

Progress Report

1978-1981

1. SUMMARY (Director's Overview)

The Unit attempts to bridge the gap between pure and applied psychology. The theoretical concepts and experimental techniques developed through pure research often allow us to view applied problems in new and productive ways. At the same time, the attempt to apply theoretical concepts outside the laboratory highlights the strengths and limitations of such concepts and in many cases leads to their further development and elaboration. We are fortunate in that cognitive psychology is at a stage of development where such an interaction between theoretical and applied research is both tractable and fruitful.

Over the past three years we have tackled a wide range of applied questions ranging from auditory warnings on the flight deck of civil aircraft to analysis of the job of the deep sea diver, and from the reading problems of brain-damaged patients to the speed of reaction of test cricketers. What ties together these apparently unrelated problems is a relatively limited set of underlying theoretical concepts. In general, the theoretical style of the Unit is to assume that cognitive behaviour reflects the operation of a number of subsystems, and to use experimentation to analyse such systems into component parts. Such an approach lends itself to clinical application in the area of neuropsychology, and over the last three years this has been one of the areas of greatest activity. Our approach however has been to use data from the breakdown of cognitive function in the brain damaged patient in order to understand normal cognition, and vice versa. We are not therefore a neuropsychology unit, we are an experimental psychology unit using and influenced by neuropsychological evidence. This will I hope become evident in the account which follows.

A characteristic of our work over the last three years has been an increased involvement in field experiments of a more long-term and ambitious nature than has previously been common at the A.P.U. Examples of this are the work on evaluating techniques of speech therapy, the project on individual differences in accident liability, the work on memory problems following closed head injury and the very extensive series of experiments on man-computer interaction. Most of these projects are still in progress, and it is in the nature of such long-term field research that results tend not to be obvious until the end of the project. However it is already clear that such research is providing a necessary and productive supplement to the Unit's more traditional laboratory-based approach to applied research. While experimental work under controlled conditions will remain the backbone of the Unit's approach, I would see field work as an essential part of the future work of the Unit. In general, the last three years has involved a development and expansion of existing work rather than a radical change in direction. The Unit's work on audition provides a good illustration of this. The theoretical analysis of auditory masking in terms of an auditory filter has been refined mathematically and extended to include a wider population experimentally. Two major applications of the model have been developed: (a) the design and evaluation of auditory warning systems for the flight decks of civil aircraft, and (b) the audiometric assessment of patients. In this latter area, the preliminary work relating filter shape to age is nearing completion and collaborative clinical research (with the Institute for Research into Hearing and Deafness) is about to begin.

Visual attention is an area of current theoretical interest which is beginning to influence our applied research in clinical contexts and in connection with accident causation. Also in a clinical context is the work on

photosensitive epilepsy: in addition to practical implications, for example in connection with T.V. induced epilepsy, attempts to locate the triggering mechanisms within the central nervous system are proving highly successful, while work on the spread of excitation within the cortex appears to have considerable promise in connection with a general model of epilepsy.

The study of perceptual motor skills combines a focus on precise models of the underlying processes with a determination to apply such models outside the laboratory. Examples are the theoretical and applied studies on handwriting and the successful application of laboratory-based theory to an analysis of the highly developed skills of the test match cricketer. The area of greatest current development however is probably in the study of movement patterns in clinical populations. The neuropsychology of movement is a relatively unexplored area, and one to which we hope to devote an increasing amount of effort over the next few years.

In the area of stress, research on performance has largely consolidated previous work, using both portable test equipment and paper and pencil tests to look at a broad range of stresses. A major development over the last few years has been in the Unit's increasingly sophisticated techniques for physiological monitoring in the field. The Psychophysiology Section's work on noise and sleep in the home is an example of this, as is the work on telephone switchboard operators and the project on trainee parachutists.

The psychology of memory continues to be an area of vigorous development within the Unit. In the area of short-term and working memory, previous conceptual developments have been expanded and applied to new tasks such as reading and arithmetic. In long-term memory the major trend over the last few years has been an attempt to test, in the field, the generality of the extensive laboratory-based research on human learning and memory done over the last ten years. Examples of this are the head injury and memory project, work evaluating saturation advertising and work on memory lapses in everyday life. Existing theories of memory tend to be ill equipped to cope with the richness of this type of data, and one of the most recent developments within the Unit has been a growing concern to develop theories of long-term memory which are capable of reflecting this degree of complexity.

