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FLYING PERSONNEL RESEARCH COMMITTEE LONDON (ENGLAND)  
RESEARCH ABSTRACTS IN THE BEHAVIOURAL SCIENCES, 1971-1975, (U)

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# Flying Personnel Research Committee

6 Research Abstracts in the Behavioural Sciences

1971-1975

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Flying Personnel Research  
Committee.

No. FPRC/Memo 259

Date. October 1979

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Abstract.

This memorandum contains 122 abstracts of research papers for use by psychologists and those working in aviation. It shows the scope of work in the fields of psychology and psychophysiology carried out by RAF workers from 1971 to 1975.

Aviation Psychology

Author(s)  
Miscellaneous

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INTRODUCTIONScope of Papers Abstracted

The abstracts of research papers contained herein are intended to present a general picture, to psychologists and those working in aviation, of the scope of work in the fields of psychology and psychophysiology carried out by RAF research workers over the five years 1971/1975. These abstracts necessarily omit the considerable number of papers that, for security or other reasons, cannot be made available at this stage. The abstracts have been collated under main topic headings as indicated in the list of Contents.

Availability of Papers Listed

- a. Papers already published in the open literature should be available through normal library channels.
- b. Reports and memoranda issued by the Flying Personnel Research Committee of the Ministry of Defence may be borrowed from the British Library Lending Division, through any library. These are annotated '(FPRC)' after the title.
- c. Individual copies of unpublished papers, annotated 'A', 'B', or 'C' after the title may, subject to availability, be obtained from originating authorities as listed below, according to annotation. Such papers can be supplied only to bona-fide research workers, in Universities and research establishments, who must specify their particular research interest when applying for a paper. Requests must be accompanied by a self-addressed envelope large enough to take an A4 size report. It is regretted that bulk requests, and requests from libraries, cannot be accepted.

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GENERAL PSYCHOLOGY

EDENBOROUGH, R.A. Order effects and display persistence in probabilistic opinion revision. Bulletin of the Psychonomic Society, 1975, 5(1), 39-40

Sixteen scientific, technical and clerical staff were divided into two equal matched groups to perform a bookbag and poker-chip task. A PDP8 computer was programmed to generate sequences of squares and crosses on a display screen. These shapes comprised the binary events in the bookbag task. Subjects' responses consisted of an indication of which shape was in the majority in the population from which the sample had been drawn, together with an estimate of how probable this was. Responses were made, using keyboard inputs, after each item of a twenty-item sample. On one run ambiguous data preceded unambiguous data. On another run, unambiguous data came first. For half the subjects only the current data item appeared. For the others, all preceding items were shown too. Final responses were higher where unambiguous data came last, which was interpreted as a recency effect. Whether the data persisted had no significant effect.

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ALLNUTT, M.F. and BOLTON, C.B. The Construction and Usage of Simple Questionnaires. Flying Personnel Research Committee Memorandum 255, 1975.  
(FPRC)

A well-constructed questionnaire can, when used in a carefully organised trial, provide a great deal of useful data. This goal is not difficult to achieve, but all those who construct and use questionnaires must be aware, of, and avoid various pitfalls e.g.

- a. errors of sampling - an incorrect or too small sample.
  - b. ambiguous questions e.g. double or negative questions, poor definitions, etc.
  - c. bias in the questionnaire design or wording - leading questions, emotional words and 'halo' effects.
  - d. bias in the Trials Team e.g. the respondents being aware of the opinion of the Trials Team either through a biased briefing or questionnaire or by loose talk.
  - e. errors of analysis e.g. non-response being ignored, rating being taken too literally, and so forth.
  - f. faulty interpretations of the results - the Trials Team assuming that their findings apply to all men in all aircraft under all conditions.
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EDENBOROUGH, R.A. Research Conference on Subjective Probability, Utility and Decision-making: Rome, September 1973. RAF IAM Scientific Memorandum No 115, 1974. (A)

The proceedings of the fourth in a series of European conferences on subjective probability and related research areas are outlined. Invited review papers at the conference dealt with heuristic devices used in judgement, multi-attribute utilities, decision-making research in socialist countries and dynamic decision making. Specific papers covered a wide range of topics, with emphasis on applications. A final session comprised a tutorial on the use of Bayesian statistics.

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EDENBOROUGH, R.A. Probabilistic opinion revision. PhD Thesis, University of Southampton, 1973.

Human performance with information indicating states in a less than certain way was examined. As well as descriptive approaches to performance, comparisons were made with the prescriptions of Bayes's Theorem. The 'bookbag and poker-chip' paradigm was used. Performance in one session was predictable from that in another, 8-10 weeks earlier, and was conservative: estimates were lower than prescribed. In another experiment responses were more optimal with an odds rather than a probability scale. In some cases knowledge of the results and information about totals of sample events improved performance. When sample length and number of responses were manipulated the usual effect of increased estimates for shorter sample was not observed. An explanation was offered in terms of saliency of opportunities for revision. Examination of sequential aspects showed non-optimal effects. With unambiguous information early in a sample, primary effects increased if the display of sample content increased. With no information about the proportion of events in the parent population, conservatism was still found. The ideal rule for this situation was not applied by subjects when the population characteristics were known. Views of conservation and models of opinion revision were critically examined in relation to the findings. The importance of 'real world' experience for performance here was suggested.

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HOPKIN, V.D. Flow diagrams. In 'Displays and Controls'. Bernstad, R.K. and Gartner, K.P. (Eds). Amsterdam: Swets and Zeitlinger, 1972, 193-212.

Flow diagrams are a means of depicting, in graphical form, the elements of a system in sequence. Both the man and the machine can be described and events shown in relation to their determinants and consequences. The diagrams are complimentary to, rather than substitutes for, alternative descriptive methods such as job descriptions and activity

analyses, which do not depict interactions so adequately but may be superior for showing individual differences. They can reveal superfluous actions and events but they cannot be modified to take account of learning effects, experience and skill. They can provide a structure for the derivation of mathematical models. Illustrative examples of the application of flow diagrams are drawn from a simple keying task in which a subject responds to a light impulse, and from a guided weapons system with complex controls and displays.

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GROUP AND INTERPERSONAL PROCESSES

STOKER, P.J. Limited Review of Research on Interpersonal Attraction.  
Research Task 267. Dec 1973. (B)

A literature survey of the research that has been done on interpersonal attraction.

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STOKER, P.J. Some Determinants and Consequences of the Differential Attribution of Ability and Effort in Training and Assessment Contexts.  
HQTC Research Branch Note Jan 76. (B)

Attributions of ability and effort are briefly discussed in relation to perception of causality and intentionality. Consideration of the consequences of differential attributions for reward and punishment behaviour in training contexts leads to the suggestion that effects may include (a) biases in assessments by instructors and (b) changes in motivational behaviour of students. The motivational changes may be moderated by the students' level of resultant achievement motivation. Some implications for the practical training situation are indicated, with an example from the specific context of flying training in the RAF.

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COOPER, C. Test Classification, G Analysis, and the DMT. CS(RAF)  
Note 13/77. (C)

The adequacy of the common classification of tests as 'projective' or 'objective' is questioned, and an alternative taxonomy proposed. The DMT is examined under such a model, and novel possibilities for reliably scoring the test responses are suggested.

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MILITARY STRUCTURE AND POLITICAL PROCESSES

JAMES, D.J. The RAF as a Total Institution. HQTC, Research Branch Note, 1973. (B)

Goffman's concept of the Total Institution is examined, criticized, and related to the internal structure of the RAF. The text includes figures from a survey of the task of the RAF Station Education Officer.

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JAMES, D.J. Alternative Models for the RAF - RUSI Journal Dec 1974.

The rationale of commissioning policies is examined, and the development of Branch Structures in the Royal Navy and the Royal Air Force is described.

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JAMES, D.J. The Development of the Royal Air Force Officer Corps. HQTC, Research Branch Note, 1975. (B)

This paper continues 'Alternative Models for the RAF' (D. J. James, 1974) and attempts to predict future developments in commissioning practice. The working of the University Cadet Scheme is described with statistics.

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JAMES, D.J. Violence and the Functions of an Armed Force. HQTC, Research Branch Note, 1976 (B)

The currently fashionable definition of an officer as a Manager of violence is criticized, and the basic philosophy of Military establishments described afresh in Mertonian terms of function. Soldiers, Police and Gendarmerie are differentiated.

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JAMES, D.J. Trenchard's Manning Revolution. RAF Quarterly, Winter 1977.

A shortened version of 'The Trenchard Tradition and its Successors' (1977 D. J. James) which discusses changes in RAF methods of recruiting officers and airmen over the period 1918 to 1970 and relates this to changes in the national education system. An attempt is made to predict the future structure of the service.

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PERSONNEL ATTITUDES AND EVALUATION

SKELLY, G.B. Airmen Assessment Research Project Phase 5. Trade Proficiency Inventories for 8 Trade Bands. CS(RAF) Note No 18/75 Oct 1975. (C)

This paper the last in a series reporting the Airmen assessment Research Project begun in 1973 describes how 8 Inventory Trade Proficiency assessment modules were developed for the assessment of junior airmen in RAF ground trades other than Engineering and Administrative.

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ANDERSON, J.D. An Examination of the Annual Confidential Reporting System for Officers. CS(RAF) Memo No 398. Oct 1975. (C)

This memorandum examines the Officers Annual Confidential Report: Form 1369. It studies the performance of the numerical assessments, in terms of their ability to give reliable and useful information about individuals. It also examines the content and coverage of the narrative reports. The aim was to indicate what, if any, improvements or simplifications could be made in the design and use of the form.

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ANDERSON, J.D. Educational Attainment vs Intelligence in an RAF Applicant Population. CS(RAF) Note No 5/77. Jan 1977. (C)

This note examines the performance of adult male applicants for ground trades in the Royal Air Force, in terms of changes in the mean scores achieved on four basic screening tests. These tests, which were introduced in 1963, have been in continuous use since that time. Three of them have a strong educational attainment component. The fourth is a comparatively 'pure' intelligence test. Complete data for each year is not available: prior to the introduction of a computer-based system in 1971 the labour costs of calculating summary statistics on a routine basis were too high, and only ad-hoc studies were carried out. Data from these studies has been included where pertinent, but only from 1971 is the picture in any sense complete.

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AVIATION MEDICINE

BARNES, G.R. The role of the vestibular system in head-eye co-ordination. J. Physiol., 246, 99-100P, 1975.

When the human subject moves head and eyes to fixate an offset target, the eye movement consists of an initial saccadic movement in the direction of the head movement, followed by a slow phase return toward orbital centre

which is compensatory to the remaining head movement. It has been shown that this pattern of eye movement was maintained when the target light had been extinguished before the end of the saccade. The author has tested two further conditions. In the first, subjects made random rotational head displacements about the vertical axis in the dark, with no incentive to make eye movements. Head displacement was transduced using a potentiometer and eye movements were recorded by electro-oculography. The eye movements were of the same pattern as those found during target acquisition, implying that the eye displacement is reflex upon head movement and not itself dependent on target offset. In the second condition, the subject was secured with the head clamped to a turntable which was moved in a manner simulating the voluntary head movements. Eye responses in this condition were the same pattern as those observed when the head moved voluntarily.

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BARNES, G.R. Vision during head movement. Paper to 46th Annual Meeting of the Aerospace Medical Association, San Francisco. April 1975. (A)

The normal function of the vestibulo-ocular reflex is to induce movement of the eyes in the opposite sense to that of the head, thus aiding the process of fixations of objects fixed in space. However, if the object of fixation moves with the head, the vestibularly induced eye movement is inappropriate and must be suppressed for visual acuity to be preserved. Such a condition arises when man and vehicle are being vibrated at the same frequency. The author tested the ability to suppress inappropriate vestibular eye movements for both yaw and pitch excitation of the semicircular canals. The subject sat on a chair mounted on a turntable which could be rotated about either a horizontal or vertical axis. His head was clamped to the chair and his body firmly harnessed. A visible display was rigidly attached to the framework of the chair so that there was no detectable movement between the head and the display. The display was a row of 3 digits which were changed for another random set by the self-paced subject. The task was to read as many digits as possible during a set period while the turntable was oscillated in either yaw or pitch. The stimulus to the vestibular equipment was a sinusoidal oscillation at 8 different frequencies between 0.2 Hz and 8 Hz in yaw and 0.2 Hz and 3 Hz in pitch, with three levels of peak angular velocity. Eight healthy subjects experienced all experimental conditions in either the yaw or pitch axis. As regards the results, all subjects showed a marked decrement in the ability to read the digits of the display at frequencies above 1.3 Hz in both pitch and yaw. With both pitch and yaw stimulation the fall off in performance was greater and started at lower frequency at the higher levels of angular velocity, indicating that the ability to suppress is a function of both frequency and velocity of eye movement. A significant decrement in reading performance was detected at a lower frequency in pitch than in yaw. The impairment of reading ability was also greater in pitch than in yaw.

