relative to the single-modality conditions.

Figure 4. First airline datalink message, using test equipment on FAA Boeing 727 (photo credit: public information available at http://ffp1.faa.gov/tools/tools_cpdlc.asp)

A fixed-base simulation study was conducted (Waller, 1992) to determine the operational consequences of transmitting altitude, airspeed, heading, radio frequency, and route data to a transport flight deck by datalink. The datalink interface, using a touch-sensitive CRT display, was integrated with the aircraft subsystems to facilitate data management. The data were displayed on the CRT and were also distributed to the flight guidance and control system, the navigation system, and an electronically tuned communication radio. In this implementation, aircrew spent less time on communication/data management process using the datalink system than using conventional voice R/T and manual data entry, and their subjective impressions were also favourable.

6.2. Possible disadvantages of datalink

Disadvantages of datalink suggested by Rehmann (1995b) include:

- longer communication times, owing to the slowness of typing compared to speech
- slower transmission times using Mode S or Satcomm, relative to R/T
- lack of party line information
- less 'head-front time', owing to the need to read datalink displays and to enter information
- loss of crew co-ordination, since conventional R/T is available to both pilots
- possible complacency if information in entered directly into the FMS

In an experimental study, Huettig, Anders and Tautz (1999) developed an experimental Navigation Display (eND) with a message field for ATC messages in an A340 simulator. Subjective workload, as measured by the NASA Task Load Index (TLX), was higher using the 'datalink' system than using traditional VHF communication. The greatest effects were noted for the TLX scales of Mental Demand and Temporal Demand. The objective data did not fully support these subjective effects. Notably, despite increased temporal demand scores with text messages, the subjects dealt with these messages more quickly than VHF messages.

Concerns associated with datalink were raised by Olson and Sarter (2001), who examined the automation strategy of 'management-by-consent'. This strategy requires explicit human permission for requests for automated action, and is generally preferred by aircrew over 'management-by-exception' systems that do not depend upon explicit operator authorisation. The study was inspired by future datalink systems involving gating, in which aircrew would be able to transfer datalink commands directly to the Flight Management Computer. Aircrew were exposed to two different types of conflict in simulated flight: goal conflicts, including inappropriate or impossible goals such as descending to an altitude higher than the current position; and implementation conflicts, such as when changing the landing runway produced unintentional modification of the vertical path. Performance was found to be very poor. Fewer than half of the goal conflicts, and no implementation conflicts, were detected before the aircrew made their decision to consent, and the conflict was often not detected even after the consent decision. Aircrew were particularly unlikely to detect conflicts that occurred because the automated systems did more than expected. When the system did *less* than expected, aircrew's common strategy of rereading the datalink text and then checking specific displays tended to be effective in identifying the conflict.

Resistance to datalink may be overcome by good design. In FAA-sponsored research conducted by NLR and reported by van Gent (1995), ratings of the acceptability of datalink increased from 56% to 94% using the same hardware but changing the page layout and optimising procedures.

6.3. Processing datalink messages

It has been shown that datalink systems using text lengthen the acknowledgement time (Kerns, 1991; McGann, Morrow, Rodvold, & Mackintosh, 1998). Part of the reason for this finding appears to be that aircrew are more likely to perform other tasks when handling datalink clearances than when in a conventional voice environment. Mackintosh, Lozito, McGann, & Logsdon (1999) reported that distractions to the datalink handling process had significant effects on timing, especially when the distractions occurred after the message had been accessed. Distractions prior to access added about 10s to the average message access time; those after message access had a much greater effect on message acknowledgement times, increasing them by 93s on average. Half of the messages with distractions were not acknowledged by the flight crews at all, and the remaining messages had acknowledgement times almost three times the length of the proposed 40-second controller 'shot clock.' The authors suggested that additional procedures or alerting mechanisms were needed to ensure that crews returned to the datalink task after interruptions.

Lozito, McGann & Corker's (1993) study confirmed that acknowledgement of ATC messages was slower using datalink (21.4 sec) than using R/T (7.9 sec). More ATC contact was initiated in the R/T condition, but this condition was associated with more errors in air/ground communication.

Rehmann (1995b) evaluated the level of effort associated with the use of datalink, using three interface designs. Datalink was rated as acceptable in some flight regimes, but unacceptable in others. Datalink was rated lower than voice when a considerable number of key entries were required, but automation to reduce this requirement removed the advantage for voice. Datalink was considered acceptable in oceanic and cruise phases, but not in descent phases.

6.4. Processing mixed datalink and voice messages

Studies have been conducted of mixed voice/datalink environments. For example, Dunbar, McGann, Mackintosh, and Lozito (2001) found that transaction times for voice messages were lengthened in a mixed-media environment when the messages were closely spaced. Although the type of environment (single versus mixed) did not affect datalink times, message times increased in both single and mixed-modality environments when time pressure was introduced. The authors concluded that, under time pressure, the use of mixed voice/datalink environments may not exploit the advantages offered by each medium.

Rehmann's (1995b) review suggested that combined voice and datalink communication would be superior to each in isolation. Datalink appeared to be suitable for low-workload phases (above 10,000 feet on approach and above 2,000 feet on climb out); however, the visual demand during high-workload phases would be too high.

7. VOICE COMMUNICATION: EVIDENCE FROM NON-AVIATION DOMAINS

7.1. Introduction

Despite recent interest in distractions on the flight deck, most aviation studies of the party line assume that this is a source of benefit to aircrew, which might be lost on the introduction of data link. Hence, to develop ideas of countermeasures against the disruptive effect of the party line, other domains such as driving and human–computer interaction were examined.

7.2. Car driving studies

Car-phone use is increasingly raising safety concerns. Strictly, telephone conversations cannot be considered to be exposure to irrelevant speech; however, this task is irrelevant to the primary task of driving, and, given the evidence that processing of even irrelevant speech is obligatory, examination of car-phone use may be instructive in the present context.

Accident statistics suggest that driver inattention/distraction is a major source of error. For example, records for the year 2000 show that in Minnesota this factor was implicated in 24% of car crashes that led to injury (Williams, 2002). Several studies (e.g., Redelmeier & Tibshirani, 1997; Violanti, 1997) have suggested that car-phone use increases the probability of accidents by a factor of about four. The finding that hands-free systems offer no safety advantage over hand-held systems (Redelmeier & Tibshirani, 1997) suggests that the problem has origins in cognitive ? probably attentional ? processes rather than simple psychomotor interference with control of the vehicle. Green (2000), in an analysis of crashes induced by driver information systems, noted that 'mind-off-of-the-road' in addition to 'eyes-off-of-the-road' effects played a contributory role. In an ICBC study (2001; see also Cooper et al, 2003), listening and responding to messages, comparable to hands-free telephony, interfered with driving performance. For familiar scenarios involving choices related to traffic signals, the messages led to more conservative behaviour. However, behaviour became potentially more dangerous (e.g., accepting shorter traffic gaps in a left-turn task under slippery road conditions) when the driving task was made more demanding. Further evidence of detrimental effects of telephone use under high workload was provided in a recent study by Liu (2003). Moreover, Sodhi and Cohen from the University of Rhode Island (http://www.eurekalert.org/pub_releases/2002-06/uori-cpu061002.php) found that car drivers using cell phones have a reduced field of view ('tunnel vision'), and that the detrimental effect persists even after a telephone call ends. The remedy, according to the authors, was to prohibit cell phone use in challenging conditions such as congested traffic or winding roads.

In a study reported by Lai et al (2001) subjects drove a simulator and listened to short navigation messages, 100-word email messages, or 200-word news stories. There was no effect of any of the listening tasks on performance. However, the authors recommended that higher levels of driving workload should be examined in later research. A study at TNO (Janssen et al, 1999) compared five in-vehicle systems providing real-time traffic information to a control condition considered to be safe (driving and listening to radio congestion information). This situation is conceptually similar to flying while receiving party line information. The results showed that use of three of the systems was as safe as driving in the standard condition, whereas the remaining two showed evidence of being less safe. The difference between these systems was basic ergonomic features, suggesting that some of the interference can easily be eliminated by sound design of factors such as size of fonts and positioning of buttons.

In a programme on adaptive driver assistance, Vollrath and Totzke (2000) reported work on adapting driver assistance to counteract the possible influences of in-vehicle communication on driving. In their study, three tasks typical of driver–car interactions were used: visual and auditory information processing, and manual operation. Half of the subjects tried to maintain their driving speed on a straight road, whereas the remaining subjects controlled lateral position on a winding road while driving at a recommended speed. The communication tasks caused the control of lateral position to deteriorate, and the manual operation task was more disruptive than the information processing tasks. The driving task also interfered with the communication tasks.