The area which has probably seen the most vigorous activity over the past three years has been the study of reading. In particular, there has been a great deal of interest in relating the patterns of reading disorders resulting from neurological injury in adults to the dimensions and variables which affect the reading performance of normal adults. Deep dyslexia, a syndrome which appears to be particularly pertinent to current models of normal reading, was the subject of an M.R.C. sponsored conference held in Cambridge, and a book in which six of the chapters were written by members of the A.P.U. Three other syndromes of acquired dyslexia have been receiving increased attention in the last year or two, and seem likely to prove theoretically very productive. I would see this line of research continuing and broadening to include an increased involvement in the study of aphasia, a topic addressed mainly over the past three years by a successful applied clinical project to evaluate speech therapy techniques for facilitating word finding in aphasic patients.

Work on design of information and factors influencing the readability of forms and tables has continued to flourish. The major focus now is to communicate our results to the enormously wide range of potential users, in a way that allows them to implement recommendations effectively. In this respect, it is obviously much more desirable to formulate principles that will assist good initial presentation of material rather than simply

provide techniques for identifying the flaws in what has already been produced. We are therefore starting a programme of research on the factors involved in good writing.

The most active current area of applied research in the Unit has been in the field of man-computer interaction, where we can cope with but a small proportion of the requests for research that we receive. Again we have been concerned to develop general principles designed to allow a user to tackle this important area himself, rather than solutions to specific limited problems. While we are clearly making progress, it is obvious that this area is sufficiently complex and important to justify substantial future Unit involvement.

The project on individual differences in accident liability is now well advanced. A battery of tests of both perceptual and attentional performance has been developed and is currently being used in a prospective study of accidents in London Transport bus drivers. At the same time the Transport and Road Research Laboratory and the R.A.F. are collaborating by testing samples of accident-involved motorists and trainee pilots. While we can obviously not at this stage predict whether the tests will prove appropriate, I think we have demonstrated that such an approach is both feasible and sufficiently attractive to outside bodies to induce them to commit considerable assistance to the project. I would therefore like to suggest that the Board should approve the designation of this area of research as an established feature of the Unit's programme, thereby allowing its continued development.

The main emphasis of work at the Psychophysiology Section has been on the study of sleep in the home, in response to an increase in extramural support for this topic. It has been shown that traffic noise can have a major effect on the sleep of people living near arterial roads, an effect which is reflected in their test performance next morning, but which can be alleviated when noise level is reduced by double glazing. Other work has concerned the sleep of shift workers and their subsequent performance. Work on portable apparatus for assessing deterioration in skill has continued, with the development of two new tasks, vigilance and short-term memory, while performance has been studied under a range of stressors, including noise, anaesthetics, antihistamines and industrial pollutants.

Work at the Oxford Outstation on the cognitive abilities of the deaf is nearing completion. A major monograph on the project has been published and extremely well reviewed. A study of the deaf children of deaf parents is nearing completion. It tests the hypothesis that extensive use of sign language during the child's early years will allow more normal cognitive development than occurs when deaf children are exposed only to spoken language.

The Unit was invited to host the ninth meeting of the International Association for the Study of Attention and Performance — the first to be held in Britain. We departed from the normal procedure of a single organiser, spreading the load of both organising the meeting and editing the proceedings widely throughout the Unit. This seems to have proved a successful policy; comments on the organisation were uniformly positive, while the proceedings (120 U) are on schedule to appear in half the time taken by recent volumes.

The Unit continues to play a very active consultant role, responding to an average of 45 requests per month for information and assistance. A substantial minority of these are requests for advice or information from the Press, radio or T.V., and while we are often able to do no more than suggest an appropriate further contact, we do regard our relationship with the general public via the media as being of some importance. Presenting

psychology in a responsible but stimulating way is part of our job, and, in addition to writing articles and contributions to semi-popular books. Unit members have recently been involved in at least three radio and eight television programmes, the latter comprising mainly popular science programmes of the "Horizon" type. The Unit continues to provide advice and assistance to a wide range of outside organisations and individuals on issues where the techniques of applied psychology are relevant. This often leads to a continued involvement in either an advisory or a collaborative capacity, something which we welcome because it allows us to extend the scope of our work in new areas, while tending to keep our theoretical feet firmly on the ground. I would see such activity continuing to be an important component of the Unit's work.