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GUNDRY, A.J. The Use and Nature of Distance Information for Movement Reproduction. Ph.D. Thesis, Dept of Psychology, University of Reading, 1975. (A)

The use and nature of distance information in normal adult humans is investigated. Use of distance information is observed when the amplitude of a movement is reproduced, irrespective of its initial and terminal positions. The terminal position of a movement can also be reproduced - this is defined as the use of position information. Both position and distance information are non-visual and are studied using blindfolded subjects. Initial experiments demonstrate that distance information is as accurate as position information for the reproduction of small amplitudes of movement. It is further shown experimentally that distance information is spontaneously adopted for the reproduction of small amplitudes, and position information for large amplitudes. It is argued that distance information can be provided by three psychological processes, speed-time cues, a visual range of distance and a motor programme. A review of the evidence concerning motor programmes reveals that their use has only been reliably observed under abnormal conditions and there is no evidence of their use in distance reproduction. It is shown experimentally that speed-time cues are the most likely source of distance information at low levels of practice. Although it is clear that speed of movement can be signalled kinaesthetically it is not clear what process provides duration information for the use of speed-time cues. It is argued that duration information may arise from kinaesthetic feedback, the output of an internal clock or a cognitive time estimation. Alternatively a motor programme may be used. It is shown experimentally that kinaesthetic feedback does not contribute to the timing of movements. Further experiments demonstrate that it is a cognitive time estimation which provides the duration information necessary for distance reproductions to be made using speed-time cues.

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GUNDRY, A.J. The use of location and distance in reproducing different amplitudes of movement. *J. of Motor Behaviour*, 1975, 7, 91-100.

Experiments have demonstrated that in order to reproduce a standard movement, subjects can move for a certain distance or move to a certain location. Available evidence suggests the use of distance for short movements and location for long movements. However, this evidence is in conflict with the motor short-term memory characteristics of short and long movements. In this study the author investigated the use of distance and location over a range of amplitudes in a movement reproduction task. Five balanced groups of subjects took part. One group was instructed to use distance and another was told to use location. Three groups were not told

what type of movement information to use, the difference in their treatments being only the amplitude of movement that they were required to reproduce. To reveal the use of distance of location, the starting point of the estimations was moved during the estimation trials, in small clockwise and then anti-clockwise steps. If subjects were attempting to reproduce the terminal point of the presentation movement, the end point of their estimations should be unaffected by the movement of the starting point. The experiment demonstrated that subjects spontaneously used distance for short movements and location for long movements. It also revealed that using distance and location to reproduce a 40 degree movement resulted in equal accuracy, suggesting that the use of large amplitudes of movement has caused previous investigators to find that distance is less accurate than location.

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BENSON, A.J. (Ed.) Orientation/Disorientation Training of Flying Personnel: A Working Group Report. AGARD Report No. 625, 1974

This report of an Aerospace Material Panel Working Group reviews orientation/disorientation training of military and civilian aircrew in NATO countries. Deficiencies in current programmes are discussed and 24 recommendations made for the improvement of ground and in-flight training. Sections of the report review groundbased training techniques, the use of familiarisation devices, more complex trainers and aspects of in-flight training. Descriptions of the conduct of ground and in-flight demonstrations, a specimen lecture syllabus and a specification for a familiarisation device are given. Topics requiring further research or development are identified.

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BENSON, A.J. Physical Characteristics of Stimuli which Induce Motion Sickness: A Review. RAF Institute of Aviation Medicine Report No. 532, 1973. (A)

The physical characteristics of motions which induce sickness in man are reviewed. The occurrence of the motion sickness syndrome is related to the nature of the dissonance between motion cues provided by the vestibular, kinaesthetic and visual sensory systems in experimental situations when symptoms were evoked by known angular and linear acceleration stimuli.

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BENSON, A.J. Spatial disorientation and 'break-off' phenomenon. *Aerospace Medicine*, 1973, 44, 944-952.

Out of seventy-eight aircrew referred for clinical assessment because of 'disorientation in flight', twenty-nine pilots described incidents in which they experienced feelings of unreality and detachment. These commonly occurred during monotonous phases of flight in conditions where external visual orientation cues were restricted. In twenty-two pilots of fixed-wing aircraft the perceptual disturbances characteristic of the 'break-off' phenomenon occurred when flying at altitudes in excess of 30,000 feet, but seven helicopter pilots had comparable sensory disturbances at 500-10,000 feet. In all but three pilots, the dissociative sensations were coupled with illusory perceptions of aircraft attitude and motion, though only in eight pilots was there a qualitatively false perception of aircraft orientation. Evidence is presented which suggests the 'spatial disorientation' occurring as a concomitant of 'break-off' was caused by minor degrees of vestibular asymmetry. The high incidence of anxiety reactions supports the view that in susceptible individuals 'break-off' can be both a precipitant and a manifestation of anxiety neurosis.

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BENSON, A.J. Use of Nystagmography in the Study of Aircrew with Spatial Disorientation. *AGARD CP 128, A4*, 1-12. 1973.

Lateral nystagmus evoked by a stopping stimulus of 60 degrees per second was recorded by electro-oculography in 133 aircrew who had come under medical care because of airsickness (55), spatial disorientation (36) or other sensory disturbances in flight without illusory perception of aircraft orientation (42). Measures of the slow phase velocity, the time constant of decay and total amplitude of the post-rotational nystagmus did not differ between the three groups. Measures of directional preponderance were found to have differences in variance structure between the groups, but these were not well defined and hence of limited value in the selection or assessment of individual aircrew.

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BENSON, A.J. and BURCHARD, E. Spatial Disorientation in Flight: A Handbook for Aircrew. AGARDograph No 1970, 1973.

Chapter titles are:

1. Spatial disorientation - the practical problem
2. Perception of spatial disorientation
3. Form and function of the vestibular apparatus
4. Somatogyral illusions
5. Somatogravic illusions
6. Visual illusions of motion
7. Other visual illusions
8. Brain mechanisms and spatial disorientation
9. Prevention and treatment

This handbook is excellently illustrated.

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BENSON, A.J. (Ed). The Disorientation Incident. Technical Evaluation. AGARD CP 95, Part 1, 17, 1-4, 1972.

The Disorientation Incident was the theme of the first part of the 28th Meeting of the AGARD Aerospace Medical Panel held in Luchon, France, in September, 1971. In his introductory remarks, Dr Benson explained that the objective of the Panel in choosing Spatial Disorientation as a special topic for this meeting was to determine the operational significance of this perceptual disturbance in the flight environment. He suggested that it was widely recognised that all aircrew suffered from disorientation at some time or other, but little up-to-date information was available about the incidence of disorientation or how frequently it was the prime or contributory cause of aircraft accidents. Apart from information about the operational consequence of disorientation, it was important that the underlying mechanism of the condition should be understood in order to provide a scientific basis for the development of techniques and training procedures which would reduce the incidence of spatial disorientation in flight. Sixteen papers were presented and they could be broadly classified under the headings: a. Description and analysis of incidents reported by aircrew: b. Analysis of accidents attributable to disorientation: c. Laboratory studies and d. Training procedures.

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BRENNAN, D.H. Colour Vision Requirements in Different Operational Roles in the Royal Air Force. Flying Personnel Research Committee Report 1319, 1972. (FPRC)

The colour vision requirements and selective methods for RAF aircrew in use today were adopted in 1959. Using subjective methods, the author examined whether these standards are relevant to the operational needs of the RAF in the 1970s. It is considered that good colour discrimination, although playing a valuable part in the total process of visual perception, is not of paramount importance. It would be possible by altering the present chromaticities of red and green signal colours to admit for all aircrew duties, except those of close air support, more severe grades of red-green defectives than at present. It is thought, however, that the small gain in recruiting would not warrant the resulting expense and disruption of present services. The pseudo-isochromatic plates (e.g. Ishihara and H.R.R.) provide a simple and rapid method of detecting even minor anomalies in colour vision and should be retained as the initial examining procedure. With present standards, the lantern is the best 'trade test' for grading colour defectives as fit or unfit for aircrew duties. Should standards be lowered, it would be necessary to supplement the lantern with a quantitative test which should be related, if possible, to the role envisaged for the candidate.

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NICHOLSON, A.N. Rest and activity patterns for prolonged extra-terrestrial missions. Aerospace Med 43(3), 253-257, 1972.

Difficulties in obtaining satisfactory sleep have been encountered during many space missions and it is generally recognised that an appropriate rest and activity pattern is essential to maintain the well-being and operational effectiveness of space crews. During earth orbital flights and lower explorations, satisfactory sleep is more likely if the crews maintain a reasonable relation with their normal terrestrial rhythm, but many missions have required unusual patterns of activity. In the future, prolonged extra-terrestrial flights may also demand that the sequence of work and rest be subordinated to operational requirements and under these circumstances work and rest regimes developed under earth conditions may be of little use. Irregular duty periods superimposed upon daily cycles of varying duration are experienced by long haul transport aircrew. An analysis of these schedules has suggested that irregular patterns of rest are compatible with a satisfactory sleep pattern as long as the workload is limited. It is considered that a similar relationship could be established for prolonged space-flights and, in this context, the sleep patterns of an airline pilot operating worldwide schedules have been examined and relevant recent work on modified sleep regimes discussed.

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NICHOLSON, A.N. Sleep patterns in the aerospace environment. Proceedings of the Royal Society of Medicine, 1972, 65, 192-194.

The author examines some rest and activity sequences of airline pilots involved in intercontinental operations and of space crews engaged in orbital missions. Working in the aerospace environment has a marked effect on sleep patterns because duty periods are irregular and the normal day-night cycle may be modified in duration or even absent. These circumstances lead to unusual rest and activity rhythms within which satisfactory patterns of sleep must be created. The airline pilot has to cope with irregular and often long hours of duty superimposed upon time zone changes, while space crews experience rapid day-night cycles of about 90 minutes duration during earth orbital flights, and complete absence of day-night cycles during extra-terrestrial journeys and lunar explorations. There is a need to define work schedules comparable with an acceptable sleep pattern and to explore the part that pharmacological control of sleep and wakefulness, without undesirable side-effects on performance, may play in the initial adaptation of man to unusual schedules of work.

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BENSON, A.J. and GUEDRY, F.E. Comparison of tracking-task performance and nystagmus during sinusoidal oscillation in yaw and pitch. Aerospace Medicine, 42, 593-601, 1971.

The present problem is to compare performance limits and nystagmus induced by angular accelerations about the pitch and the yaw axes. Sinusoidal torsional oscillation (0.04 Hz, peak angular velocity  $\pm 60$  to  $\pm 159$  degrees per sec) degraded subjects' performance of a compensatory tracking task because inappropriate nystagmic eye movements impaired visibility of the display. Responses to angular oscillation in yaw and pitch were compared. During angular motion in the pitch-forward direction the nystagmus frequency and slow phase velocity, and the consequent performance decrement, were significantly greater than during the pitch-back half cycle. No such asymmetry was found during the oscillation in yaw where the nystagmus measures and error scores were similar to those obtained in the pitch-back half cycle. The poorer suppression of vestibular nystagmus during pitch-forward motion is attributed to the higher frequency and the smaller amplitude of downbeating nystagmus. Angular oscillation in pitch induced motion sickness more rapidly than a comparable yaw-axis stimulus. This was probably caused by differences in the dynamic response of vertical and lateral canals and the greater mis-match of canal and gravi-receptor signals during oscillation in pitch.

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BENSON, A.J., REASON, J.T. and DIAZ, E. Testing Predictions Derived from a Model of Progressive Adaptation to Coriolis Accelerations. Flying Personnel Research Committee Report 1311, 1971. (FPRC)

A theoretical model for progressive adaptation to Coriolis accelerations is described. Thirteen subjects were tested under procedures identical to those using fixed velocity increments described in previous studies, but in this instance diminishing velocity increments, with an initial step of 3 rev/min, were used. The findings provide positive but, as yet, limited support for the theoretical model described.

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BENSON, A.J. Neurological aspects of disorientation in aircrew. Proc. Roy. Soc. Med., 66, 519-523, 1973.