The effect of a speech-based e-mail system on drivers' response to a periodically braking lead vehicle was investigated by Lee et al (2000). Reaction time increased by 30% when the speech-based system was present, and subjective workload was significantly higher. In Alm and Nilsson's (1994) study, brake reaction time and control of lateral movement were impaired by use of a mobile telephone.

An in-car speech system has been developed that is claimed to increase safety (http://www.asia. microsoft.com/presspass/Press/2002/Apr02/04-22InCarSpeechPR.asp). This system includes two components:

- a Speech User Interface (SUI) to implement voice recognition and realistic text-to-speech technologies.
- a Speech Application Programming Interface (SAPI 5.0). The SUI works with SAPI 5.0 to provide a system capable of understanding natural speech and handling multiple interactions.

The SUI has 'Driver Distraction Control' elements including a speech queuing system to maintain order among a set of speech-based applications. Speech interaction can also be suspended when driving conditions become unsafe.

7.3. Open-Plan Office Environments

The reaction to open plan offices depends upon the nature of the tasks to be performed. Open plan arrangements are favoured by those required to perform simpler tasks (Block & Stokes, 1989), whereas private spaces are preferred by those with more complex tasks (Brookes & Kaplan, 1972; Sundstrom et al., 1994). Noise levels appear to be a major cause of dissatisfaction with open-plan environments (Stone, 2001; Oldham & Brass, 1979; Sundstrom et al., 1982; 1994).

In one of the few systematic studies of office noise, Banbury & Berry (1998) reported the results of three experiments. Office noise with speech disrupted performance for both memory for prose and mental arithmetic, whereas noise without speech disrupted only the latter. Disruption was greater when noise was present in both learning and recall phases, and both speech comprising random words and speech meaningless to the subjects (numbers and speech in Greek) impaired performance. Banbury and Berry (1997) showed habituation to background speech after 20 minutes' exposure; meaning and repetition of the material did not affect the degree of habituation. Habituation was also demonstrated for office noise without speech. A brief (5-min) period of quiet partially reinstated the disruption after habituation to noise, but a change in voice did not.

In a more recent study (Evans & Johnson, 2000), female clerical workers were assigned to a control condition or to a condition in which low-intensity noise simulated typical open-plan office conditions. Typing performance was unaffected, and the groups did not differ in perceived stress. However, the 'office noise' condition increased urinary epinephrine (adrenaline) levels, and had behavioural consequences including fewer attempts at insoluble puzzles and a dramatic reduction in the number of adjustments to workstation items such as chairs, footrests, whiteboards and document holders. In a study reported by Witterseh (2001), simulated open-plan office noise conditions decreased satisfaction, and increased fatigue and difficulty in concentrating.

7.4. The Party Line in Railway Operations

In a study of train dispatchers, Roth et al (2001) found that the dispatchers valued the party line even though radio communication was often noisy and congested. The information provided by the party line was considered to facilitate forward planning, and to indicate possible delays, problems, or need for assistance. Although the subjective opinion of dispatchers does not guarantee real operational benefit, Roth et al recommended that any new communication system preserve safety- or productivity-related information currently provided by the party line.

Work-Package 3.1:
Data Collection

8. TASK ANALYSIS

8.1. Introduction

The purpose of this element of WP3 was to determine the types of aircrew activity typically undertaken when party line messages are present, and hence to infer where interference is most likely to occur. It was initially proposed that this be achieved by applying conventional task-analytic methods to videotapes of actual flight that contained audio tracks.

A possible source of material was Link 2000+, a Eurocontrol-led project co-ordinating the implementation of datalink. However, it was found that this project had not produced recordings of R/T transmission on the flight deck. Simulation videotapes from VINTHEC II, an EC Fifth Framework project being led by NLR with contributions from QinetiQ and others, were also considered to be potentially useful. However, examination of these videotapes revealed that R/T messages were rather artificial, and did not include a realistic party line environment.

The difficulty of accessing realistic communication data for our present purposes was unexpected. However, further examination of the literature suggested that this was part of a more general problem, with practical implications. For example, in a training context, Longridge, Bürki-Cohen, Go, and Kendra (2001) noted that

> "Initial research on the simulation of radio communications for U.S. airline pilot training strongly suggests that in order to be fully effective in developing the cognitive and workload management skills associated with radio communications, significant improvements are needed in the resources available to the pilot instructor for that purpose…considerable additional research is needed to reduce the cost and labor requirements associated with simulating radio communications in an operationally realistic fashion".

Longridge et al cited the results of analysis of ASRS reports for the period January 1993–October 1999, yielding 93 incidents related to flight events during initial operating experience (IOE). Radio communications, which are often poorly addressed during training for the reasons described above, featured strongly in 72 percent of the reports. Examples included:

- demanding, inadequate, or erroneous ATC instructions
- amended clearances that required reprogramming of the automation
- erroneous “expect” instructions
- inadequate crew resource management (CRM) or task management related to radio communications
- ATC interruptions including traffic calls and frequency congestion
- stuck microphones blocking an entire frequency
- pilots intruding into an ongoing conversation
- radio-tuning problems
- unfamiliar phraseology and accent

8.2. Material used in WP3.1

A commercial source of flight deck videotapes was located to use as a basis of the task analysis, and the publishers were asked to recommend video footage with the best representation of party line messages. Intelligent Television and Video Limited recommended two videos for the quality of the ATC recordings: a Boeing 757-200 flight from Manchester International Airport to Dalaman in Southern Turkey; and a Boeing MD-11 flight from Schiphol Airport to Palma de Mallorca.

The UK Civil Aviation Authority (CAA) library was also consulted. The library holds a large number of videos, and library staff identified several videos as being potentially useful. However, only one video contained footage comprising adequate party line messages: a Ryanair flight from Waterford to Stansted.

These three videos were studied to explore real cockpit footage. This material was intended to show the tasks that pilots perform and how both 'direct' and party line ATC communications can interrupt those tasks. Although there were a number of good examples of direct communications interrupting tasks, the nature of such commercially available videos meant that some party-line transmissions had been edited out. However, there were several key instances in which the background party line R/T occurred whilst the pilot was carrying out procedures, occasionally visibly resulting in interruption.

In addition to utilising these sources, an opportunity presented itself during the course of the WP for a member of the project team to observe a real Transatlantic flight, as a source of supplementary evidence and to allow discussion of the project issues with aircrew. Following the acquisition of formal permission from the Civil Aviation Authority to allow research to be conducted on the flight deck, an observation session took place during October 2003.

The direct observations were made on the outbound and return flights from London Heathrow to Washington Dulles. The flight included approximately one and a half hours of European air traffic control, the Atlantic crossing, and then about two and a half hours of Canadian and US air traffic control. Discussion with the pilot prior to the observation session and during the flight itself indicated that the air traffic communications that were observed were broadly similar to those found in Europe and in other developed air traffic systems around the world. The crossing of the Atlantic was, however, markedly different from this, with very little air traffic information being available. Further details of the resulting impact on direct and party line communications can be found at Section 8.3.6 below. Owing to the similarity of the outbound and return flights, these have been combined for the purposes of description and analysis.

The flights studied in detail comprised:

- Ryanair: Waterford to Stansted
- Airtours: Manchester to Dalaman
- Virgin Atlantic: Outbound and return between Heathrow and Washington Dulles

Party line transmissions were much quieter than direct ATC communications during the Manchester to Dalaman flight. They were therefore more difficult to detect during the analysis (although, according to streaming theory, just as disruptive for the aircrew).

The task analyses are summarised in Figure 5. The activities being undertaken are depicted with both direct and party line communication. An attempt has also been made to quantify the amount of party line activity.