A more detailed account of the Unit's research follows, together with a concluding comment on an overall evaluation of our current progress and suggested directions for future development.

2. HEARING

2.1 Noise disruption of auditory processing (Barton, Johnson-Davies, Lutfi, Milroy, Nimmo-Smith, R. Patterson, Weber)

This project aims to produce a mathematical model of auditory masking capable of predicting when an interfering background noise will make an important signal difficult or impossible to hear. The primary problem is to specify the frequency-resolving power of the ear with a set of accurate, but convenient, equations. We are pursuing two approaches to this problem. The first involves describing the frequency resolution in terms of an auditory filter shape; it is a direct extension of our earlier work. The second involves specifying the frequency resolution in terms of an auditory excitation pattern and it represents a new and complementary approach to the problem.

When a listener is trying to hear a signal in the presence of a noise background, he behaves as if he were centering a filter on the signal to improve its detectability. The auditory filter passes the signal and progressively rejects the noise as the distance of the noise component from the centre frequency of the filter increases. The ability to predict masking depends entirely on the accuracy with which we can specify the attenuation characteristic or shape of the auditory filter (178). The filter is not always symmetric and at times its centre is shifted away from the signal a little to improve detection. Until recently the interaction of these two phenomena limited the accuracy of our filter-shape estimates. To alleviate this problem, Nimmo-Smith has developed a completely new mathematical analysis which has disposed of most of the restrictive assumptions required by earlier methods. The success of this new approach was demonstrated by Patterson and Nimmo-Smith (184) and it is now being used to extend the generality of the model to high intensity noise backgrounds (124 U; 125 U) and to a wider population of listeners (185 U). The method has also been adopted in several other laboratories to extend the frequency range of the model.

The alternative approach to the specification of auditory frequency selectivity has the advantage that it is more directly related to the physiological mechanisms underlying the process. It has the disadvantage, however, that the appropriate experiments required to create a competent, quantitative model of masking are much more difficult to perform. This approach involves the use of electrodes to measure neural processes in animals,

followed by an attempt to generate similar data behaviourally with humans. Our initial investigations showed that the analogy between animal and human experiments has serious flaws (114 U; 115).

Since then we have concentrated our efforts on determining how the psychophysical experiments could be changed to improve the analogy with the animal data (237; 239 U).

2.2 The design and evaluation of auditory warning systems (Barton, Milroy, Nimmo-Smith, Patterson)

With increasing technology, there is a growing use of machines to monitor for dangerous conditions. When a problem is detected, the incident is typically signalled using an auditory warning, since its effectiveness does not depend on where the observer is looking. We are using the auditory filter-model of masking to develop a set of principles for designing auditory warnings for specific noise backgrounds. Currently most of our work on this project involves the auditory warnings used on the flight decks of civil aircraft. We have so far established the appropriate sound levels, and investigated the relationship between number of warnings and probability of confusion between them (180; 182). On the basis of this research we were asked to review the auditory warning set proposed for a new aircraft (183) before going on to design a prototype advanced warning system (177).

2.3 Improved methods of audiometric assessment (Milroy, Nimmo-Smith, Patterson, Weber)

The traditional hearing test, the audiogram, provides only a rudimentary evaluation of hearing, a specification of how intense a sound must be to get into the system without regard for the fidelity of the system. It seems probable that the auditory filter measure of frequency resolution might provide a better estimate of a listener's ability to process sound effectively. Hearing deteriorates with age, and so before proceeding to work involving hearing-impaired patients, we have performed a survey study to determine how the auditory filter shape changes with age (181). This initial study showed that there is indeed a significant broadening of the filter for people beyond age 60. In addition, it showed that the shape of the filter changes and this has led us to choose a new class of functions to represent the auditory filter (185 U). Currently this work has been extended, using the method of Patterson and Nimmo-Smith to assess the asymmetry of these broader filters and to determine whether listeners with broad filters have reduced ability to understand speech.

3. VISUAL PERCEPTION

3.1 Visual masking and conscious awareness (Forster, Marcel, Sunderland, Wilkins)

Experimental and theoretical work by Marcel (131; 132; 133) has related visual masking to consciousness; and work by Forster has related it to spatial frequency characteristics of visual stimuli. Several extensions are now being conducted of Marcel's original demonstrations that when words are masked so that they are undetectable, their visual and semantic characteristics nevertheless affect subsequent processes.