Spatial disorientation is a term used in aviation medicine to describe a group of incidents, occurring in flight, where the aviator has a false perception of the position, attitude or motion of either himself or his aircraft. Only on rare occasions is the disorder of perception caused by disease, commonly it is the manifestation of a natural limitation of sensory function. In flight, man is taken out of his normal terrestrial environment and exposed to patterns of linear and angular motion to which his sensory systems are not functionally adapted. Spatial disorientation is thus one manifestation of the physiological and psychological cost of attempting to live and work in an unnatural environment. The author deals with:

- a. Types of spatial disorientation.
- b. Incidence of spatial disorientation.
- c. Operational consequences of spatial disorientation (Behavioural response to disorientation stress: Anxiety reactions).
- d. Etiology of disorientation.

With few exceptions the vestibular asymmetry found in aircrew with spatial disorientation lay within the normal distribution and was not considered to be the manifestation of vestibular disease. Nevertheless, it was concluded that minor degrees of asymmetry could be the matrix of illusory perceptions when there was a heightened awareness of vestibular cues engendered by anxiety and high arousal in flight environment where external visual cues of aircraft orientation were absent or inadequate.

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PHYSIOLOGICAL PSYCHOLOGY AND PSYCHOPHARMACOLOGY

NICHOLSON, A.N. Residual Effects of Hypnotics. AGARD R-642, 1976.

Using adaptive tracking techniques, the author studied the residual effects of hypnotics after their therapeutic purpose has been fulfilled. He found the effects on performance vary considerably. It would appear that the benzodiazepines, nitrazepam (10 mg) and flurazepam hydrochloride (30 mg) have residual effects comparable to those of heptabarbitalone (400 mg) and pentobarbitalone (200 mg), and in this respect do not offer an advantage over the barbiturates. Methaqualone hydrochloride (400 mg) and diazepam (10 mg) may prove to be of value as an hypnotic for persons involved in skilled activity, but more information is required on the effectiveness of these drugs as hypnotics. It is, however, likely that diazepam or a closely related drug will prove to be of particular value in the context of this work.

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NICHOLSON, A.N. and STONE, B.M. Effectiveness of diazepam and 3-hydroxy-diazepam (temazepam) for day-time sleep. Brit. J. clin. Pharmac., 1976.

The usefulness of an hypnotic is usually assessed by its effect on nocturnal rest, though with the irregular work pattern of many present-day occupations such as aviation, it is often necessary to rest when the desire to sleep may not be optimum. It cannot be assumed that an hypnotic acceptable for use at night would be equally suitable for use at other times of the day. Indeed, the response of man to many drugs varies with his circadian rhythm and it is possible that such effects may be relevant to the use of hypnotics in the management of sleep in people with irregular work. The effect of 5, 10 and 15 mg diazepam and 10 and 20 mg 3-hydroxydiazepam (temazepam) on day-time sleep was studied in six healthy adult males using electroencephalography for sleep measures and analogue scales for subjective assessments of wellbeing and sleep quality. It is considered that diazepam in the dose range 5-10 mg is a useful hypnotic for sleep at unusual times of the day and may be relevant to the management of sleep disturbance in air-crew.

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NICHOLSON, A.N., and STONE, B.M. and CLARKE, C.H. Effect of diazepam and a soluble salt of diazepam, fosazepam, on sleep in man. Brit. J. clin. Pharmac., 1976.

The suitability of an hypnotic for people involved in a skilled activity require information which is not usually included in the evaluation of drugs. Individuals in skilled activity often work irregular hours and suitable

hypnotics must be free from residual effects on performance, and effective when used at times which do not coincide with the usual sleep periods. In this experiment the effect of 5 and 10 mg diazepam and of 60 and 80 mg fosazepam on sleep was studied in six healthy adult males using electroencephalography for sleep measures and analogue scales for subjective assessments of wellbeing and sleep quality. The authors found that:

- a. The effect of diazepam was limited to the night of ingestion but the effect of fosazepam was carried over to the next night and so modified sleep for about 30 hr after ingestion.
- b. Effects on total sleep time were limited to the night of ingestion. There were increases with 10 mg diazepam ( $P=0.05$ ) and with 60 and 80 mg fosazepam ( $P=0.001$ ). For the night of ingestion sleep onset latencies were shortened and awakenings were reduced by both drugs. The latency to stage 3 was shortened by 60 and 80 mg fosazepam ( $P=0.05$ ).
- c. The low and high dose of each drug reduced the duration of stage 0 sleep ( $P=0.01$ ), but fosazepam also reduced the duration of stage 1 sleep ( $P=0.001$ ) and there was an increase in stage 2 sleep ( $P=0.01$ ). With fosazepam there were carry over effects to the next night with reduction of stage 1 sleep ( $P=0.05$ ). There were no effects on the duration of stage 3, but there was evidence that stage 4 activity was reduced during the recovery night after ingestion of 80 mg fosazepam. No effects were observed on rapid eye movement sleep.
- d. Subjects reported an improved sense of wellbeing during the day after ingestion of diazepam and fosazepam, and with fosazepam they reported improved sleep. Correlations were calculated for sleep measures and subjective assessments.

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NICHOLSON, A.N., STONE, B.M., CLARKE, C.H. and FERRES, H. Effect of N-desmethyldiazepam (nordiazepam) and a precursor, potassium clorazepate, on sleep in man. *Br. J. clin. Pharmac.* 1976, 3, 429-438.

The effect of N-desmethyldiazepam (nordiazepam, 5 and 10 mg) and potassium clorazepate (15 mg, a precursor of nordiazepam) on sleep was studied in six healthy adult males. EEG's were used for sleep measures, and analogue scales were used for subjective assessments of wellbeing and sleep quality. Effects on total sleep time were limited to the night of

ingestion. There were increases with nordiazepam (5 and 10 mg) ( $P = 0.05$  and  $0.001$  respectively), and with clorazepate (15 mg) ( $P = 0.01$ ). Sleep onset latencies were shortened, particularly with nordiazepam, and awakening to stage 0 activity was reduced by both drugs. The latency to stage 3 was reduced by nordiazepam (5 and 10 mg) ( $P = 0.05$ ). There were no effects of nordiazepam (5 mg) on the duration (minutes) of sleep stages. Nordiazepam (10 mg) and clorazepate (15 mg) reduced the duration of stage 0 and stage 1, and there were increases in stage 2. Reduced stage 1 and increased stage 2 sleep were observed during the recovery night. No effects were observed with stage 3 but there was evidence that stage 4 activity was depressed on the recovery night only. No effects were observed on rapid eye movement (REM) sleep except that the appearance of the first REM period was delayed with clorazepate (15 mg) ( $P = 0.01$ ). The effect of nordiazepam (10 mg) and clorazepate (15 mg) were comparable and each modified sleep for about 28-30 hours after ingestion. With nordiazepam (10 mg) and clorazepate (15 mg) the subjects, as a group, reported improved sleep, but subjective assessments of wellbeing were not altered. Correlations were calculated for sleep measures and subjective assessments.

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BORLAND, R.G. and NICHOLSON, A.N. Comparison of the residual effects of two benzodiazepines (nitrazepam and flurazepam hydrochloride) and pentobarbitone sodium on human performance. *Br. J. clin. Pharmac.*, 1975, 2, 9-17.

The residual effects of two benzodiazepines, nitrazepam (10 mg) and flurazepam hydrochloride (30 mg), and pentobarbitone sodium (200 mg) were studied by adaptive tracking and by reaction time. Performance was measured at 10 hours, 13 hours, 16 hours, 19 hours and 34 hours after ingestion of each drug. Impaired performance on adaptive tracking was observed at 10 hours, 13 hours, 16 hours and 19 hours after nitrazepam and pentobarbitone sodium and at 10 hours, 13 hours and 16 hours after flurazepam hydrochloride. Enhanced performance was observed at 34 hours after nitrazepam and pentobarbitone sodium. Increased reaction time persisted to 16 hours after nitrazepam, flurazepam hydrochloride and pentobarbitone sodium and reaction time was also increased at 34 hours after nitrazepam and pentobarbitone sodium. During the morning immediately after ingestion, the subjects as a group were able to differentiate correctly between placebo and drugs, but were not able to assess accurately the persistence of the residual effect of nitrazepam and pentobarbitone sodium. Flurazepam hydrochloride would appear to be a more promising benzodiazepine than nitrazepam for use as a hypnotic by persons involved in skilled activity. There was a rapid recovery of performance during the afternoons and, unlike pentobarbitone sodium and nitrazepam, subjects retained the ability to recognise impaired skill.

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BORLAND, R.G. and NICHOLSON, A.N. Immediate effects on human performance of a 1,5-benzodiazepine (clobazam) compared with the 1,4-benzodiazepines, chlordiazepoxide hydrochloride and diazepam. *Brit. J. Pharmacol.*, 2, 215-222, 1975.

This is one in a series of experiments to find the effect of drugs on people involved in a skilled activity, especially those employed on shiftwork and aircrew. In this investigation, the immediate effects on human performance of the 1,5-benzodiazepine, clobazam (20 mg), and the 1,4-benzodiazepines, chlordiazepoxide hydrochloride (20 mg) and diazepam (10 mg) were studied using adaptive tracking and measurement of reaction time. Each drug was ingested at 0900 hr and performance was measured at 0930 hr (0.5 hr), 1130 hr (2.5 hr), 1430 hr (5.5 hr) and 1830 hr (9.5 hr after ingestion). With diazepam, decrements in performance on adaptive tracking were observed at 0.5 hr and 2.5 hr, and performance was enhanced at 9.5 hr after ingestion. With clobazam performance at individual times did not differ significantly from control, but there was evidence of an improvement in performance during the day. There was no evidence of impaired performance on adaptive tracking after chlordiazepoxide hydrochloride. Reaction time was slowed at 0.5 hr and 2.5 hr after diazepam and chlordiazepoxide hydrochloride. A decrease in reaction time was observed at 9.5 hr after diazepam. No changes in reaction time were observed after clobazam. The subjects as a group differentiated correctly between performance decrements on adaptive tracking after diazepam and the absence of performance decrements after clobazam and chlordiazepoxide. The persistence of the decrement in performance after diazepam was accurately assessed. It is evident that the nature and persistence of impaired performance and the ability to appreciate impaired performance vary considerably between the benzodiazepines, and the choice of a benzodiazepine should include careful consideration of performance sequelae.

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BORLAND, R.G., NICHOLSON, A.N. and WRIGHT, C.M. Behavioural sequelae of methaqualone in man and in the monkey (*Macaca mulatta*). *Brit. J. clin. Pharmacol.*, 2, 131-142, 1975.

Residual effects in man of methaqualone hydrochloride (400 mg) were studied by adaptive tracking and using reaction time. Performance was measured at 10 hr, 13 hr, 16 hr, 19 hr and 34 hr after the overnight ingestion of the drug. There is no evidence of impaired performance on adaptive tracking from 10 hr to 19 hr but enhanced performance ( $P = 0.001$ ) was observed 34 hr after ingestion. With reaction time, an increase ( $P = 0.01$ ) was observed 10 hr and a decrease ( $P = 0.05$ ) was observed 19 hr after ingestion. Effects in the monkey (*Macaca mulatta*) of methaqualone (20 and 30 mg/kg body weight) were studied by a delayed matching task in which total response time was measured. No consistent effects on matching

behaviour or on total response time were observed 2 hr after intraperitoneal ingestion. The studies suggest that methaqualone hydrochloride may be a valuable hypnotic for occasional use by persons involved in skilled activity.

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BLAGBOROUGH, AVRIL E., BRIERLEY, J.B. and NICHOLSON, A.N. Alternation behaviour in the rhesus monkey after profound hypoxia. *Journal of Physiology* 232, 106-108 P, 1973.