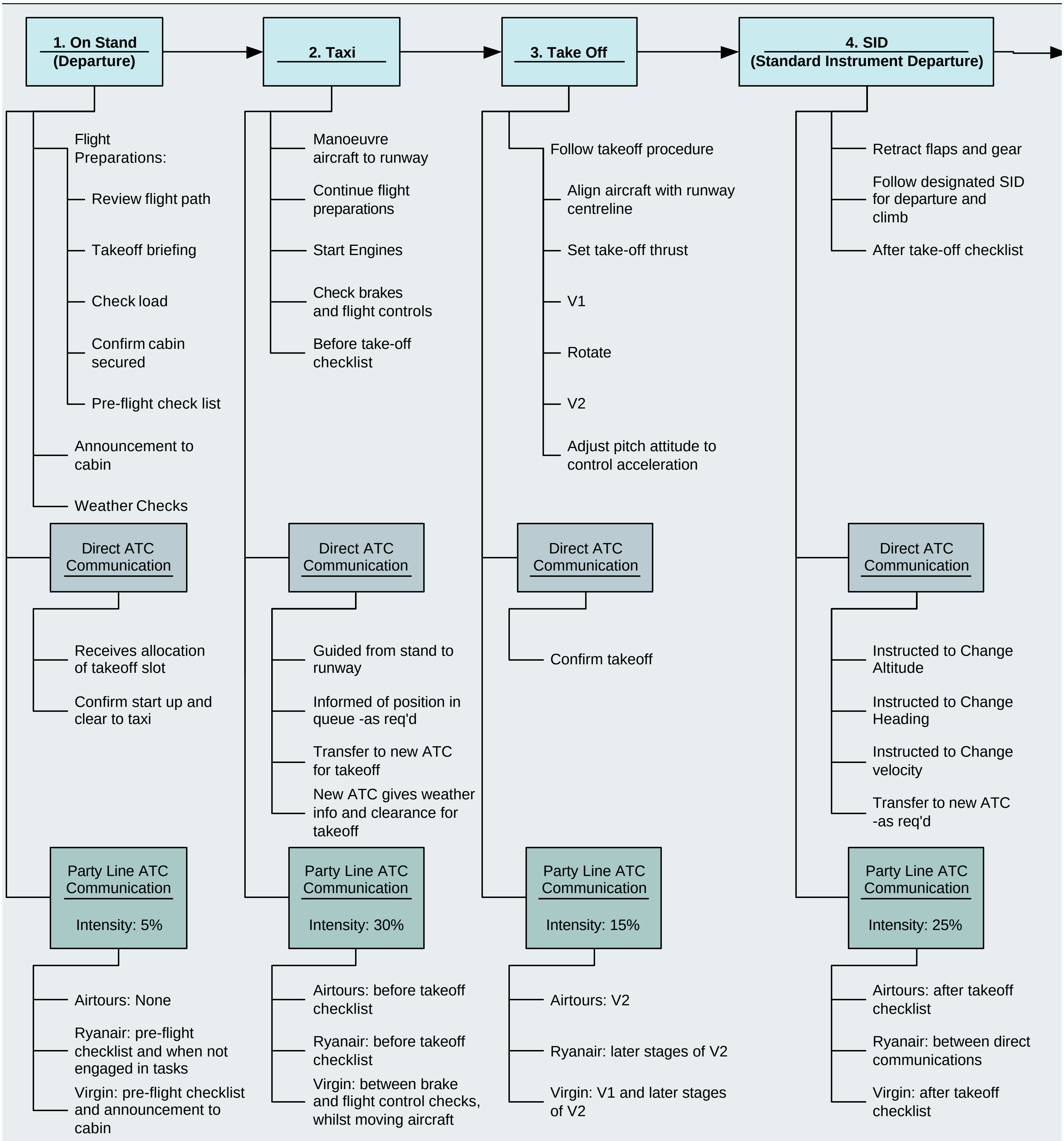

Figure 5. Task analysis summary

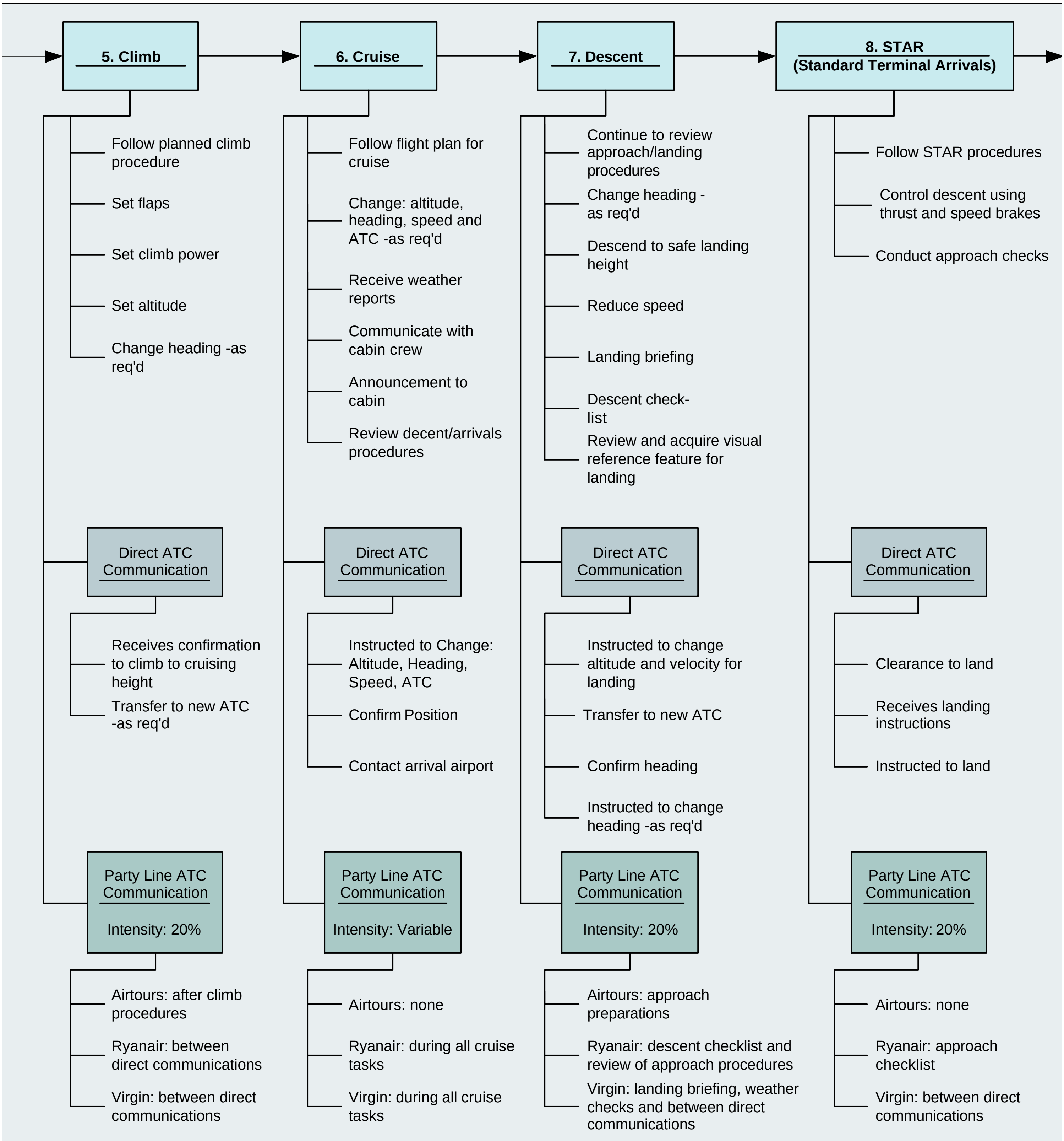

Figure 5. Task analysis summary (continued)