Two extensions of Marcel's theoretical work on conscious and unconscious visual perception (133) are being conducted by Marcel and Wilkins. In one, patients with lesions of the visual cortex are being investigated. Some patients, while having no phenomenal vision in one half of the visual field, show significant ability to point to and grasp objects of which they are not aware (so-called "blindsight"). In addition, after-images in the

blind field are apparently facilitated by stimulation of the sighted field. This is in contrast to patients with "visual neglect", studied by Sunderland, where awareness of stimuli in one field is impeded by stimulation in the contralateral field.

Another extension is the creation of situations whereby normal subjects experience illusory conjunctions of separate visual features (shape, colour) under conditions of attentional demand. Such experiments mimic the experiences of certain visual agnostic patients and address the issue of how we normally experience a cohesive visual world.

3.2 Object perception (Evelt, Hinton, Marcel, Morton)

Morton and Evelt are attempting to use experiments on picture perception to develop an analytic model applicable to clinical failures of object recognition. Their experiments have shown that when we recognise and name the drawing of an object (e.g. a bicycle), another drawing with the same name (a different bicycle) is more easily recognised up to at least 45 minutes later. Reading the name of the object out loud, on the other hand, has no subsequent effect on object recognition (223 U). The result has been applied to problems of object recognition in brain damaged patients, notably giving rise to a functional distinction between optic aphasia and visual agnosia.

Both Hinton and Marcel are using preparatory hand adjustments in grasping to explore the internal representation of perceived objects and their spatial location. An important aspect of this work is the notion of structural descriptions, which Hinton has developed theoretically and experimentally (105) in relation to visual imagery. The importance of this is to emphasise, at a certain level of representation, the spatial coordinates and axes with reference to which an object or pattern is described. Related to this aspect of imagery is Baddeley's (21) work suggesting a separation of spatial and visual components of working memory.

3.3 Visual attention (Duncan)

Duncan's work on visual attention is related theoretically to Hinton's and Marcel's concern in its use of levels of visual processing, and to Baddeley's techniques in focussing on attentional demands. Duncan's work suggests that while all aspects of a visual stimulus may be completely analysed prior to attention (79; 80 U), it is nonetheless easier to direct attention on the basis of one rather than a combination of features. In addition while people have little difficulty attending to different aspects of a stimulus (size, form), they do have difficulties attending to spatially separate stimuli.

A project which has now been completed is that by Poulton and Edwards (204; 205) on the use of colour in sonar displays used for tracking submarines. They showed that for a constant ratio of signal to noise, tracks are easier to detect when the gain of the display is turned up, even if this means displaying a lot of background noise. The use of colour does not substantially improve performance.

3.4 Colour coding in sonar displays (Edwards, Poulton)

The experimental evidence on which the above inferences are based has appeared in several papers (40; 41 U; 246; 247; 249 U) and been reviewed in more detail (248).

The theory that seizures occur when physiological excitation exceeds a critical level within a region of "equipotential" hyper-excitabile cortex has proved to be useful in interpreting the "reflex" mechanism not only of the photosensitive seizures but also of seizures induced by thought (253 U).

3.5 Photosensitive epilepsy (Wilkins in collaboration with colleagues at Runwell Hospital and the Instituut voor Epilepsie-bestrijding, Holland)

Certain patients with epilepsy are photosensitive and suffer attacks that are precipitated by visual stimuli such as flashing lights or patterns of stripes. The nature of the stimuli that provoke this EEC response is of interest both from the point of view of treatment and from the inferences that can be drawn about the chain of neural events that culminates in a seizure.

3.5.1 Theoretical inferences

Our study of the characteristics of epileptogenic visual stimuli and of the paroxysmal EEC responses they evoke had earlier suggested

1. that the epileptiform activity is triggered when normal physiological excitation in the striate cortex exceeds a critical threshold level, and
2. that the threshold varies from one patient to another. More recently our studies have shown
3. that the critical level of excitation is similar throughout different areas of the striate cortex of each hemisphere
4. that excitation of the striate cortex alone can be sufficient to induce epileptiform EEG activity
5. that the hyperexcitability of the two cerebral hemispheres is not uniform but can differ considerably, even in patients with primary generalised epilepsy in whom there is no evidence of cerebral trauma.