Twenty-two rhesus monkeys (*Macaca mulatta*), trained on tasks of object alternation and spatial alternation, were exposed to an ambient pressure of 523 mm Hg (equivalent to an altitude of 10,000 feet with a calculated inspired oxygen tension of 100 mm Hg) for 15 minutes, then decompressed to an ambient pressure of 160 mm Hg (37,500 feet with a calculated inspired oxygen tension of 24 mm Hg) within 12 seconds. The exposures were continued until respiratory arrest appeared imminent and ranged in duration from 9½ to 22½ minutes. Eighteen animals survived the decompression. In seven there was no evidence of neurological or behavioural impairment and at subsequent neuropathological examination their brains were normal. The remaining eleven animals exhibited typical ischaemic alternations along the arterial boundary zones of the cerebral or cerebellar cortices and often in the caudate and lentiform nuclei. All showed behavioural and/or neurological impairments, which in six cases were incompatible with survival. Disturbances in alternation behaviour were always associated with damage to the frontal cortex, and its projections to the basal ganglia. The time course of impairment was similar to that found in an earlier study (Blagborough, Avril E. et alia). In the animals which survived, the changes appeared between the 2nd and 9th days after decompression and had virtually disappeared by the 22nd day). Monkeys which showed neurological impairments within the first 24 hours after decompression failed to survive the first week, though some showed evidence of a delayed onset of impairment in the alternation tasks. It seems that primary damage in localised areas of the brain is essential for specific behavioural impairments but that secondary factors make an important contribution to their appearance. The rapidity of the recovery from both neurological and behavioural disturbances in mildly damaged animals suggests that this may have involved the removal of influences interfering with normal neuronal function rather than compensation by other cerebral areas.

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BLAGBROUGH, AVRIL E., BRIERLEY, J.B. and NICHOLSON, A.N. Behavioural and neurological disturbances associated with hypoxic brain damage. *J. Neurol. Sci.*, 18, 475-488, 1973.

Twenty-one monkeys (*Macaca mulatta*) trained on tasks of object alternation, spatial alternation and visual discrimination were exposed in air to a steady ambient pressure of 160 mm Hg (equivalent to an altitude of 37,500 feet with a calculated inspired oxygen tension of 24 mm Hg). Ten animals which sustained hypoxic-ischaemic brain damage exhibited behavioural and neurological impairments. Observations on the nature and time course of impairment after hypoxia suggests that:

- a. Behavioural and neurological disturbances are dependent upon damage in specific regions of the brain.
- b. Although primary brain damage is essential, factors other than neuronal loss contribute to the impairment.
- c. Recovery of function in animals with restricted lesions proceeds in the presence of permanent brain damage.

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BORLAND, R.G. and NICHOLSON, A.N. Use of hypnotics by aircrew - adaptive tracking as a technique for the evaluation of performance decrements related to the flying task. AGARD CP No. 108, 1973.

This paper concerns the use of hypnotics on aircrew many hours after a drug has been administered. Six subjects aged between 25 and 40 years took part in an adaptive tracking task requiring the centring of a spot in a small circle displayed on a CRT. The subject controlled movement of the spot, using a joystick simulating aerodynamic characteristics. Subjects were given adequate tracking practice. The drug used was secobarbitone at a dose of 3.3 mg/kg of body weight. The authors found drug effects up to 30 hours after administration. They concluded that adaptive training may provide a reasonable approach to evaluating drug after-effects of possible significance to the flying task. Nevertheless, training of personnel and the experimental procedures involved demand considerable effort on the part of subjects and experimenters. It is considered that such a procedure can only be used when there is a likelihood that a specific drug may prove of value. Behavioural studies in primates have an important part to play in initial studies.

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BRIERLEY, J.B. and NICHOLSON, A.N. Neurological sequelae of decompression in supersonic transport aircraft. *Proc. Roy. Soc. Med.*, 66, 527-530, 1973.

The forthcoming generation of SSTs will operate at altitudes far in excess of present-day aircraft. Altitudes around 70,000 feet are envisaged, but immediate developments concern the range between 55,000 and 60,000 feet. The effect of a small structural failure must be carefully evaluated because, although emergency measures such as increased flow of air into the cabin and the descent of the aircraft will reduce the maximum altitude reached within the cabin, the occupants could be exposed to a prolonged period of hypoxia. The authors describe some neurological, electro-cortical and neuropathic decompression duties carried out on monkeys (*Macaca mulatta*) at simulated altitudes up to 53,000 feet and they set out the effects for different decompression profiles. The expected profiles are little different from those which may follow decompressions in present-day subsonic transports, due to the rapid emergency descent of over 7,000 feet per minute which can be effected by SST planes.

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FIRTH, PATRICIA A. Psychological factors influencing the relationship between cardiac arrhythmia and mental workload. *Ergonomics*, 1973, 16, 5-16.

This paper examines the development and use of cardiac arrhythmia as an index of mental workload in terms of several issues. These include the relevance of autonomic response to the measurements of task difficulty and the implications of general principles of psychophysiology to the application of cardiac arrhythmia as an applied measure. In addition the complexity of the psychological factors which may influence task difficulty is discussed with particular reference to second-by-second changes in heart rate variability. In conclusion it is suggested that the usefulness of global concepts of task difficulty such as mental load may be questionable. A greater understanding of what a task entails, with reference to increased psychophysiological knowledge, is necessary in order that global changes in cardiac arrhythmia may be interpreted in relation to task difficulty.

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NICHOLSON, A.N., HILL, L.E., BORLAND, R.G. and KRZANOWSKI, W.J. Influence of workload on the neurological state of a pilot during the approach and landing. *Aerospace Med* 44(2), 146-152, 1973.

The workload of a pilot during the let-down of a B707 was modified by coupling the aircraft to the ILS localiser and glide slope path (coupled approach) or by increasing the participation of the co-pilot in the handling

of the aircraft (shared approach). The ECG of the pilot was recorded during the let-down and finger tremor was recorded after landing. The mean rr intervals around touchdown of the coupled approaches, which were all of low workload, were increased compared with the let-downs of equal difficulty handled throughout by the pilot (manual let-down). In the shared approaches to 1000 feet, the relation between the mean rr interval around touchdown and workload was similar to that for manual let-downs, but shared approaches to 500 feet increased the mean rr interval around touchdown over let-downs of a wide range of difficulty. The appearance of finger tremor was not affected directly by the modified workload approaches. It is concluded that flight deck workload patterns during the initial part of the approach influence the neurological state of the pilot around touchdown. The operational significance of these studies is discussed.

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NICHOLSON, A.N., WRIGHT, CATHERINE M. and FERRES, HELEN M. Impaired performance on delayed matching in monkeys by heptabarbitalone, pentobarbitalone, sodium and quinalbarbitalone. *Neuropharmacology* 12, 311-317, 1973.

The effect of three barbiturates, heptabarbitalone (20 and 30 mg/kg), pentobarbitalone sodium (10 and 15 mg/kg) and quinalbarbitalone sodium (10 and 15 mg/kg) have been studied in monkeys on a delayed matching task. No differential effects could be shown between the three drugs, nor could the effect of the drugs be related to the delay between stimuli. Both doses of each drug produced very highly significant increases in total response time two hours after administration, but only the higher dose of each barbiturate had an effect at the six-hour interval. Changes in accuracy of matching were not observed after the lower dose of each drug, but at the higher doses there was a reduction in accuracy of matching significant at the 5% level. It was considered that barbiturates have a depressive effect on motor responsiveness, but that the decreased performance in accuracy of matching was not due to the impaired motor activity. The present studies do not provide any evidence of an effect of barbiturates on short term memory.

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ROLFE, J.M. Proceedings of a symposium on 'The measurement of heart rate variability'. *Ergonomics*, 1973, 16, 1-104.

In October 1971, the Ergonomic Research Society sponsored a meeting on the subject 'Heart rate variability and the measurement of mental load' at the Medical Research Council's National Institute for Medical Research, Holly Hill, London. In an introductory paper, Dr Rolfe remarked that it

would be widely acknowledged by those who have measured heart rate variability that an anomaly frequently presents itself viz., that while a recorded trace of heart rate often shows clearly the suppression of variability in the work condition, it is difficult to quantify the change in cardiac response and relate it to the task. The study of heart rate variability is at the stage where the problem is no longer one of getting effective electrodes and portable cardiac apparatus; rather it is in the development of techniques to process and analyse the data. Ten papers were presented at this symposium.

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CLIFFORD, J.M. and COOKSON, J.H. Use of hypnotics by aircrew - Considerations of metabolism and excretion. AGARD CP 108, 1972.

The metabolism of secobarbitone, heptabarbitalone and the non-barbiturate hypnotic, methaqualone, have been studied in man, using gas liquid chromatography techniques. A polarographic method for measuring plasma levels of nitrazepam has also been investigated. The conclusions are too lengthy to quote.

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ALLNUTT, M.F. and O'CONNOR, P.J. Comparison of the encephalographic behavioural and subjective correlates of natural and drug-induced sleep at atypical hours. Aerospace Medicine, 42, 1006-1010, 1971.

Eight trainee pilots retired to sleep under laboratory conditions from 2000 hours to 0300 when they were woken to spend 8 hours, with refreshment breaks intervening, performing 2 behavioural tests (calculation and vigilance). This regime was repeated on alternate nights in a 4 x 2 design. The 4 experimental conditions under which they slept were no drug, placebo, mogadon (5 mgs) and seconal (100 mgs). Each subject spent 2 nights under each condition, and during every alternate 24-hour period they were off-duty and free to sleep as they pleased. Continuous EEG recordings were made on each 'experimental' night and subjective ratings of mood and quality of sleep were used to complement the behavioural measures. Under both the drug conditions there were changes in the EEG together with a slight decrement in vigilance performance in the latter (1100 - 1500 hours) runs of the day, and an improvement in the rated quality of sleep.

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NICHOLSON, A.N., FREELAND, S.A. and BRIERLEY, J.B. A behavioural and neuropathological study of the sequelae of profound hypoxia. *Brain Research* 22 (1970) 327-345.

Eighteen monkeys (*Macaca mulatta*), trained on tasks of visual discrimination and spatial alternation, were exposed in air to a steady ambient pressure of 160 mm Hg (equivalent to an altitude of 37,500 feet with a calculated inspired oxygen tension of 24 mm Hg). In seven animals there was neuropathological evidence of brain damage, and examination revealed two patterns of cellular loss. Damage was either predominantly cortical, centred on the boundary zones between the cerebral arteries, or it was predominantly sub-cortical (i.e. in the basal ganglia). In both patterns ischaemic necrosis was found in the hippocampus and cerebellum. Disturbance of visual discrimination and spatial alternation behaviour were observed only in animals with brain damage and were consistent with previous studies on the sequelae of restricted surgical lesions. There was no evidence of behavioural disturbances in animals without brain damage.

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#### STRESS AND PERFORMANCE

BARNES, C.R. and RANCE, B.H. Head movement induced by angular oscillation of the body in the pitch and roll axis. *Aviation, Space and Environmental Medicine*, 1975, 46, 987-993.

The transmission of angular acceleration to the head of the human subject has been investigated during sinusoidal angular oscillation of the body in either pitch or roll about an axis through the upper lumbar vertebrae. The results indicated that angular acceleration of the skull was induced in all three axes of the head by both pitch and by roll motion. At frequencies below 102 Hz the head moved with the body, but in the frequency range 2-8 Hz the amplitude of head acceleration was augmented, indicating that oscillation about a centre of rotation low in the body may induce angular movement in this frequency range, because of the linear component of acceleration delivered at the cervical vertebrae. At the higher frequencies, the acceleration at the head was attenuated with an associated increase in phase lag, probably due to the absorption of input acceleration by the upper torso.

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RANCE, B.H. and CHAPPELOW, J.W. Aircrew assessment of the vibration environment in helicopters. AGARD CP 145, B1, 1-7, 1975.

A survey of military helicopter crews was carried out to determine the scope and nature of problems due to vibration. Three hundred questionnaires were completed. The chief consequences of vibration were discomfort and difficulty in reading displays. The occurrence of these effects was associated with significant increases in reported fatigue. The major effects were mainly confined to the larger aircraft. Most of the reports from Royal Navy helicopters were associated with hovering or transition to or from hover; turbulence was found to increase the number of reports of vibration effects. Loading of the aircraft was not found to cause any increase in the number of reports.

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READER, D.C. The effects of high acceleration of the head upon psychomotor performance, Ph.D. Thesis, University of London, 1975.

Concussion resulting from head acceleration could explain the poor survival rates in some types of aircraft accidents. Experiments have been conducted on a decelerator using a tracking task to test the hypothesis that high head accelerations could affect psychomotor performance. Eight subjects were exposed to impact accelerations of 0 (sham), 5, 10 and 12 g facing forward. Measurements were made of the linear and angular accelerations experienced at the head and the neck and high speed cine photography was used to determine the angular displacement and velocity of the head. Conditions were varied by the use of a restraint plate which reduced the linear acceleration and the angular displacement and velocity, but increased the angular acceleration to the head. A step tracking task was used to examine psychomotor performance. EEGs were recorded to determine whether a correlation existed between the psychomotor performance, head acceleration and EEG activity. As expected, both the linear and angular accelerations at the head were increased at the higher level of impact acceleration. At 5 g there were no significant differences in psychomotor performance when compared with controls, but at 10 g and especially at 12 g significant differences were found. The EEG activity did not vary significantly and no concussive effects were observed in any subject. It was concluded that head acceleration adversely affects psychomotor performance; that higher levels of head acceleration increase the decrement in performance; but that neither linear nor angular acceleration have significantly more effect than the other. These results suggest that impairment of psychomotor performance severe enough to jeopardise survival could be produced by high accelerations of the head.