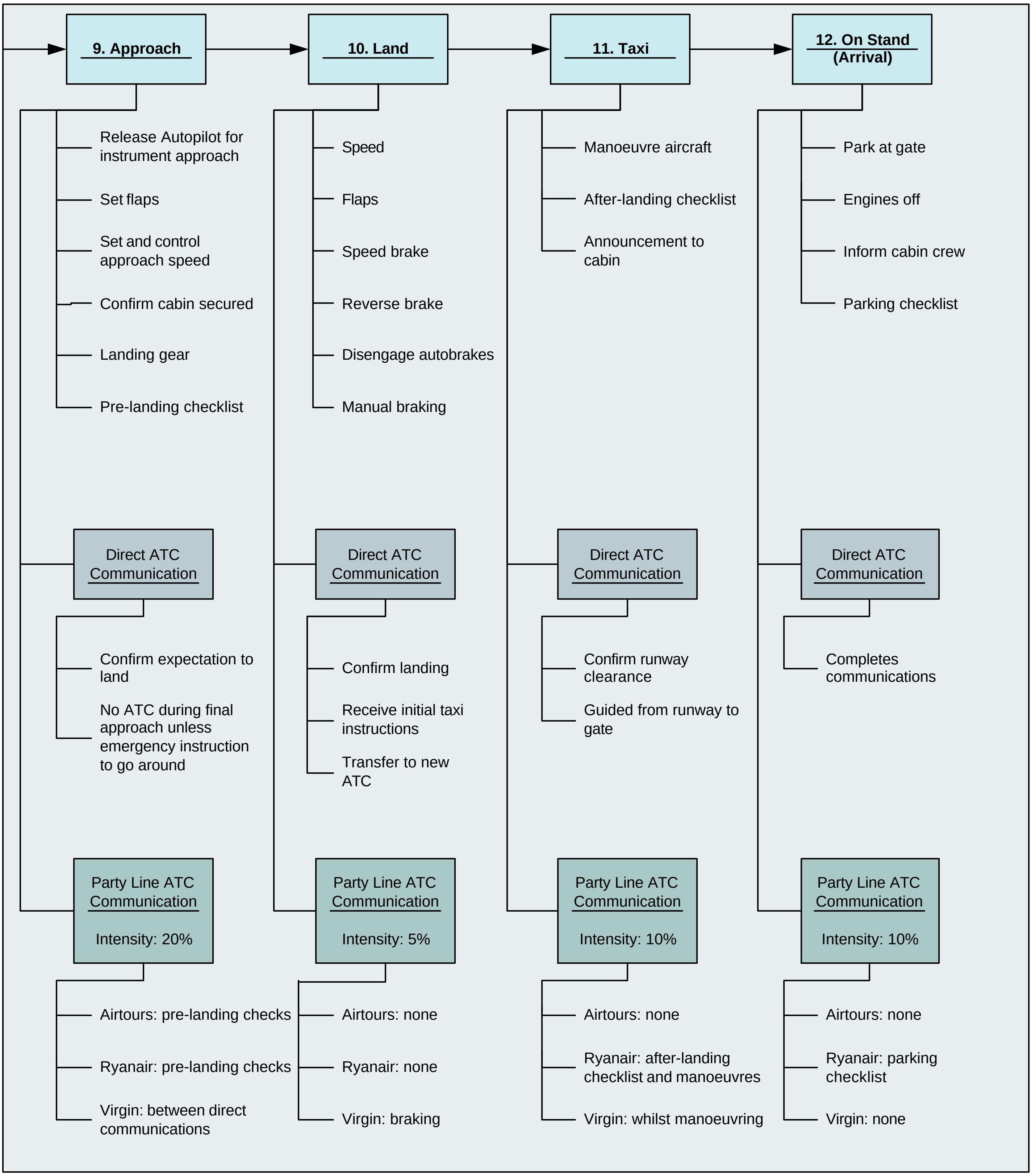

Figure 5. Task analysis summary (continued)

8.3. Phases of the Flight

8.3.1. On Stand (Departure)

Waterford to Stansted
The pre-takeoff checklist was started whilst on the stand and some party line communications interrupted this activity. Additionally, this checklist was interrupted by communications from the cabin crew.

Flights between Heathrow and Washington Dulles
The party line communications were muted during the first of the pre-flight preparations, and thus their influence could not be determined. Once the air traffic communications had been turned on, the pre-takeoff checklist was interrupted by party line, as was the announcement to the cabin.

8.3.2. Taxi

Manchester to Dalaman
Some party-line communication occurred whilst the pilots were going through the Pre-takeoff checklist. The pilots continued the checklist without pause, indicating that they were not intentionally attending to this transmission.

Waterford to Stansted
The pre-takeoff checklist continued during taxi and was frequently interrupted by party line. Sometimes this resulted in a visible disruption and at other times the pilots continued their tasks without apparent interruption.

Flights between Heathrow and Washington Dulles
Party line communications occurred between the flight control checks and checks of the brakes, demonstrating the occurrence of party line communications at crucial stages of the flight preparations. It was also observed that a high volume of party line communication occurred during this phase, although the majority was whilst the aircraft was being manoeuvred and when held in the queue for the runway.

8.3.3. Take Off

Manchester to Dalaman
A few seconds of party line communication occurred during the takeoff, shortly after the pilot had rotated the control column. This is a period of high cognitive workload for the pilots to ensure that the standard operating procedures for takeoff are strictly followed and that the aircraft is functioning normally.

Waterford to Stansted
During the early stages of takeoff there were no party line communications. However, at later phases party line communications occurred between each direct communication.

Flights between Heathrow and Washington Dulles
Party line communications occurred during all stages of takeoff, including initial movement down the runway, V1, rotate and V2. These communications tended to be of short duration and did not appear to interrupt the tasks of the pilots; however, these stages are especially critical and any impact of party line at this stage would be of particular importance.

8.3.4. Standard Instrument Departure (SID)

Manchester to Dalaman
The pilots followed procedures according to the SID before commencing the After Take-off checklist. During this spoken checklist party line communications occurred, but there was no visible or audible reaction from either pilot.

8.3.5. Climb

Manchester to Dalaman
This phase requires the pilot to maintain the optimum climb, as set in the standard operating procedures; this involves setting the flaps and the climb power. Party line communications were frequently heard during this phase. However, as the pilot's tasks required few audible checks, the extent to which the communications were heard or absorbed by the pilots was not clear.

Waterford to Stansted
Party line communications occurred between the direct ATC communications throughout the climb phase. The extent to which this interrupted the aircrew’s tasks was not clear.

Flights between Heathrow and Washington Dulles
During the climb phase of the flight, party line communications occurred between all direct communications. The specific tasks undertaken by the pilots during the climb tended to be of short duration, reducing the potential for their being interrupted, and indeed there were no observable effects of such interruption. However, the density of party line was high and therefore the potential for the party line to affect the pilots' performance was also high.

8.3.6. Cruise

Waterford to Stansted
During the cruise phase, the pilot carries out a number of ongoing procedures, including checklists, briefings, monitoring instruments, manipulating displays or controls, programming flight deck computers, and communicating with passengers. Depending on the route the aircraft is flying, the cruise phase might be in an area of low traffic density and therefore the quantity of party line information is likely to be low. European flights are likely to experience a generally much higher level of party line during the cruise phase than transatlantic flights.

A high volume of party line communications was present throughout the cruise phase of the Waterford to Stansted flight. It was not clear how this affected some of the aircrew’s tasks such as instrument monitoring. However, clear disruption occurred during the receipt of weather reports, the cruise checks and the discussion of landing and approach procedures that began towards the end of the cruise phase.

Flights between Heathrow and Washington
The cruise phase of this flight could be divided into two distinct sections: the crossing over the Atlantic and the cruise phase over North America. The air traffic communications during each of these sections were markedly different and as a result they are described separately below.

Over the Atlantic there are low levels of ATC and radar coverage; as a result the majority of transatlantic flights are routed via a small number of pre-ordained parallel tracks across the Atlantic. The observed flights were no exception to this. Rather than being subject to normal ATC instructions, the aircraft followed its designated ‘track’ and the pilots were required to radio the controller (Shannon and Prestwick as far as 30 degrees West; Gander from 30 degrees West onwards) every tenth degree of longitude. In this communication they reported their altitude, heading, velocity and estimated time at the next tenth degree of longitude. Between these R/T transmissions, aircraft frequently communicated informally with other aircraft using a ‘social’ frequency that provided regular party-line information. Excessive background noise, however, was reduced during this phase via the SELCAL (Selective Calling) system that allows pilots to switch off the radio, and receive visual and auditory warning when direct R/T is incoming. Informal evidence suggested that, because the workload is significantly lower during the Atlantic crossing than during the other phases of the flight, pilots are keen to communicate with other aircraft and/or receive party line information during this phase.

The cruise phase following the Atlantic comprised conventional air traffic communications including party line and direct communications. The density of air traffic, and resultant party line, varied significantly during this time: there were long periods in which no air traffic communications occurred, and there were other time periods in which the stream of auditory information was almost continuous. Thus, the observed cruise phase can be considered representative of operations in a range of air traffic environments. During the observed cruise phase all the different cruise tasks were interrupted at some point by party line information. This included tasks such as reviewing arrival and descent procedures, communicating with the cabin and receiving weather reports.

8.3.7. Descent and Standard Terminal Arrivals (STAR) Phases

Waterford to Stansted
The pilot's initial descent preparations were visibly interrupted by a party line broadcast. The procedures involved reviewing the approach and descent procedures verbally with the co-pilot.

This phase of the flight requires the pilot and co-pilot to work through several checklists and rehearsal of procedures following an aborted landing. Damos and Tabachnick (2001) identified that ATC communications had a probability of 1.0 of interrupting checklists, i.e. ATC communications were always given priority over checklists. This is partly because of the importance of the ATC transmission, and partly because checklists are by their nature segmented and therefore easier to pause and resume.

Flights between Heathrow and Washington
The density of party line communications during the descent phase was more consistent than during the cruise phase, possibly because the descent will always occur within the proximity of an airport, where air traffic would be expected to be higher. During the observed flight, there was a moderately high level of party line communications during this phase, which interrupted the tasks of conducting the landing briefing and checking weather reports, as well as occurring between the direct communications.

8.3.8. Approach

Waterford to Stansted
The pilot's pre-landing checklists were disrupted by a party line communication during the approach.

Flights between Heathrow and Washington
Although there was a significant level of party line communications during the approach phase, the actual tasks of the aircrew did not appear to be interrupted by these communications. The observations suggested a potential for party line to interrupt tasks at this phase as party line communications were present, although this interruption was not directly observed.