3.5.2 Practical consequences

Television viewing is responsible for many of the seizures suffered by photosensitive patients. We have shown that the epileptogenic properties of the television derive mainly from the pattern of stripes which "reverses" at 25 Hz. Televisions with small screens are less likely to cause an attack partly because they stimulate a relatively small area of retina but mainly because the line pattern is difficult to resolve (251). Generally speaking the television appears to be more likely to cause a seizure under conditions of high ambient illumination (39). The consequences of the above work for the design and use of visual display units have been reviewed (242).

A substantial proportion of photosensitive patients have been found to induce their attacks by rolling their eyes upwards under closed eyelids (38). This action may result in a rapid tremor of the lids and thereby cause an intermittent stimulation of the retina (75).

There are several arguments that favour the introduction of tests for pattern sensitivity as part of the routine EEC examination. Simple techniques and the rationale for their selection have been described in detail (76).

4. SKILL AND ACTION

4.1 Timing and control of movement (Long, Nimmo-Smith, Wing)

Within the broad and traditional area of APU interest in skill and action, a recent central concern has been with the timing and control of movement. Consider the simple task of tapping with a single finger. It involves two antagonistic phases, moving the finger down and lifting it again on completion of the tap. The two phases could be coordinated by separate though linked peripheral loops, or could be operated by a single central timer. If

movement control is based on two separate peripheral components, one would expect the interresponse interval variability to be different for the up and downward phase. Wing (267) has shown that the two movements do not differ in variability, implicating a single central timing system.

An equivalent logic can be applied to the problem of coordinating movements with the two hands, such as would be required when a tray is lifted and kept level. Once again, the evidence suggests a single central timer. It is proposed in the future to apply this technique to the study of patients with difficulties in the coordination of movement.

Long and Nimmo-Smith have studied the response timing involved in the performance of skilled typists. A mathematical model of fluency in performance of this task has been developed and is being explored using an on-line experimental facility whereby a computer records both the time at which the typist strikes each key, and when she shifts direction of gaze amongst source text, keyboard and printout.

4.2 Handwriting (Baddeley, Lewis, Nimmo-Smith, Wing)

Our research on handwriting is concerned with both theoretical and applied questions. Wing (268) has shown that overall size of writing can be adjusted by changing the intervals between reversal of pen direction but that this is not the basis of size differences between letters within a word, for example between *E* and *U*. Unlike speech, where utterance length affects the time to initiate a response time, it does not take longer to initiate the writing of a series of digits than to initiate a single digit, hence indicating that the subject does not take time to set up a more complex programme before writing a longer series (269). On the other hand, overall speed of repeatedly copying sequences of letters is affected-by number of letters in the sequence (272), a result which is tentatively interpreted as reflecting the operation of a short-term memory buffer for the written strokes. Such a concept is also consistent with some of the "slips of the pen" reported in a corpus of writing errors (271).

Applied research in this area has looked at the relative rate of copying and reading cursive and block capital modes of writing (264). Block capitals are read more rapidly, but written substantially more slowly than cursive script. An ongoing project for the Home Office is concerned with the variability in handwriting (273). The data should be of considerable interest to forensic document examiners, as well as providing a useful data base for more fundamental studies of the nature of handwriting. The size of handwritten ticks has been shown to be a sensitive stress measure (270) which has the useful advantage of being both unobtrusive and rapidly and easily collected. Finally, in the clinical field a joint project is planned with Mr. John Gleave of the Addenbrooke's Department of Neurosurgery on the influence on handwriting of Parkinson's Disease. The writing of a large group of patients was sampled before and after stereotactic surgery. It will be analysed using the computer-based system devised by Wing.

4.3 Control systems (McLeod and Poulton, in collaboration with colleagues from RAE Farnborough and the Warren Spring Laboratory)

We have investigated the effects of ship motion on a variety of manual control tasks (142). It was demonstrated that even in comparatively mild sea states there are considerable differences in the amount of degradation that control tasks suffer depending on whether continuous or ballistic hand movements are required by the control, and depending on whether the whole arm or only the hands are involved. The drop in

performance is not primarily due to nausea. Since different sorts of tasks are degraded to different degrees by ship motion it appears that a useful human factors gain could be achieved by designing the man/control interface around comparatively motion-resistant tasks. It is hoped to continue this work if a suitable simulator can be made available.