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CORKINDALE, K.G.G. A flight simulator study of missile control performance as a function of concurrent workload. AGARD CP 146, A5, 1-6, 1974.

Eight pilots took part in a part-task simulation of the delivery of a stand-off air-to-air surface guided missile. The attack phase of a sortie was simulated. This phase lasted some 3 minutes and included a low level run to the weapon release area, weapon release, target detection on the TV simulator display and aiming of the missile at the target. Four levels of workload were studied. These were:

- a. Missile control tasks only.
- b. Manual control of the simulator.
- c. Missile control tasks plus manual control of the simulator.
- d. Missile control tasks plus auto-pilot monitoring.

The results showed that:

- a. Performance at the missile control tasks was degraded by increases in concurrent workload.
- b. Manual flight control and auto-pilot monitoring were adversely affected by concurrent missile control tasks.

A small group of non-pilots was put through the same experimental programme. A similar pattern of results to those of the pilot group was obtained but the absolute levels of performance were predictably different. Eye movement data and subjective data allow the deterioration in two-task performance to be explained. The results of this study confirm laboratory secondary task experiments in that a deterioration in primary task performance is associated with the occurrence of a secondary task, despite instructions given to the subjects to maintain the highest level of performance possible on the primary task.

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HOPKIN, V.D. The changing pattern of stress. The Controller, 13, 14-20, 1974

The pattern of stress on the air traffic controller is changing mainly for two reasons:

- a. ever-increasing traffic demands imply that future systems must be able to handle more traffic than current ones can and
- b. in response to these demands for greater system capacity, air traffic control systems are becoming more automated.

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LINDSAY, S.J.E. and EVANS, R.L. A semantic analysis of workload. RAF IAM Scientific Memorandum No 118, 1974. (A)

Three flights, each one presenting either a physical, mental or perceptual workload, were undertaken by six professional pilots in a flight simulator (with HS 125 characteristics). Three different types of questionnaire concerning the flights were designed to measure the prominence of a number of flying activities, the magnitudes of workload and the workload of four selected activities. The object was to establish whether the flights could be discriminated from one another by the questionnaires completed by the subjects after each flight. This was accomplished successfully as shown by multi-variate analysis. The advantages of such statistical techniques are discussed.

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ROLFE, J.M. and COOKE, ISABEL. The effect of variation in information load on physiological response. RAF IAM Scientific Memorandum No 113, 1974. (A)

This paper summarises the results of an experiment conducted to investigate the effect of changes of information load on time estimation, heart rate and respiratory rate. The results obtained showed changes in all three measures, suggesting that they were sensitive to variations in mental load.

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MILLS, N.H. and NICHOLSON, A.N. Long range air-to-air refuelling: A study of duty and sleep patterns. AGARD CP 146, A14, 1-9, 1974.

The authors have explored the relationship between workload and sleep patterns during a long range air-to-air refuelling exercise and they have shown that, in practice, disturbances of sleep pattern could be predicted from a study of anticipated individual workload. Disturbances may affect adversely the wellbeing and operational effectiveness of aircrew and contribute to fatigue which is likely to be, in any case, a potential factor in this sort of exercise. It is considered, therefore, that careful attention to workload is necessary to ensure that aircrew are not unnecessarily fatigued and that particular attention should be paid to the relationship between cumulative workload and the duration of the individual's schedule. Studies on long range transport aircrew have shown that unusual patterns of work and rest have an effect on the ability of aircrew to obtain satisfactory sleep and it is suggested that the relationship between cumulative workload and duration of schedules for long range transport aircrew, which is known to be just compatible with an acceptable sleep pattern, could be used initially as a model for both tanker crews and fighter pilots. It is appreciated that the workload demanded of Lightning pilots differs greatly from that of long-range transport aircrew, but it can hardly be expected that operational effectiveness can be maintained if workload in excess of what would be tolerated for transport aircrew is demanded. Studies could be carried out on aircrew involved in particular exercises to determine the nature and significance of unusual duty patterns. Such studies could assist in the planning of operations and may help commanders to predict the overall effectiveness of their crews at any time during a complex operation.

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ALLNUTT, M.F. and ALLAN, J.R. The effects of core temperature elevation and thermal sensation on performance. Ergonomics, 1973, 16, 189-196.

A liquid-conditioned suit was used to obtain a state of raised body temperature in conjunction with skin temperatures compatible with sensations of thermal comfort. This condition produced a similar increase in speed of performance on a high level reasoning test which has been found in previous experiments, but no decrement in score. Head cooling was included as a separate variable but appeared to have no additional effects on the speed or level of performance. It is suggested that deep body temperature may determine the speed, and comfort the level, of performance and that the temperature of differentially heating body core and skin should prove a useful tool for further research.

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KRZANOWSKI, W.J. and NICHOLSON, A.N. Analysis of pilot assessment of workload. *Aerospace Med* 43(9): 993-997, 1972.

About 200 let-downs within a four year period were studied to determine the technique used by the pilot to evaluate overall workload from the various factors of the let-down, and to assess the consistency of his technique. This study suggests that assessments of workload by aircrew under difficult circumstances should be based on individual factors of workload rather than overall impressions of total difficulty, and that predicted workload using a suitable model based on the individual factors of workload may prove valuable for let-downs of limited difficulty. Further, the continuous-line technique for subjective assessments may give an unwarranted impression of accuracy, and the question arises whether a box technique would be more appropriate. This may indicate a greater significance of the movements of the assessment and reduce the variance of assessment in high workload situations.

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GREEN, R.G. Some Observations of Crew Fatigue State during a Hovercraft Exercise. RAF IAM Scientific Memorandum No 100, 1972. (A)

A representative of the Institute of Aviation Medicine accompanied two SRN6 hovercraft on a four day field exercise. A considerable amount of data was gathered by subjective assessment, largely of crew fatigue state and sortie difficulty. The way in which crew fatigue and other subjective factors (e.g. headache, nausea) increase over the duration of the exercise is demonstrated.

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ROLFE, J.M. Whither Workload? *Applied Ergonomics* 1973, 4, 1.

The author examines the implications of some recent research in relation to the study of workload. It is argued that workload is a combination of the demands of the tasks and the capabilities of the operator. The idea that workload must be kept low is questioned in the light of studies relating to job satisfaction.

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FLIGHT SIMULATION

ROLFE, J.M. Keeping Up on the Ground. Aeronautical Journal, July 1977

The paper attempts a critical appraisal of flight simulators as training devices. After a brief historical review consideration is given to the competing requirements of achieving fidelity of simulation and obtaining cost-effective training.

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GUNDRY, A.J. The Role of Motion in Flight Simulator Training. An Alternative Interpretation of some Recent Evidence. RAF IAM Scientific Memorandum No 123, 1975. (A)

Roscoe (1974) and Hopkins (1974) have interpreted the results of an experiment by Koonce (1974) as showing that the presence or absence of motion during simulator training makes no difference to the transfer of training observed, thereby supporting the case that motion systems are not necessary in flight simulators used for training. This report shows that the design of Koonce's experiment does not allow this conclusion to be drawn, since there is no evidence that training occurred.

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EVANS, R.L., HUNTER, S. and ROLFE, J.M. A Bibliography of Human Factors Research using Flight Simulators. RAF IAM Scientific Memorandum No 119, 1974. (A)

The bibliography contains 315 references dealing with human factors research using flight simulators. Classified material, in-flight and space simulation have not been included. The period covered is 1940 to 1973. Subject and author indices are provided.

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ROLFE, J.M., CHAPPELOW, J.W., EVANS, R.L., and LINDSAY, S.J.E. Evaluating measures of workload using a flight simulator. AGARD CP 146, A4, 1-13, 1974.

Any attempt to measure workload must be based on a satisfactory definition of the nature of the workload that is being investigated. Workload can be considered as having task oriented and subject oriented elements. A variety of measures can be applied to the assessment of either or both of these elements. Moreover, the experimental evidence available suggests that if a comprehensive analysis of workload is to be achieved, a range of

measures must be employed. This paper describes an experiment in which an instrument trainer with HS 125 (twin-jet) characteristics was used to evaluate questionnaire, performance and activity analysis measures of pilot workload. Attempts were made to distinguish between the physical, perceptual and mental components of workload. For this purpose three flight plans were devised of about equal duration, differing markedly with respect to the three above components. Six professional pilots flew each flight plan and, after landing, completed questionnaires to assess the workload levels and the task content. During the flights, video recordings were made of the pilot's manual and communication activity. Performance during ILS approaches immediately before and after the experimental flight plans was also measured. From these measures it was possible to obtain significantly different results relating to the different flight plans. These results were capable of distinguishing between the three components of workload in the flights.

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CHAPPELOW, J.W. and LAKIN, T. Pilot opinion on simulation. Proceedings of the RAeS. Second Flight Simulation Symposium, London, England May 1973.

This report describes two pilot opinion surveys regarding simulation. One study was conducted by BALPA and involved 400 airline pilots and the other undertaken by the RAF IAM implicated 500 Royal Air Force instructors and aircrew. The authors concluded that the most important motion simulations are in pitch, roll, yaw, turbulence and vibration. All the simulators visited had, at least, pitch and roll motion systems. The simulation of these motions was categorised as 'quite realistic'. As regards the outside world view, a visual system is most needed during take off, approach and landing, and in low-level missions. Most needs are satisfied by a device presenting only an approach and runway view. Functions which evoked considerable criticism were poor simulation of the aircraft's handling characteristics, poor presentation of control lever loadings and 'feel'. Considering the flight deck environment, cockpit lighting was considered to be adequately represented. Background R/T was a desirable facility, though not generally available. Engine noise was not adequately represented and aerodynamic noise was either poorly represented or absent. Regarding transfer, more than 70% of respondents thought that the simulator's success as a training device was satisfactory while 58% thought that the simulator checks for predicting performance in the aircraft were very good or adequate. 90% of the aircrew thought that the instructor needed flying practice on the aircraft being simulated and 89% thought that he needed teacher training. More free time should be available for students to practice weak points. There was general approval for the way the simulator was being used for management, procedural and emergency practice, refresher training, competency checks and IR renewals. Digital programmed simulators (e.g. B 707, BAC 111 and VC 10) were less popular than the analogue-controlled type (e.g. Comet, Trident, Vanguard, Viscount and Britannia). This may be due to the greater degree of serviceability of the latter.

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ROLFE, J.M. Flight simulator research at the Royal Air Force Institute of Aviation Medicine. Applied Ergonomics 1973, 4, 2.

The author describes the behavioural research programme using flight simulators of the RAF IAM. Studies have been undertaken using the Institute's own facilities and a range of civilian and military devices. Four main fields are described:

- a. Research to improve the quality of simulation e.g. the assessment of motion systems.
- b. Research to develop and assess cockpit equipment e.g. the evaluation of altimeters and head-up displays.
- c. Basic research into the nature of the skills employed when controlling a simulated aircraft e.g. studies of individual differences in control strategies.
- d. Opinion surveys to determine the attitudes of aircrew and instructors towards flight simulators and simulator training programmes.

Specific examples are provided to demonstrate the application of simulators to behavioural research - for example, an assessment of a simulator as a problem solving situation for student test pilots. Consideration is also given to the problems of measuring performance in complex task instructions. Reference is made to use of subjective and objective measures of performance in conjunction with psycho-physiological measures. The author concludes with a description of the Institute's HS 125 instrument trainer, shortly to become operational.

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#### HUMAN FACTORS AND EQUIPMENT DESIGN

ROLFE, J.M. Human Factors and Flight Deck Design. Published in Aircraft Engineering November 1976.

This paper examines the criteria against which flight deck workspace should be designed, and assesses the relative value of physical, physiological and psychological requirements in relation to efficient design of flight-deck dimensions, environment and contents. A cockpit assessment checklist is provided.

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ROLFE, J.M. The Measurement of Human Response in Man-Vehicle Control Situations, in 'Monitoring Behaviour and Supervisory Control', Plenum Press. 1976.

The paper examines some of the techniques that can be used to study the response of the human operator in vehicle control situations. An attempt is made to identify some of the specific reasons why such measures are necessary and the relative value of the different measures in relation to various research objectives.