8.3.9. Land

Waterford to Stansted
No party line.

Flights between Heathrow and Washington
Some party line during braking.

8.3.10. On Stand (Arrival)

Waterford to Stansted

Party line communications were observed to occur during the parking checklist, although the tasks of the pilots did not appear to be affected by this.

Flights between Heathrow and Washington

Once on the stand, there were no party line communications. However, it was noted that the air traffic information was turned off once the direct communications had been completed, thus preventing the party line from interrupting many of the tasks during this phase of the flight.

8.4. Discussion

Party line communications had often been edited out of videotaped records of flight, and were not available in the case of sources such as VINTHEC. However, suitable resources were identified and were supplemented by direct observations from a real flight.

Direct ATC communications were associated with particular points during the flight. They increased during the taxi, SID/climb phases and descent/STAR/Approach phases. The level of direct communications fluctuated during other phases of the flight, depending on the particular demands of the route and air traffic situation.

Party line communications were also identified at all stages of the flight, although once again this varied according to the nature of the air traffic and the location of the aircraft.

The streaming model suggests that the party line would disrupt many of the activities recorded for the flights. For example, WP2, which used aviation-relevant tasks, demonstrated significant levels of interference for all but strictly psychomotor activities. The highly proceduralised flying task, in which steps must be completed in a fixed order and without omissions, appears to provide rich opportunities for disruption.

Party line communication did noticeably disrupt some of the aircrew's tasks. The occurrence of party line communications, however, was not regular. When flying through areas of increased air traffic, it was naturally found that the amount of party line communication and thus its potential to interrupt aircrew tasks increased. For example, on the Waterford to Stansted flight there was an increased level of party line information particularly during the cruise phase in which the aircraft passed through an area of dense air traffic. Similarly, during the direct observations there was a greater volume of party line communications associated with passing over the cities of the north west USA than when passing over northern areas of Canada.

Task interruption is likely to be affected not only by direct disruption owing to the presence of speech, but also by the nature of the task. In a series of cockpit observations, Damos and Tabachnick (2001) confirmed that some ongoing activities were more likely than others to be interrupted by ATC communications. For example, high probabilities of disruption were apparent for:

- checklists
- briefings
- programming

These findings were attributed to factors such as task length and the ability to segment task activities. Tasks that could be segmented were likely to be paused during ATC communications. Moreover, short tasks such as tuning the radio frequency were less likely to be interrupted, partly because short tasks had a lower probability of being interrupted, and partly because they could not easily be broken down into sub-tasks; hence the pilot was more likely to resist the interruption. It was also found that pilots had a tendency to talk through ATC communications, when they might have been expected to give the ATC transmission priority. This might be because pilots are much slower to acknowledge events when their ongoing activities are auditory rather than visual (Latorella, 1998).

Task interruption is increasingly being studied, partly because human–computer interaction often involves a computer-controlled application attempting to gain the user's attention while he is occupied on other activities (cf. e-mail notifications arriving during completion of a word-processing task). Bailey, Konstan, and Carlis (2000) studied the results of interruption on six web-based task categories: addition, counting, image comprehension, reading comprehension, registration, and selection. The interruption tasks were comprehension of a short news summary and a decision concerning company stocks; these tasks lasted from 10 to 30s. Interruption increased task completion time for all except the registration task, and the outcome was unaffected by the type of interruption task. The degree of disruption increased with the memory load imposed by the primary task, and the time penalty varied from 5% to 40%. It was also found that the similarity of the interrupting task to the primary task did not affect the degree of disruption, a result that is difficult to reconcile with multiple resource theory, but consistent with the assumption of cognitive streaming theory that similarity of content does not lie at the root of task interference. The news interruption task took longer to complete than the stock interruption task, but the effects on primary task performance did not differ.

There is some debate in the literature concerning the effect of interruption on the speed of task completion. For example, Zijlstra et al (1999) reported that interrupted tasks were completed more quickly. However, Burmistrov and Leonova (2003) showed that interruptions slowed the performance of relatively complex tasks but left simpler tasks unaffected. Interruptions in the form of Instant Messaging were found in other studies to impair performance when the computer user was typing, using buttons or menus, or evaluating search results, and to be particularly problematic when presented early during search tasks (see Cutrell et al, 2000).

Dismukes, Young, and Sumwalt (1998) emphasised the safety implications of cockpit interruptions and distractions. As part of a NASA project, they set out to discover why crews are liable to commit this type of error. Their findings included:

- Of NTSB reports of accidents in which crew error was implicated, nearly half involved lapses of attention associated with interruptions, distractions, or preoccupation with a single task.
- Of 107 ASRS reports involving 21 types of routine task that crews neglected while dealing with another task, 69 percent were associated with failure to monitor the current status or position of the aircraft, or failure to monitor the actions of the pilot who was flying or taxiing.
- There were 34 types of competing activities that caused distraction or preoccupation, most of which could be classified as communication, head-down work, searching for VMC traffic, or responding to abnormal situations.

8.5. Concluding Remarks

The task analysis confirmed that party line messages occur during many phases of flight. The streaming model and supporting research provide strong evidence that processing of irrelevant sound such as party line messages is obligatory, and has a detrimental effect on a wide range of tasks (of the tasks studied in WP2, only tracking failed to show significant impairment). Performance decrement has been confirmed in naturalistic studies, such as those of open-plan office environments.

During the last few years, there has been growing interest in the effect of any distraction or interruption on the flight deck. These studies have not been conducted within the conceptual framework of the cognitive streaming model, but are generally consistent with the streaming model prediction that auditory information cannot be ignored.

Work-Package 3.2:
Counter-Measures

9. COUNTERMEASURES

9.1. Introduction

As discussed earlier, any intervention that simply reduced the volume of party line transmissions would fail to eliminate their disruptive effects: similar disruption can be produced by sounds corresponding to a whisper or a shout. Thus, more sophisticated approaches would be necessary. The sections below summarise those that seem most promising.

9.2. Technological solutions

9.2.1. ADS-B

VDL mode 4 is intended to provide a single system solution, comprising a range of applications including Automatic Dependent Surveillance – Broadcast (ADS–B). With ADS–B, every aircraft transmits its position over a radio datalink. All users thus have access to knowledge of the locations of all other surrounding aircraft (see http://blinder.lfv.se/ans/card/docs/rio/applic2.pdf). The concept extends also to ground vehicles and ground stations. A Cockpit Display of Traffic Information (CDTI) or a Traffic Situation Display (TSD) can be used to show the position and intent of local traffic. This system will to some extent replicate the auditory party line, but without the potentially damaging effect of speech.

9.2.2. 'Time-shifting' of R/T messages

Technologies such as TiVO allow the domestic consumer to pause television broadcasts to deal with interruptions, and then to recommence viewing from that point. It would be relatively easy to produce a somewhat analogous flight deck system that could store R/T messages during tasks most vulnerable to disruption. Naturally, only non-essential messages to other call signs would be suitable for delayed transmission, and so it would be necessary to classify messages as 'suppressible' versus 'non-suppressible'.

A system developed for automotive use includes a Speech User Interface (SUI) with 'Driver Distraction Control' elements such as a speech queuing system to maintain order among a set of speech-based applications (see www.microsoft.com/automotive/windowsautomotive/winceauto/ AutomotiveSpeech. pdf). Using this system, speech interaction can be suspended under unsafe driving conditions. Such a system might prove suitable as the basis for a flight deck application allowing greater control over the timing of R/T messages.

9.2.3. Changing the modality of the message

Voice-to-text systems would allow R/T messages to be recoded visually, providing a pseudo-datalink system that would circumvent the problem of irrelevant speech. A brief audio alert for incoming messages would be unlikely to cause the disruption associated with lengthy speech-based messages.

In another project under the CARE Innovative Action, Cardini (2003) reviewed voice-to-text systems. He noted that modern systems allow natural speech, and predicted that accuracy would be comparable to that using a keyboard.

9.3. Aircrew strategies

Dismukes et al (1998), in an *ASRS Directline* article, suggested possible strategies for reducing vulnerability to interruptions and distractions on the flight deck:

- *Recognise that conversation is a powerful distracter*: conversation should be suspended at critical moments, and even under low workload, to allow effective monitoring of status
- *Recognise that head-down tasks greatly reduce one's ability to monitor the other pilot and the status of the aircraft*: for example, try to reschedule head-down tasks to low workload periods.
- *Schedule activities to minimise conflicts*: for example, when approaching or crossing an active runway, suspend all activities unrelated to taxiing; or reduce workload during descent by performing some tasks while still at cruise.
- *When two tasks must be performed concurrently, set up a scan and avoid letting attention linger too long on either task*: switch attention back and forth every few seconds between tasks.
- *Treat interruptions as red flags*: for example, when interrupted while running a checklist, some aircrew place a thumb on the last item performed to remind them that the checklist was suspended.
- *Explicitly assign Pilot Flying and Pilot Not Flying responsibilities, especially in abnormal situations*: this helps to prevent both pilots being drawn into trying to solve problems.