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LAYCOCK, J. Helmet-Mounted Sights and Displays. AGARD Report No 642, 1975.

The possible applications of helmet-mounted sights and displays are considered. Software and hardware problems are discussed as are psychological aspects. The author describes how binocular rivalry may be used to increase the rate at which a pilot can absorb and process information.

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READER, D.C. Current and Future Escape Systems. AGARD Report No 642, 1975.

Almost all combat fixed-wing aircraft in NATO countries are equipped with ejection seats and considerable effort is spent on improving the performance of these seats. The author describes areas where current escape systems are deficient and some ways in which future systems seek to overcome these deficiencies.

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READER, D.C. Warning systems in aircraft. Considerations for Military Operations. AGARD Report No 642, 1975.

The author describes and assesses the different types of warning systems currently used in military aircraft and he makes some suggestions for future designs. He concludes that the concept of a visual display combined in a 'standard warning systems' layout is probably the most efficient method of presenting essential emergency information to the crew. This system is sited outside the blind flying panel but within the 30° cone of vision of the pilot. Attention getters and audio warnings should be used to assist the presentation. Apart from a few specific cases, audio warnings do not have distinct advantages over visual displays. In some aircraft tactile warnings can be used to good effect and extension of tactile displays to other situations should be examined.

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ROLFE, J.M. Advances in Military Cockpit Displays. AGARD Report No 642, 1975.

The author examines the background against which recent advances in display technology have taken place in military cockpits. Emphasis has been placed on providing an adequate assessment of the information needed by the aircrew to perform their task and on the presentation of this information. The necessity for a multi-function, multi-senso information processing and display system is evident. At the moment, the most widely used form of display with the required flexibility is the CRT. Other display techniques are being developed. The most promising of these involves the use of solid state techniques. However, it is likely that these will supplement the CRT rather than supplant it. This means that devices such as liquid crystals and light emitting diodes (LED's) will be applied to the display of alphanumeric graphic displays which will displace electro-mechanical ones. The brightness of LED's has been increased to such an extent that they can successfully be used in both head-up and head-down displays. Their addressable nature and the high resolution achievable by those displays make it possible to construct complex alphanumeric and graphic displays which are often much more effective than the electro-mechanical ones they replace.

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TAYLOR, R.M. The psychologist in aircraft accident investigation. Paper to Conference of Western European Association of Aviation Psychology Stockholm. September 1975. (A)

In both military and civil flying operations a large proportion of all accidents occur in perfectly serviceable aircraft when the only failure in the system was the human element. There is, therefore, an obvious case for a psychologist to attempt to understand the nature of the errors made in the hope that such an understanding may lead to avoidance of such errors in the future. There are two courses open to the psychologist:

- a. To identify those aircrew who have been involved in accidents, examine all the flying and personal records available on these people and to see whether any factor or factors distinguish them from the rest of the aircrew population.
- b. To examine the accident situation, the ergonomics of the controls and displays involved, the nature of the prevailing physical environment, and the recent domestic and professional history of the aircrew.

Although these courses are being pursued in the RAF, the author is exclusively

concerned with the second approach. The method used is for the psychologist to attend a Board of Inquiry and listen to formal evidence, but also, and more importantly, to have discussions with the aircrew involved and other pertinent individuals. The paper describes some of the results of this work, as well as some of the problems encountered by the psychologist. It is hoped that, in addition to the recommendations which are made after each accident, a body of first hand experience will be built up which will prove valuable both in the analysis of future accidents and in the formulation of general conclusions about the nature of human error accidents.

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BROWN, L.E. and EDENBOROUGH, R.A. Evaluation of MRSL/KGM video-aids TV character format ATCEU Report No 410, 1974. (A)

The objectives were (a) to determine the acceptability of the display characters produced by the 7 x 9 dot-matrix generator proposed by Marconi Radar Services Limited for use in the LATCC touchwire displays and (b) to propose alternative shapes for any characters that are not acceptable. Although it would be possible to use the system operationally, subjective opinion indicates that there would be improvements if the imbalance of brightness between the strokes making up the characters was corrected to provide horizontal, vertical and diagonal strokes of equal, brightness. If it is impractical effectively to balance the brightness of the horizontal, vertical and diagonal strokes of the characters and the diagonal stroke remains much less bright than the other two, it may be necessary to increase the thickness of the diagonal strokes in certain characters. The authors also recommended that, to lessen confusion, consideration should be given to changing seven character shapes.

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READER, D.C. Human Factors aspects of In-Flight Escape from Helicopters. AGARD CP 134, 1973.

A comparison of the accident statistics from some helicopter users of the NATO forces has shown that helicopter operations impose a greater risk to their crews than do fixed-wing aircraft. Cost analyses have shown that the crew cost more to replace than their aircraft. Thus, it is considered that a strong case exists for in-flight escape from helicopters. Some human factors to be considered when designing such a system are described. The paper discusses human tolerance to acceleration, egress path requirements, centre of gravity data, restraint and parachute requirements, blast, noise, fragmentation and toxic hazards, and vision and egress time requirements.

ROLFE, J.M. and CHAPPELOW, J.W. The Application of Aircrew Opinions on Cockpit Tasks and Equipment to Flight Safety Research AGARD CP 132, 1973.

The investigations described provide information about aircrew attitudes towards their equipment and tasks. The techniques do have their limitations. They identify problems but offer little in the way of any solutions. Nevertheless this information if gathered early enough can accelerate agreement on the need to initiate modifications and thus prevent accidents.

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ERGONOMICS OF AIR TRAFFIC CONTROL SYSTEMS

WEBBER, D.S.R., JOHNSON, A. and HOPKIN, V.D. Initial implementation of RDPS, 9020D system. ATCEU Report No 435, 1976.

The object was to investigate the accommodation and ergonomic aspects of the provision of controller-operated input devices on horizontal suites with shared displays, and the controller workload arising from the input task. The evaluation relied extensively on subjective responses to reveal ergonomic problems associated with the positioning of input devices on the suites. Alternative suite layouts were studied and photographs of the controllers' position were taken. The method and comments demonstrated the main ergonomic problems, some of which were intrinsic to horizontal suites and could be alleviated but not resolved. Postural and visual difficulties were demonstrated, as were the effects of liaison and shared displays.

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EDENBOROUGH, R.A. and HOPKIN, V.D. A note on Sizes, Colours and Viewing Distances for Operations Room Visual Displays. RAF IAM Scientific Memorandum No 125, 1975.

(A)

Guidelines for sizes, colours and viewing distances for alphanumeric characters on general displays in operations rooms are considered. Numerous factors affecting legibility and visual comfort render a simple rule linking character size with viewing distance involved. Under normal conditions letter heights subtending between a and b milli-radians should be acceptable. In certain displays these figures may have to be modified. Professional human factors advice should be obtained before this is done.

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GEORGE, P.H., JOHNSON, A.E. and HOPKIN, V.D. Automatic Conflict Detection and Resolution on a Controlled Airspace En-route Sector. ATCEU Report No 434, 1975.

It was shown that, using computer techniques, it is feasible to have valid radar conflict resolution in a simple route system with prediction times

of the order of 15 minutes. Controllers are prepared to accept such computer assistance provided that they retain the freedom to exercise their professional judgement, if required. The results of this man-machine relationship were judged to be most encouraging and topics for further research are outlined.

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HOPKIN, V.D. The controller versus automation. AGARDograph No 209, Vol. 1, 43-60, 1975.

There is no fundamental conflict between the controller and automation, but merely different views on the desirable form and extent of automation in air traffic control. Man as a system component is compared with the machine in competitive or complementary terms, but complete comparisons are not possible because of the machine concepts which have to be used. The timing of the introduction of automated aids often depends more on technological development than on human needs. Automation often brings extra tasks as well as benefits and most functions cannot be automated entirely. When automation is extended to problem solving and decision making it affects job satisfaction, the exercise of skill, and responsibility. Some aids may be of least use when they are most needed, e.g. in high density traffic. Computer assistance alters the nature of tasks and new information is useless unless it is presented in an intelligible and acceptable form.

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HOPKIN, V.D. The provision and use of information on air traffic control displays. AGARD CP 188, 13, 1-12, 1975.

Several kinds of mismatch can occur at the man-machine interface in air traffic control systems. One, often overlooked, concerns the provision of certain essential information in a form which is usable. The traditional reliance on man's strengths of adaptability and flexibility to match man and machine in the system is thwarted if he cannot use the information presented to him. Changes from qualitative to quantitative information, incomplete automation, and the apparent retention of decision-making roles which, in fact, have been greatly modified, all pose problems of ensuring that the displayed information has been adapted and can still be used. Because such changes alter the role of human memory and attention, these must be aided and supplemented in new ways. As regards the provision of information, technological advances do not necessarily bring ergonomic benefits. Novel display techniques may embody obscure human factors problems which emerge only at a late stage in display development. Evaluation of innovations may inadvertently be biased by the emphasis of known merits and the exclusion of hidden inadequacies.

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HOPKIN, V.D. The psychologist's view. AGARDograph No 209, Vol. 1, 75-102, 1975.

Psychology is the scientific study of human behaviour and experience. The applied psychologist uses his professional knowledge, derived from experimental and theoretical findings from his own studies and those of his

colleagues, to resolve human factors problems. The role of human factors in air traffic control depends on the stage at which it is first applied. The psychologist's contribution is most effective early in the system evolution, when he can forestall problems as well as cure them. In studying air traffic control problems, he uses systems and job analyses which he can both conduct and interpret. Aspects of the man-machine interface such as displays, controls and communications are optimised in relation to the efficiency and wellbeing of the operators. The psychologist's knowledge of differences between men is applied to recruitment, selection, training and screening. The effects of ageing and of experience are predicted from known progressive changes within each individual. Knowledge of the capabilities and tolerances of the man is applied to problems of work-rest cycles, stress and workload. To solve these problems the psychologist uses orthodox methods and specially devised techniques for assessing and measuring the man at work.

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CROMPTON, J.W., ABLETT, R. and HOPKIN, V.D. Test of Mediator Suite without 9020D Input Devices. ATCEU Report No 418, 1974. (A)

The aim was to establish, by subjective and analytical methods the traffic capacity of a Sector Team (in particular, the Assistant Sector Controller) working on the Clacton Mediator Sector at IATCC without the services of computer input devices. It was found that, provided the distribution of traffic remains as forecast in CP/168/010 of July 1973 the team, equipped with 9020D Flight Strip printers but without sector update equipment, may be expected to maintain efficiency while the average peak hourly flow rate through the sector rises to 68 aircraft per hour.

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HOPKIN, V.D. Designing Controllers' Tasks in Relation to Human Capabilities. RAF IAM Scientific Memorandum No 114, 1974. (A)

To cope with an ever increasing demand, future ATC systems must provide a service for substantially more traffic than current ones. At the moment, traffic is often congested in terminal areas, on the approaches, and departures from runways and in the airways between main cities. Traditional procedural methods of control have relied on information typed on flight strips and amended by hand from verbal messages passed between controllers and pilots, but this system is gradually being replaced by computer techniques. Radar, area navigation and data link are innovations which will lighten the controllers' workload but will add to the complexity of the job. Automation can help to match task designs with human capabilities if it provides aids which are most useful in high density traffic and which may be used or discarded at the option of the controller.

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HOPKIN, V.D. Some Effects of SST and General Aviation Traffic on Controller Capacity. RAF IAM Scientific Memorandum No 121, 1974. (A)

Both SST operations and General Aviation traffic have implications for controller capacity, which are expressed preferably in terms of the amount of work for the controller rather than in terms of the traffic handling capacity of the system. It can be deduced that controller capacity is affected by increased work derived from the greater unfamiliarity and less predictable behaviour of SST and General Aviation traffic. In the case of SST aircraft much of this unfamiliarity will dissipate with greater experience, and some of the extra workload will therefore be transient. Ultimately, an experienced controller will learn and follow appropriate standard strategies. In the case of General Aviation traffic, patterns of traffic behaviour will remain less predictable and less possible to learn, so that some additional workload will persist. General Aviation aircraft are more variable than commercial flights in the competence of pilots, in their familiarity with ATC procedures and instructions, in the navigational aids in the aircraft and in the controller's knowledge of the performance of each aircraft type. As a result, General Aviation traffic will continue to demand proportionately more attention from the controller.