9.4. Reducing the amount of R/T messages

9.4.1. Communication in CDTI-equipped aircraft

In an evaluation entitled OpEval-1, Prinzo (2001) analysed audiotapes of the communications between pilots flying aircraft equipped with a cockpit display of traffic information (CDTI) and terminal radar approach controllers. There was evidence of greater collaborative communication between aircrew and controllers, which reduced radio-frequency congestion and improved overall communications. Pilot appeared to show greater persistence in scanning for traffic called by ATC, particularly when it was visible on the CDTI display but not out the window. Inaccuracies in messages were low (4%), and were attributable to factors such as the novelty of pilot-initiated traffic calls. Prinzo concluded that new procedures and training would be needed to support CDTI. However, it is clear that new technology can reproduce some of the traditional party line information and reduce the need for R/T messages that may disrupt performance.

9.4.2. ASAS Procedures

The notion of an Airborne Separation Assistance System (ASAS) was developed in 1995 in response to pressure to produce a flight deck system that could provide aircrew with a comprehensive picture of the surrounding air traffic (ICAO, 2003). A number of procedures for controllers and flight crews are associated with ASAS (Schaefer, personal communication, 2003; EUROCONTROL, 2001):

- *Free Route Concept (A1)*: allows aircrew to decide freely on their preferred, most economical routing across designated Free Route airspace without reference to an organised route structure. Free Route airspace is foreseen to be fully managed airspace; however, ATC will probably require new tools to manage the random nature of the flight trajectories efficiently.
- *Air Traffic Situation Awareness Systems ? ATSAW (A2)*: a pre-requisite of any new techniques designed to involve aircrew in the decision-making processes of air traffic control. ASAS applications are dependent on the aircrew being fully aware of other aircraft in their vicinity.
- *ASAS Spacing (A3)*: involves the delegation to the pilot of certain spacing and positioning tasks in relation to a specified target aircraft. The pilot takes responsibility for identifying the target aircraft and establishing separation based on instructions from the ground. Although this procedure relieves the controller of several routine tasks, the controller remains responsible for ensuring standard separation.
- *ASAS Separation (A4)*: involves total delegation to the pilot of responsibility for a separation manoeuvre in relation to a specified target aircraft. In contrast to ASAS Spacing where responsibility for ensuring that standard separation minima are not infringed, ASAS Separation utilises airborne separation standards known as Instrument Separation and the entire responsibility for separation maintenance is transferred to the pilot for a specified manoeuvre.

- *Airborne Self-Separation (A5)*: also known as Free Flight, this is the most advanced ASAS application. Implementation of Airborne Self-Separation is proposed in specific volumes of airspace known as Free Flight Airspace (FFAS). Within this specific airspace, pilots, with the support of their onboard ASAS systems, will maintain instrument separation from all other aircraft. It is foreseen that ATC will provide only a monitoring and alerting service in FFAS.

Such procedures, and associated new technologies, would be likely to reduce the amount of auditory party line communication. For example, fewer instructions would be issued by controllers, and on-board systems would help aircrew to develop and maintain situation awareness.

9.4.3. Phraseology

The pilot/controller glossary associated with the FAA Air Traffic Control publication 7110.65 (see http://www1.faa.gov/atpubs/PCG/index.htm) provides the basis for concise, unambiguous communication. However, aircrew tend to use non-standard phraseology (Prinzo & Britton, 1993), and factors such as message complexity mean that a substantial proportion of messages have to be repeated (Prinzo & Britton, 1993; Cardosi & Boole, 1991). The average total time for a message to be conveyed is over 10 sec (Cardosi & Boole, 1991). Prinzo and Britton suggested that frequency congestion may be attributed in part to the need for repetition. It appears that greater discipline in adherence to standard phraseology might reduce the amount of unnecessary party line activity, and hence the potential for disruption of performance.

9.5. Improving communication

Brown (2003), an air traffic controller, presented a 'top ten' list of practical advice to improve communication.

- **Number 10: Format** — use the correct AIM (Aeronautical Information Manual) format for call signs
- **Number 9: Questions** — often, when a pilot answers a clearance with a question he forgets to use his call sign; also terminology such as "Request control for lower" should be used: aircrew often use voice inflection to indicate a question, which may be difficult to detect in a static-filled radio transmission.
- **Number 8: Direct vs. "Cleared to"** — Brown noted a case where his transmission "Airliner123 cleared to the SHINE intersection, hold northwest as published, expect further clearance at one five one zero" was interpreted as changing the pilot's assigned routing rather than merely stating his new clearance limit.
- **Number 7: Ride Reports** — "I've seen sectors get completely out of control because the controller couldn't maintain control of the frequency due to ride reports and requests for ride reports. In almost all cases the worst report was moderate *chop*. We know it's uncomfortable (we fly too) and we'll do our best to get you out of it."
- **Number 6: Key Words** — Key words such as 'descending' are often omitted, and replaced with unsatisfactory substitutes such as 'down to' .
- **Number 5: Mumbling** — one-third of all ATC transmissions are some form of "Say again?".
- **Number 4: Call Signs** — many pilots forget to use the *air traffic controller's* call sign, which is mandatory only for the initial call but helps to prevent confusion in communications.
- **Number 3: Requests** — not only are requests too numerous, but they should be made much more efficient.
- **Number 2: Clipping** — pilots often do not leave a slight pause to ensure that the first word is transmitted properly, leading to messages such as *"(click)teen thousand Airliner one twenty three."*
- **Number 1: Frequency Congestion** — frequency congestion could be greatly reduced if all the advice above were acted upon.

9.6. Evidence from Human–Computer Interaction Studies of Interruption

There is current interest in the best way to co-ordinate interruptions during computer use. McFarlane (1999) examined four interruption methods, illustrating the approaches by recourse to the notion of a human user supervising a robotic driver and conversing with a passenger:

- Negotiated co-ordination: the robotic driver announced its need to interrupt and then negotiated with the human user.
- Immediate co-ordination: the robotic driver asked the human user to stop conversing with the passenger immediately.
- Scheduled co-ordination: the robotic driver interrupted at pre-determined time intervals.
- Mediated co-ordination: the robotic driver initially sent a message to the user's personal digital assistant.

In the experiment, subjects performed a computerised game task, and an intermittent graphical matching task acting as the source of interruption. None of the co-ordination methods was superior in every respect to the others. For example, the negotiated approach was associated with good performance on some task measures, but at the cost of poorer completeness and promptness on the interruption task.

Latorella (1998) reported simulation studies in which airline pilots were exposed to interruptions. She found that auditory interruptions extended overall performance time more than visual interruptions, and that interruptions to auditory tasks were not acknowledged as quickly as interruptions to visual tasks. Latorella suggested counter-measures such as a) a playback feature for interrupting auditory messages, b) development of task management aids that are sensitive to both interrupted and interrupting tasks, and c) inclusion of interruption management strategies in training programmes. As stated earlier, communications are poorly represented in current training, and hence there is considerable scope for improvement. A more formal 'Interruption Management Stage Model' was developed (see McFarlane & Latorella, 2002, for an overview).

9.7. Lessons from office environments

Work on office noise has shown effects of irrelevant sound on performance that are probably applicable to the flight deck. However, the counter-measures developed in this domain are of limited relevance. Although in a strict sense irrelevant, the speech-based information in the party line is considered by many pilots to be useful and hence worth retaining in some form; in the office, on the other hand, there is consensus that irrelevant sound should be minimised.

Countermeasures for office noise (Banbury, personal communication) include:

- Speech privacy systems, such as that produced by Birdwell Acoustics, Inc, that provide steady ambient noise levels to override the varying levels of office noise.
- Reduction in subjective noise levels:
    - Adequate partitioning
    - Sound absorbing materials and equipment 'silencers'
- Reduction in the variability of the sound
    - Introduction of continuous noise to mask disruptive sounds
    - Acoustic ceilings & partitions
- Reduction in the susceptibility of the task to disruption
    - Task redesigned so that order is less important
    - Memory cue
    - Computer support
- More careful office planning
    - Noise management
    - Office etiquette (meetings held only in meeting rooms, quiet maintained when transiting)

9.8. Individual differences in selective attention

The work of Gopher on individual differences in the voluntary control of attention suggests that a suitable test could be incorporated within pilot selection programmes. Gopher (1982) investigated the usefulness of a selective attention test in the pilot selection test battery of the Israeli Air Force, using 2,000 flight cadets. The subjects were presented with 48 auditory messages, each comprising strings of words and digit names. In this 'dichotic listening' test, different strings were simultaneously presented to the two ears, and the subjects were required to detect digit names in the channel defined as relevant, and to switch channels during the test. Three types of error (omissions, intrusions, and switching errors) were investigated. Cadets who had completed a two-year training programme had significantly lower error scores on all these measures. The measures were not well correlated with other tests in the pilot selection battery, suggesting that attention capabilities were an independent dimension that improved the predictive validity of the test battery.