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MIRFIELD, W.E., and EDENBOROUGH, R.A. Evaluation of 22 inch and 16 inch Vertical Radar Displays in the Mediator Environment. ATCEU Report No 411, 1974. (A)

The purpose of this simulation was:

- a. To assess the optimum viewing distance for a 22 inch vertical radar display and to study the ergonomic aspects.
- b. To compare the relative merits of 22 inch and 16 inch vertical radar displays for Upper Airspace (UAS) General Air Traffic sector of a large area.
- c. To evaluate and compare the following arrangements of vertical radar displays for a TMA Sector:
  - (1) Two 16 inch displays used individually by the arrival and departure controllers.
  - (2) A 16 inch display shared by the arrival and departure controllers.
  - (3) A 22 inch display shared by the arrival and departure controllers.

The 22 inch unit was preferred for the UAS task but some of the ergonomic aspects need further consideration. No firm choice was made between the three TMA display configurations examined. There was no preference in terms of operational efficiency but there were conflicting views with regard to liaison and comfort.

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CROMPTON, J.W., JOHNSON, A.E. and HOPKIN, V.D. Radar Separation Minima for SST Aircraft. ATCEU Report No 395, 1973. (A)

A simulation was carried out a. to examine the performance of air traffic controllers when separating supersonic and transonic aircraft by means of radar and b. to evaluate a range of separation standards (15, 20, 25 and 35 mm) for use by controllers in the tactical control of SST aircraft. It was found that:

- a. The ability of the radar controller to detect conflicts between SST aircraft were sufficient to ensure safety.
- b. Unaided controller judgement results in some aircraft already separated being vectored unnecessarily, but the penalties incurred by those aircraft on diversions from planned track were smaller than those aircraft necessarily vectored.
- c. When a separation standard smaller than 36 mm was supplied, the mean separation achieved was greater than the standard.
- d. The percentage of infringements which occurred when a 15 mm standard was in use for the separation of accelerating aircraft was found to be greater than those occurring in all other cases. The authors have made useful suggestions about control procedures and some specifications for display equipment. The paper is excellently illustrated both with photographs and graphs.

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CROMPTON, J.W., WATTS, F.C. and EDENBOROUGH, R.A. Mediator Stage 1A: Controller Airspace Sectors: Irish Sea - Howarden Sectors LATCC. ATCEU Report No 402, 1973. (A)

This simulation investigated the responsibilities of the Irish Sea and Howarden en-route sectors at LATCC in the Mediator 1A organisation, and how these sectors would relate to each other, to the Isle of Man sector at Manchester sub-centre, and to the other sectors and units about them.

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FEARN, C.W., WATTS, F.C. and HOPKIN, V.D. Mediator Stage 1A:  
Controlled Airspace Sectors: Lichfield - Pole Hill - Daventry. ATCEU  
Report No 397, 1973. (A)

The structure of the Daventry, Lichfield and Pole Hill sectors to be operated from LATCC (West Drayton) was evaluated in three phases. After each of the first two phases, modifications to airspace and procedures were made and tested until, on reaching phase 3, an airspace structure with procedures approaching the optimum was reached and tested. The simulation proved that the best way to establish co-ordination between the Pole Hill, Manchester TMA and Daventry sectors was to establish standard agreed levels in order to reduce, and thereby contain, the co-ordination required by the Chief Sector Controllers.

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GEORGE, P.H., JOHNSON, A.E. and HOPKIN, V.D. Radar Monitoring of Parallel Tracks. ATCEU Report No 406, 1973. (A)

The evaluation demonstrated that the use of an auto-alert warning device similar to the one used in this simulation should enable opposite direction parallel tracks to be placed closer together. It was also found that use of this device had no significant effect on controller capacity.

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HOPKIN, V.D. Expedition and Human Factors in Air Traffic Control. RAF IAM Scientific Memorandum No 107, 1973. (A)

Various methods for expediting traffic are described, together with their consequences for the air traffic controller. Expedition depends partly on the quality of the navigational data available. As these data become more accurate, reliable and frequently up-dated, the closer proximity of aircraft shortens the time available for detecting and resolving potentially hazardous situations. New information formats to meet these changed circumstances are suggested. The omission of human factors requirements often leads to achieved expedition falling short of its potential.

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HOPKIN, V.D. Industrial Spin-off from Military Ergonomics - Civil Air Traffic Control. RAF IAM Scientific Memorandum No 104, 1973. (A)

A considerable amount of the information contained in standard ergonomics textbooks and handbooks has been gathered from original military research, much of which was conducted on ground-based equipment, e.g. air defence complexes or guided weapons systems. The benefits which Civil Air Traffic Control have derived from related military studies are outlined and evaluated.

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EDENBOROUGH, R.A., HOPKINS, V.D., CASTLE, G. and WAGSTAFFE, A.E. A Note on the Design of Sector Suites and Consoles. RAF IAM Scientific Memorandum No 101, 1972. (A)

Ergonomic and medical problems in the present LATCC sector suites and factors relating to vertical displays are discussed. Procedures for design, planning and evaluation of console positions are recommended. Large horizontal radar displays are unsatisfactory in terms of viewing and seating, and because they constrain other facilities. These problems produce difficulties in correcting vision, lead to neck and backache and increase overall stress. Vertical displays permit more comfortable postures. Smaller displays appear preferable to larger. Recommended stages in console development are: job analysis, profile specification, consideration of relative location of displays and controls, verification of reach and viewing distances, consideration of the physical environment and final evaluation.

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GEORGE, P.H., WATTS, F.C. and HOPKIN, V.D. Mediator Stage 1A - Controlled Airspace Sectors. Irish Sea Area Simulation. ATCEU Report No 376, 1972. (A)

The problems of controlling low level traffic in the Irish Sea area would be alleviated if the LATCC/Scottish ATCC FIR boundary were to be moved to the north-west, possibly to 55° north. This would help in the implementation of the recommendation that all low level traffic in the Irish Sea area should be the responsibility of one authority. It is suggested that this authority be the IOM sector (Manchester sub-centre) and that its area of responsibility extend over all CAS and ADRs in the area up to, and including, FL 110. The airspace above this level would be the responsibility of the Irish Sea/Hawarden sector at West Drayton. Consideration should be given to the raising of the upper limit of the Ronaldsway CTR to FL 75 or 80.

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HOPKIN, V.D. Human engineering problems in air traffic control. The Controller, 1972, 11, 9-12.

The contribution which the psychologist can make to the evolution and testing of air traffic control systems is described, together with certain human factors problems associated with control tasks. These tasks are very complex, particularly in terms of their information sources and the procedures leading to the input of data, and there are many variables involved with intricate interactions between them. Answers can be found only by working from first principles and by conducting evaluation trials to confirm the acceptability of recommendations.

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HOPKIN, V.D. Measures of manual workload. In 'Displays and Controls'. Bernotat, R.K. and Gartner, K.P. (Eds) Amsterdam: Swets and Zeitlinger, 175-192, 1972.

Manual workload has traditionally been assessed using time and motion criteria. In an ATC context, it is dependent on the type of control used (e.g. keyboard, joystick, rollball or light pen), on control/display relationships, on characteristics of the display and on the difficulty of the task. Features of the control which influence workload, are its demands for manual dexterity and its sensitivity. Distinctions can usefully be drawn between manual and mental workload, and in attempts to reduce workload it is important to make these distinctions. In experimental work manual workload is mostly measured on a basis of speed and accuracy.

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HOPKIN, V.D. Some neglected psychological problems in man-machine systems. The Controller, 1972, 11, 16-19.

Most psychologists dealing directly with problems arising within man-machine systems, e.g. air defence or air traffic control, are concerned either with the selection and training of operators for those systems or with ensuring that trained operators can reach acceptable operational standards when performing their tasks. The author suggests that because most experimental psychologists working on systems problems have become specialists in one branch of psychology, some practical problems in such systems are attacked in an unduly restricted way and others are neglected altogether, either because the psychologist does not feel equipped to deal with them or because he fails to recognise that they exist.

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MIRFIELD, W.E., JOHNSON, A.E. and HOPKIN, V.D. Computer Assisted Approach Sequencing Feasibility Study: Phase 2. ATCEU Report No 380, 1972. (A)

This simulation is part of a study of a Computer Assisted Approach Sequencing (CAAS) system. The authors examined the air traffic controller/CAAS relationships and compared the CAAS systems in its present stage of development with the manual systems in operation at Heathrow. The touchwire display system linking the controller and the computer received general approval but the sequencing programme was considered too inflexible in its present stage of development. A metering system to regulate the flow of traffic into the CAAS system is needed.

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ORR, N.W. and HOPKIN, V.D. The role of the touch display in Air Traffic Control. The Controller, 1972, 11, 87-89.

Currently, the application of automation to Air Traffic Control is, in large measure, a matter of using computers to drive or print tabular traffic displays. Much of the updating and amending of traffic information has to be done by the controller or his assistant through the computer, so that the effectiveness of this automated system depends upon communications between the controller and the computer. This man/machine interface is generally regarded as one of the weakest links in the controller-aircraft-computer loop. Evidence suggests that the touch display (a means of keying in and displaying updated ATC information) represents a major advance in the field of man/computer communications. Users of the Touch Display are enthusiastic about this additional application of automation to Air Traffic Control, since it makes their job easier and more congenial.

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THAYER, F.E., BROWN, L.I., WATTS, F.C. and HOPKIN, V.D. Radar services for RAF student pilot training. ATCEU Report No 393, 1972. (A)

A simulation was carried out to examine an airspace organisation and an associated ATC organisation planned to provide a radar service for pilot training operations flown from RAF Leeming. It was concluded that the organisation is suitable as a basis for operational trials.

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EDEN, F.R., PASCOE, J.W., EDENBOROUGH, R.A. and MORGAN, A.T. EDD Formats for use by GAT Controllers - Mediator, Post Stage 1. ATCEU Report No 339, 1971. (A)

This report describes trials, held at West Drayton, to assess the value of three types of Electronic Data Display format suggested for use by Upper Airspace, General Air Traffic controllers in Mediator, post Stage 1. The trials determined that the Dynamic format would be of the greatest value to controllers using Electronic Data Displays in conjunction with a Labelled Plan Display. Certain modifications have been recommended for the improvement of the Dynamic display. Problems concerning the size and location of the flight progress board and the workload of the assistant sector controller have been highlighted, and a follow-up simulation recommended.

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GEORGE, P.H., WATTS, F.C. and HOPKIN V.D. Manchester Sub-centre - Isle of Man - Irish Sea Sectors. ATCEU Report No 347, 1971. (A)

This simulation established the feasibility and practicability of the layout for the Manchester sub-centre terminal area sectors referred to in ATCEU Report No 296, and the relationship with the Pole Hill/Irish Sea Sector at West Drayton. An upper limit of FL 110 is recommended for the Manchester terminal area. This level is also considered to be the most suitable division of responsibility for the Barton Holding Area between the Pole Hill/Irish Sea sector (LATCC) and the Manchester sub-centre. The simulation confirms the need for an Initial Contact Frequency.

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HOPKIN, V.D. Conflicting criteria in evaluating air traffic control systems. Ergonomics, 14, 557-564, 1971.

Sources of conflicting criteria in evaluating air traffic control systems include the multiple aims of air traffic control, the numerous performance measures for each task, incompatibility among behavioural, physiological and subjective data, the needs of man in contrast with those of the system, and individual differences. The extent of the conflicts may have been under-estimated in the past because certain relevant measures have been neglected. The solution requires greater awareness and quantification of these measures and of the sources of conflict in evaluation criteria, together with a practical acknowledgement of them in the initial specification of air traffic control systems.

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HOPKIN, V.D. The evaluation of touch displays for air traffic control tasks. IEE Conference Publication No 80, 'Displays', 83-90, 1971.

A touch display exploits the operator's body capacitance so that a finger touch on wire keys attached to the display unbalances an electrical bridge and activates a computer primed with ATC information. Its prospective use would be for updating this information as, for example, in the re-timing of an aircraft schedule or a change in the type of aircraft used, with consequent speed and ceiling changes. The author conducted some comparative work to find if this device is better than conventional equipment in use and he found that:

- a. The touch display is quicker and easier to use as a data entry device, requires no selection procedures for operators, is silent, avoids most search and coding problems, can be adapted for programmed instruction and is preferred by its users.

- b. The touch display is superior in both system and operator-paced tasks, especially when programmes permit the entry of blocks of data with a single touch.
- c. The touch display can provide the operator with appropriate choices and lead him through the correct operating sequences.
- d. The device is equally effective with touch wires within the face of the display or with keys in front fulfilling the same function.
- e. The learning procedures for a touch display are similar to those for a conventional keyboard. A good deal of training in their use can be achieved using photographs, without the display being on line.

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HOPKIN, V.D. and EDENBOROUGH, R.A. Computer-derived alphanumeric information on air traffic control displays. IEE Conference Publication No 80, 'Displays', 109-123, 1971.

Much of the workload of the air traffic controller is related to spoken R/T communications concerning data that could easily be displayed automatically in alphanumeric form on a radar screen. Two examples of such data are the identification and the altitude of aircraft. If this information appeared as a display item, then R/T and hence the workload of the controller would be reduced. The effectiveness of this approach was examined in a series of studies in which the task of an air traffic controller dealing with westbound flights into Heathrow Airport was simulated. In this experiment, a group of input operators simulated the pilots by acknowledging instructions (e.g. identification, changes of heading, altitude and airspeed) using conventional R/T terminology, and by entering instructions into a computer so that the responses and content of the labels on the controller's screen corresponded with actual aircraft behaviour.

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HOPKIN, V.D. and PARSONS, J.F. Computer-generated displays for psychological research. IEE Conference Publication No 80, 331-338, 1971.

The authors describe some psychological work carried out using computer generated displays with joystick, rollball, lightpen, and push-button controls. Among the experiments were an interception task, tracking and steering exercises, following climbing arrows, apparent motion studies, calculation and memory tests, and teaching aid trials. It was found that the use of this

equipment enables a quick turnover both in subjects and programmes and provides flexibility in the generation of displays. The on-line computation facilities save time and effort in routine data handling and in statistical analysis of the results. The certainty of presenting, with a given programme, the same stimuli to all subjects provides tight control and universality. Using this device permits the operator to randomise or balance automatically the order of presentation of items to meet stated statistical requirements. The authors demonstrated that, with the help of CCTV, videotape and film, the displays can be used in a variety of environments, eg. in stressful conditions, with or without the computer on-line.

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LLOYD, M.L. and EDENBOROUGH, R.A. Automatic prevention of label overlap. ATCEU Report No 351, 1971.

The authors describe trials held at West Drayton to investigate three automatic means of preventing label overlap. The trials determined that one of the methods, i.e. alternation, is not suitable. The other methods, Machine Repositioning and Tabular, whether used separately or together, are effective but should be brought into operation manually and not automatically. Certain suggestions have been made regarding modification to the method investigated, and it is recommended that a follow-up project be sponsored.

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THAYER, F.E., GEORGE, P.H., WATTS, F.C. and HOPKIN, V.D. Airways crossing services, ATCEU Report No 358, 1971.

This report describes a simulation carried out to determine the relative merits of three airways crossing organisations for aircraft operating in the U.K. Middle Airspace from 1974 onwards. The authors conclude that an airspace sector organisation offers the safest and most consistent service and contains the greatest scope for flexibility of operation.

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#### ERGONOMICS OF MAP DESIGN

TAYLOR, R.M. A Survey of Operational Requirements for Map Reading at Night, RAF IAM Report No 560, 1977. (A)

Many map specifications restrict colour coding in order to maintain legibility under red cockpit lighting conditions at night. Such maps have

proved unpopular with aircrew compared with their full colour-coded counterparts. 672 aircrew drawn from the three Services and flying in 12 different aircraft types equipped for all-weather, night operations completed a questionnaire on operational requirements for map reading at night. Optional red and white Auxiliary lights were fitted to all the aircraft stations for map reading. 37% considered these Auxiliary lights inadequate and many made frequent use of torches. 21% used red map light under the most critical operational conditions. Chi-squared tests indicated that altitude, phase of flight, age and night-flying experience had no significant effects on map-light colour usage. Aircraft type and the colour of instrument lighting on current and previous aircraft types had a significant effect at the 0.1% level. Jet aircrew and aircrew who had experience of white instrument lighting used white map lighting most frequently. Attitudes to map lighting problems tended to support the colour of lighting used. But generally, problems associated with the use of red lighting (map reading difficulties) were considered more serious than those associated with white lighting (a slightly raised threshold). Map reading techniques and preferences for scale, accuracy, handling, content and coding are identified, and the requirement for special purpose night maps is discussed. Removal of map colour coding restrictions is recommended and methods for improving map lighting fittings are suggested.

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TAYLOR, R.M. Projected Map Display Legibility: An Evaluation of an Experimental 1:250,000 Scale Topographical Map. RAF IAM Report No 545, 1976. (A)

Factors affecting projected map display (PMD) legibility are discussed and a laboratory evaluation is described of an experimental 1:250,000 topographical map designed to meet airborne PMD legibility requirements. Individual point, linear, area and alphanumeric symbols are compared with corresponding symbols from a conventional map of the same area on a symbol identification task under normal (paper map) and degraded projected viewing conditions. The responses of 48 subjects show statistically significant differences between viewing conditions, maps, symbol sets and individual symbols; projected viewing increased response times and gave 155% more errors, the original map gave 33% more errors and more systematic confusions when projected than the experimental map, and there was little improvement for the area symbol set. General design principles are discussed, as well as distinguishing symbol and background coding effects. Specific recommendations are made for map content, colours, contrasts, symbols, line-widths and type of characteristics.

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TAYLOR, R.M. Human Factors in Aircraft Map Displays. RAF IAM Report No 557, 1975. (A)

Three major types of map display are distinguished - direct view roller maps, optically projected maps and electronically generated displays. These have been developed to reduce the navigation workload in low altitudes tactical operations and their advantages include increased map/navigation data storage, reduced head-down time and improved interpretability and anticipation of ground features. The man-machine interface has generated many important design issues. Although most of these have been resolved through practical experience such as the question of whether the map or the aircraft symbol should be the moving component, several problems still exist e.g. map annotation, display legibility and brightness, radar-map matching, and display complexity. As operational requirements change and are extended to include night operations and as multi-sensor combined displays are introduced, map displays will continue to present human factors problems.

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TAYLOR, R.M. Information theory and map evaluation. In International Yearbook of Cartography. Ed. Kirschbourn, G.M. and Meine, K.H. p 165-181, Kirschbourn Verlag, Bonn, 1975.

Analysis of maps as a means of communicating information has led to the development of descriptive cartographic models. The author has derived models using the Information Theory. This theory measures information content in terms of the extent to which it informs, is unexpected and adds to what is already known. When applying the theory to visual displays such as maps, the display is conceived as a series of stimuli corresponding to the map symbols, these being the system inputs. These stimuli elicit a series of responses to outputs, corresponding to the symbol meanings. One information channel, the map user, with limited processing capacity links the stimuli and responses. The Information Theory uses the binary system of measurement to provide an index of the difficulty of identifying input and output elements from the set or ensemble of alternative elements. This has been described as the amount of information or uncertainty. With maps, both the symbols and their associated meanings are sources of measurable information or uncertainty. The two uncertainties are related, but if errors occur in interpreting the symbols the relationship is less than perfect. The author has applied the information theory to the evaluation of various types of maps used in aviation.

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TAYLOR, R.M. Map Displays. AGARD Report No 642, 1975.

The major types of aeronautical map displays are distinguished and their functions are described. The principal design parameters are reviewed with particular reference to user requirements and human factors, and an outline is given of current problems of map annotation, display legibility and brightness, radar-map matching and display complexity.

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TAYLOR, R.M. 'Where am I?' Paper presented to the Annual Meeting of the British Association for the Advancement of Science, University of Surrey, Guildford. August-September, 1975. (A)

The ability to sense and respond to geographic orientation is an important requirement for manned flight. Man has limited orientation mechanisms and relies, not always successfully, upon information displays such as maps for guidance. Recent psychological research into the design and use of maps in aircraft navigation are described. Chapter headings are a. Geographic disorientation b. Map reading c. Moving map displays d. Map design and e. Recent research.

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TAYLOR, R.M. and HOPKIN, V.D. Effects of Density of Cartographic Information on Marking Verbally-described Pinpoints on a Map. RAF IAM Report No 546, 1975. (A)

High information density and excessive clutter are major user criticisms of topographical aeronautical charts. In an effort to acquire some knowledge of these effects, the authors asked aircrew subjects to pinpoint locations on a 1:250,000 scale map from verbal descriptions of topographical information, grid references, or both. Pinpoints were selected according to a quantitative formula of information density. It was found that grid references produced less accuracy and more gross errors than topographical descriptions. Greater density of cartographic information around a pinpoint led to greater accuracy and less time in locating it from topographical descriptions without influencing the plotting of grid references. General methods for improving the quantitative descriptions of cartographic information are suggested.

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TAYLOR, R.M. and HOPKIN, V.D. Ergonomic principles in map design. *Applied Ergonomics* 1975, 6, 196-204.

Ergonomic principles have seldom been applied to the design of maps for use in aviation. Maps are not usually evaluated as displays of information, and the contents of maps often do not match the needs of the user. Most maps are visually so complex that it is not immediately apparent whether standard recommendations for the coding and display of information apply to them. Methods for evaluating maps have to be devised and comparisons made between subjective and objective measures. A series of experiments has considered the content of maps in relation to the needs of the users and has examined new methods for presenting information on maps with a view to increasing the efficiency of map communication.

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TAYLOR, R.M. Subjective Assessment of 1:250,000 Scale Maps for En-route Low Altitude, High Speed Navigation. RAF IAM Report No 544, 1974. (A)

Subjective scaling techniques were used to obtain quantitative data from 26 pilots and 10 navigators in order to determine the perceived dimensions of eighteen 1:250,000 maps and to assess the suitability of the maps for en-route navigation of low altitude, high speed aircraft. Comparisons were made between perceived dimensions and assessments of map efficacy and between pilots' and navigators' assessments. The perceived dimensions correspond to major known differences in cartographic content and coding and were associated with the assessment of map efficacy. None of the maps tested was ideal; and pilots tended to be more critical of the maps than navigators, perhaps because they have less time for map reading in flight. Pilots preferred maps with bold distinctive layer tint colours for representing relief, and both groups preferred maps with reduced information content and less visual clutter. 1:250,000 scale maps for en-route low altitude high speed flight should use smaller selection rates for features than on conventional 1:250,000 scale maps and should be designed to give a clear and unambiguous impression of features that are distinctive from the air.

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TAYLOR, R.M. and HOPKIN, V.D. Human factors principles in map design. *Revue du Medecine Aeronautique et Spatiale Revue Trimestrielle*, 13, 87-91, 1974.

Human factors principles have seldom been applied to the design of maps for use in aviation. Maps are not usually evaluated as displays of information, and the content of maps often does not match the needs of the users. Most maps are so visually complex that it is not immediately

apparent whether standard recommendations for the coding and display of information apply to them. One approach to studying maps is therefore to verify which display recommendations remain valid for maps. Methods for quantifying cartographic information have to be devised and comparisons made between subjective and objective measures of information density. A series of experiments has considered the content of maps in relation to the needs of the users and has examined new methods for presenting information. The effects of type-face and coding have been assessed and also the limitations imposed by conventional cartographic practices and by the form in which surveyors collect data. Comparisons between maps presenting the same information have used a variety of tasks and collateral material. Interactions among coding conventions, task requirements and visual balance are discussed.

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HOPKIN, V.D. An Experimental Study of Height Layer Tints in the Joint Operations Graphic Map. RAF IAM Scientific Memorandum No 108, 1973. (A)

Three experiments were conducted on the layer tints used in the Joint Operations Graphic Map. The first survey established that, although many subjects do not consider that the order in which the tints are placed is the most logical possible order, they fail to agree on any preferable alternative. The second series of trials showed that, even when subjects had fore-knowledge of all these tints and they knew how many there were and the order in which they occurred in the set, they were still unable to remember them well enough to sort them into boxes assigning one tint to each box. In the third test it was shown that, without fore-knowledge of the tints, it was impossible to sort them although a reasonable performance at such a task would be expected if each was absolutely discriminable from all other and if the set of tints formed a logical sequence. Not only adjacent tints are confused but also tints not adjacent to each other, so that the direction of slope of the land could still be mis-represented when two or three tints are used.

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HOPKIN, V.D. Human Factors in the Design of Maps. RAF IAM Scientific Memorandum No 105, 1973. (A)

The complexity of information on maps is of a different order from that on most other displays on which ergonomic advice is given. Therefore, although textbooks and handbooks of ergonomic data provide numerous recommendations on the content, layout and coding of information on displays, it is not immediately obvious how much of this information is applicable to the design of maps. Whether existing ergonomic principles can be applied to the design of maps is a key question, the answer to which must be found before detailed specifications of maps can be drawn up.

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