Gopher (1993) found that trainee pilots who practised dividing their attention using the computer game 'Space Fortress' were twice as likely as other trainees to become qualified pilots within 18 months. Thus, it appears that selective attention skills can to some extent be trained.

The current interest in flight deck distractions may provide the impetus to consider selective attention skills more thoroughly during aircrew selection and training. Data from cognitive streaming experiments suggest that most, or all, individuals will be affected by irrelevant sound; however, it may be possible to attenuate the magnitude of the effect.

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10. GENERAL DISCUSSION

10.1. Distraction effects on the flight deck

This Work Package was concerned with methods of preventing performance impairment attributable to the party line. WP2 had shown that several types of task were impaired by irrelevant sound: only tracking failed to exhibit a significant performance decrement. Task analysis of actual flights showed that party line transmissions were present during several phases of flight, with the capacity to disrupt performance. In some instances, disruption was apparent from direct observation; on the basis of our laboratory studies, we would expect more detailed examination of performance of flight deck performance than was possible using task analysis to reveal widespread disruption.

The aviation psychology literature has during the last few years shown increased interest in distraction and interruption on the flight deck. Although this literature has not specifically been based on the cognitive streaming approach, it provides converging evidence that distraction is a key human factors topic in aviation. Moreover, problems associated with pilot–controller communication are the most common topics of reports to the ASRS, and some of these are clearly related to the party line (e.g., Prinzo & Britton, 1993).

10.2. Counter-measures

Possible counter-measures that were identified include:

Simple techniques that could be applied with little cost or effort:
- Following the strategies outlined by Dismukes et al (1998) to reduce vulnerability to interruptions and distractions on the flight deck
- Encouragement of greater discipline in adherence to standard phraseology to reduce the amount of unnecessary party line activity
- Following the guidance given by Brown (2003) on methods of improving communication

Solutions that will become possible with the introduction of new aviation technology:
- ADS–B with a Cockpit Display of Traffic Information or a Traffic Situation Display, which would replicate aspects of the auditory party line without the potentially damaging effect of speech
- Airborne Separation Assistance System procedures, with greater delegation of responsibility to aircrew

New technology that could be developed:
- 'Time-shifting' of R/T messages that could store the messages during tasks most vulnerable to disruption. A promising development is an automotive system that includes a subsystem allowing control over the timing of speech-based messages.
- Voice-to-text systems to allow R/T messages to be recoded visually, providing a pseudo-datalink system that would circumvent the problem of irrelevant speech

Evidence from studies of task interruption that could form the basis of future counter-measures:
- A playback feature to manage interrupting auditory messages
- Development of task management aids sensitive to both interrupted and interrupting tasks
- Inclusion of interruption management strategies in training programmes

Possible selection and training interventions:
- It may be possible to develop tests of selective attention for airline pilots, extending the work of Gopher
- Evidence that skills of selective attention can be trained could be exploited to reduce disruption.

10.3. Next steps

The final Work Package in this project will examine the effects of irrelevant sound during a realistic simulation exercise. This study will allow us to draw more definitive conclusions concerning the extent to which performance may be disrupted. Based upon the evidence obtained to data, substantial effects are predicted.

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Appendix:
Data from Video Analysis

12. APPENDIX A: RYANAIR FLIGHT: WATERFORD TO STANSTED

Raw data from video analysis:
The first column describes the phase of the flight in which the activity took place, and a categorisation of the type of activity that was going on in the cockpit at the time. The second column provides details of activities and the quantity of party line information at each particular point.

On stand	
Task	Pilot contacts ATC to receive whether instructions and time check.
Party line	PL
Task	Pre take-off checks commence
Cabin crew	Cabin crew on intercom to confirm passenger numbers, pilot instructs cabin crew to close up the aircraft.
Task	Pre take-off checks continue. Interrupted on four occasions by PL.
Cabin crew	Cabin crew report that cabin is secured for take-off.
Direct comms	Pilot contacts ATC to confirm ready for taxi.
Taxi	
Task	Pilot begins to manoeuvre aircraft.
Task	Checks continue
Direct comms	ATC give details of take-off clearance.
Task	Checks continue. Interrupted on five occasions by PL.
Direct comms	Pilot contacts ATC to confirm ready for take-off, details of climb and weather conditions.
Take off	
Task	Pilot sets power, takes off and follows details of climb previously identified.
Direct comms	Pilot contacts ATC to confirm time airborne and altitude
Standard Instrument Departure	
	Not clear where this phase occurred between take-off and climb
Climb	
Task	Post take-off checks completed
Party line	PL
Direct comms	Pilot reports altitude to ATC
Party line	PL
Direct comms	Pilot instructed to change ATC and confirm altitude to next ATC
Direct comms	Pilot changes ATC and reports altitude. Then instructed to increase altitude.
Party line	PL

Appears to be a break in the filming	
Cruise	
Task	Receive weather report
Direct comms	ATC interrupts this to instruct pilot to change to new ATC and receive initial landing instructions
Party line	PL PL PL PL PL PL PL PL PL
Direct comms	ATC confirm altitude change
Party line	PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL
Task	Further weather reports received
Party line	PL
Task	Continue to receive weather report
Task	Flight crew discuss impact of weather
Party line	PL PL PL PL PL PL PL PL
Task	Adjustments made to instruments
Party line	PL PL PL PL PL PL PL
Task	Cruise checks. Interrupted on one occasion by PL
Party line	PL PL PL PL
Task	Instruments examined
Party line	PL PL PL PL PL PL PL PL PL
Task	Pilot examines details of arrival airport
Party line	PL PL PL PL PL PL
Task	First officer conducts announcement to the cabin
Party line	PL PL PL
Task	Pilot examines landing and approach procedures. These are discussed by the flight crew; during this time PL continues.
Party line	PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL
Direct comms	ATC confirms radar heading
Party line	PL PL PL PL PL PL PL PL PL
Direct comms	ATC confirms change in heading
Party line	PL PL PL PL PL PL
Direct comms	Pilot contacts ATC at arrival airport to confirm estimated arrival time and weather at destination.
Party line	PL PL PL PL PL PL PL PL
Direct comms	ATC confirms change in altitude – start of descent
Descent	
Direct comms	Descent checks, interrupted on five occasions by PL

Party line	PL
Direct comms	ATC confirm change in heading
Task	First officer receives weather report
Party line	PL PL PL PL PL
Cabin crew	Cabin crew come into cockpit to check flight crew are okay for drinks
Party line	PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL
Direct comms	ATC confirm change in heading
Party line	PL PL PL PL PL PL PL PL PL PL
Direct comms	Pilot reports heading to ATC, then instructed to change heading
Party line	PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL
Direct comms	ATC instruct aircraft to descend
Party line	PL
Direct comms	ATC instruct aircraft to descend and change heading
Direct comms	ATC instruct aircraft to descend and change heading
Party line	PL PL PL
Standard terminal arrivals	
Approach	
Direct comms	ATC instructed to change altitude and to confirm heading to new ATC
Direct comms	Hand-over to new ATC
Direct comms	Heading confirmed, new ATC instructs to decrease velocity and altitude
Task	Approach checks
Direct comms	ATC confirm heading change
Task	Checks continue
Direct comms	ATC confirm decrease in altitude
Cabin crew	Cabin crew on intercom confirm cabin secured for landing
Party line	PL PL PL
Direct comms	ATC instructed to descend and contact tower at arrival airport
Party line	PL PL
Direct comms	Pilot contacts tower at arrival airport, conditions and runway confirmed
Land	
Task	Landing gear engaged
Task	Landing checks
Party line	PL PL
Direct comms	ATC confirms clear to land

Party line	PL PL PL PL
Task	Follow altitude down
Task	Land
Task	Brakes
Party line	PL PL
Taxi	
Direct comms	Pilot confirms landing to ATC
Direct comms	ATC instructs aircraft to vacate runway to right and contact land control when complete
Party line	PL PL
Task	Aircraft manoeuvred off runway
Direct comms	Pilot contacts ground control and confirms runway clearance
Direct comms	ATC confirms stand and given instructions to the stand
Task	Aircraft manoeuvred, interrupted four times by PL
On stand	
Direct comms	Pilot confirms on stand to ATC
Party line	PL PL PL
Task	Hand brake on
Party line	PL
Cabin crew	Pilot confirms clear to open door to cabin crew
Task	Engines off

13. APPENDIX B: VIRGIN ATLANTIC FLIGHT, HEATHROW ? WASHINGTON

The first column describes the phase of the flight in which the activity took place, and a categorisation of the type of activity in the cockpit at the time. The second column provides details of activities and the quantity of party line information at each particular point.

On stand	
Task	Weather checks
Task	Planning for take-off
Task	Entering information on weather into navigation computer
Cabin crew	Bring tea
Task	Continue setting onboard computer
Task	Examine weather report
Ground crew	Discuss load information
Task	Check load of aircraft
Task	Recheck weather
Task	Take-off briefing
Task	Continue flight preparations
Task	Announcement to cabin. Interrupted six times by PL
Cabin crew	Instructed to secure doors
Direct comms	Confirm take-off slot
Direct comms	Confirm clearance to push back
Task	Pre-flight checklist. Interrupted once by PL
Taxi	
Task	Remove parking brake
	PL PL
Task	Manoeuvre aircraft. Interrupted nine times by PL
Task	Start engines one and two. Engines fail to start
Ground crew	Resolve problem through discussion with ground crew, PL turned down during this time.
Direct comms	Inform ATC of possible delay
Task	Start engines three and four
Task	Check flight controls
Task	After-start checklist
Direct comms	Confirm position
Direct comms	Confirm okay to continue taxi
Task	Manoeuvre aircraft. Interrupted four times by PL
Task	Check brakes
Cabin crew	Confirm cabin secure for take-off
	PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL
Direct comms	Informed of holding location
	PL PL PL PL PL PL PL PL PL PL
Direct comms	Clarification of instructions
	PL PL PL
Task	Pre-takeoff checklist
Task	Manoeuvre aircraft. Interrupted six times by PL
Cabin crew	Informed of delay to takeoff
Direct comms	Informed of position in queue
	PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL
Task	Move to runway. Interrupted twice by PL
Direct comms	Clear to take off

Direct comms	Takeoff instructions confirmed
Take off	
Task	Power down runway. Interrupted twice by PL
Task	V1
Task	Rotate
Task	V2
Task	Gear up
Direct comms	Instructed to contact new ATC
	PL PL
Direct comms	Contact new ATC
Direct comms	Confirm position
Direct comms	Receive instructions to climb
Task	Set flaps. Interrupted twice by PL
Task	Set altitude
Standard Instrument Departure	
	Not clear where this phase occurred between take-off and climb
Climb	
Task	Post-takeoff checklist. Interrupted twice by PL
Task	Enter information into navigation computer. Interrupted once by PL
Direct comms	Confirm heading
Direct comms	Instructed to change heading
	PL PL PL PL PL PL PL
Direct comms	Report heading and altitude
Direct comms	Instructed to change altitude
	PL PL PL PL
Direct comms	Instructed to change altitude
	PL PL PL PL PL
Direct comms	Instructed to change heading
	PL PL
Task	Receive clearance for Atlantic crossing via datalink
Direct comms	Instructed to change ATC
Direct comms	Confirm ATC change
Direct comms	Instructed to change altitude
Task	Enter wind speed into flight computer
	PL PL PL PL PL PL PL PL
Task	First officer plots flight path across Atlantic
	PL PL PL PL PL PL PL
Direct comms	Request altitude change
Direct comms	Altitude change confirmed
	PL PL PL
Cruise	
Direct comms	Instructed to change heading
	PL PL PL PL
Direct comms	Confirm heading
Direct comms	Informed of air traffic situation
Direct comms	Instructed to change altitude
	PL PL PL PL
Cabin crew	Check flight crew are okay
	PL PL

Task	Enter wind speed into flight computer. Interrupted four times by PL
	PL PL
Direct comms	Instructed to change altitude
	PL PL
Direct comms	Instructed to contact new ATC for Atlantic crossing.
	PL PL
Direct comms	Contact new ATC, confirm details of flight and receive clearance for crossing
Atlantic crossing	
	PL occurs only on 'social' frequency
	At every longitude report flight details and time expected at next longitude to ATC
Cruise	
	PL PL
Cabin crew	Discuss situation in cabin
	PL PL PL PL PL PL PL
Task	Review charts
	PL PL
Cabin crew	Bring ice cream
	PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL
Direct comms	Instructed to change ATC
Direct comms	Confirm ATC change
	PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL
Task	Receive weather information
Task	Discuss impact of weather information on flight. Interrupted twice by PL
	PL PL PL PL PL PL PL
Task	Examine layout of arrival airport. Interrupted four times by PL
Direct comms	Request information
Task	Continue examining airport layout. Interrupted twice by PL
	PL PL
Task	Enter wind speed into flight computer. Interrupted twice by PL
Direct comms	Request change in flight plan
Direct comms	Change confirmed
	PL PL
Cabin crew	Bring afternoon tea
	PL PL PL PL PL
Direct comms	Instructed to change ATC
Direct comms	Confirm ATC change
Direct comms	Enquire if aircraft is able to increase altitude if required
Direct comms	Confirm this is okay
	PL PL PL PL PL PL PL PL PL PL PL PL PL PL
Task	Discuss landing airport
Direct comms	Instructed to change heading and altitude
	PL PL PL PL PL PL PL PL PL PL
Direct comms	Relay ATC information for other aircraft
	PL
Direct comms	Instructed to change ATC
	PL
Direct comms	Confirm ATC change

	PL PL PL PL PL PL PL PL PL PL
Task	Enter wind speed into flight computer
	PL PL
Direct comms	Instructed to change ATC
Direct comms	Confirm ATC change
	PL PL PL PL
Task	Enters information about arrival airport into flight computer. Interrupted four times by PL.
Task	Landing briefing. Interrupted three times by PL
Descent	
Direct comms	Instructed to change altitude
Cabin crew	Clear loose items from cockpit
	PL PL
Task	Continue landing briefing. Interrupted five times by PL
Direct comms	Confirm heading
	PL PL PL
Direct comms	Instructed to change altitude
	PL
Direct comms	Confirm altitude change
	PL PL
Task	Captain makes announcement to cabin. Interrupted four times by PL
	PL PL PL
Direct comms	Confirm heading
Direct comms	Instructed to change heading
	PL PL PL PL PL PL PL PL PL PL PL PL
Direct comms	Instructed to change ATC
	PL PL
Direct comms	Confirm ATC change
	PL PL PL PL PL PL PL PL PL
Direct comms	Instructed to change altitude
	PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL PL
Direct comms	Instructed to change ATC
Direct comms	Confirm ATC change
	PL PL PL PL PL PL PL PL PL PL
Direct comms	Request altitude change
Direct comms	Confirm altitude change
Direct comms	Instructed to change ATC
Direct comms	Confirm ATC change
	PL PL PL
Task	Descent checklist
Direct comms	Instructed to change altitude
	PL
Direct comms	Instructed to change altitude
	PL PL PL PL
Task	Pre-landing checklist
	PL PL PL PL PL PL PL
Task	Weather checks. Interrupted seven times by PL
Direct comms	Instructed to change heading
Direct comms	Instructed to change altitude
	PL PL PL PL

Direct comms	Confirm ATC arrival frequency
	PL PL PL
Direct comms	Instructed to change ATC
Direct comms	Confirm ATC change
Task	Turn on anti ice. Interrupted once by PL
Task	Turn on seatbelts
	PL PL
Task	Set flaps
Direct comms	Request localiser
	PL PL PL PL PL PL PL
Direct comms	Instructed to change altitude
	PL PL PL
Direct comms	Instructed to change velocity
Task	Set flaps
	PL PL
Direct comms	Instructed to change velocity
	PL PL PL PL PL PL PL PL
Standard terminal arrivals	
	Not clear where this phase occurs between descent and approach
Approach	
Direct comms	Instructed to contact tower
Direct comms	Confirm contact tower
	PL PL PL PL PL
Direct comms	Receive landing instructions
Task	Reduce velocity
Task	Landing gear down
Task	Set flaps
Task	Pre-landing checks
	PL PL PL
Direct comms	Confirm expectation to land
Land	
Task	Lower aircraft to runway
	PL PL PL PL
Direct comms	Confirm landing
Direct comms	Contact land ATC
Direct comms	Confirm clear to taxi
Taxi	
Task	Manoeuvre aircraft
Task	First officer makes announcement to cabin
Cabin crew	Confirm doors are open
	PL PL
On stand	
Task	Engines off
Direct comms	Confirm aircraft on stand
Task	Parking checks