4.4 Visual control of action (McLeod, Wing)

Work on the visual guidance of movement is an area of current rapid development. In addition to the work by Marcel, Hinton and Wilkins described in the Vision section, Wing has developed a computer-based system for recording movements between a starting point and a target. It is proposed to use this to investigate the mechanisms underlying Fitts' Law which relates the time taken to reach a target to the distance and size of the target. In addition to research on normal subjects, joint experiments with Dr. Edgar Miller, Chief Clinical Psychologist at Addenbrooke's Hospital, have begun to explore the question of whether Fitts' Law applies to patients with motor disorders. Patients so far studied include those with Parkinson's Disease and with Wilson's Disease.

In collaboration with Carol Fraser of the Occupational Therapy Department at Addenbrooke's Hospital, Wing has recently started to study the ability of patients to pick up objects of various sizes at varying distances.

High-speed cine film records of the movements of the arm and hand are used to study the coordination between the timing of the two constituent elements, transport of the hand toward the object and opening of the hand. The aim is to contrast normal hand control with that achieved by skilled artificial hand users.

A source of dispute in the field of experimental psychology is the adequacy of 'artificial' laboratory tasks for understanding the functioning of the nervous system. Some people believe that the full power of the nervous system can only be demonstrated when it is performing 'natural' tasks which it experiences in everyday life.

With this criticism of laboratory-based studies in mind, McLeod has been examining the visual control of the arm movements of professional batsmen playing cricket. It turns out that their performance, in terms of the speed with which they pick up visual information and the accuracy of the timing of their movements, is similar to that obtained by the best subjects in laboratory experiments.

4.5. Attention and Action (McLeod, Shallice)

McLeod has shown that when people carry out two independent tasks simultaneously, performance is restricted by the operation of some limited capacity control device which does not appear to be involved in the performance of the tasks themselves (138; 139; 140). A continuing programme of research is trying to discover what the nature and function of this 'control device' might be.

A new model for the role of attention in the control of action has been developed by Shallice in collaboration with Dr. D.A. Norman of the University of California (165). It incorporates two levels of control. "Contention scheduling" enables rapid but crude selection to occur. "Supervisory attention control" biases the operation of the simpler mechanism to deal with more novel or complex contingencies.

5. STRESS AND PERFORMANCE

General Notes. *This material has been scanned from the original typescript, while we have done our best to remove errors, some may well remain. You can access other parts of this particular Progress Report either*

from the menu at the bottom of this entry or by navigating back to the Unit history timeline. Reference for this report are indexed by number and these can be found in a dedicated section also accessible from the menu at the bottom of this entry.

5.1 Effects of Noise on Performance (Baddeley, Edwards, Forster, Poulton)

Work in this area has primarily been concerned with further discussion of Foulton's theory that noise affects performance by masking the sounds of the response equipment and of inner speech (86; 187; 188; 189; 192; 196), together with a further discussion of Forster and Grierson's failure to observe attentional selectivity in noise. This aspect of the project has now been completed.

A second line of investigation has been carried out by Dr. P. Salame (visiting the A.P.U. from the C.N.R.S. Strasbourg) and Baddeley on the observation that short-term memory for visually presented material may be disrupted by unattended speech. Results so far have shown that the disruption effect does not depend upon the meaningfulness of the speech or its synchronisation with the material to be recalled. Disruption does not occur with tasks involving reading or rhyme judgments, suggesting a specific memory decrement rather than a general attentional effect. We plan to explore the generality of the effect further and attempt to identify its location within working memory. This should allow an evaluation of the usefulness of the technique as a theoretical tool for analysing memory together with its likely practical significance within the working environment (208 U).

5.2 Anxiety and performance (Baddeley, Idzikowski)

While there is abundant anecdotal evidence that fear may impair performance, there is surprisingly little good empirical evidence on this point (113). The project has attempted to collect evidence from two stressful environments, public speaking and sport parachuting. In both cases subjective state was measured using questionnaires, and physiological arousal was monitored by means of electrocardiography using small portable (Medilog) recorders. Cognitive performance was tested shortly before the critical event. Both situations generated considerable anxiety as evidenced by both subjective responses and heart rate. In general performance effects have been small, with only digit span and verbal fluency showing significant impairment. Unfortunately, however, for practical and ethical reasons it did not prove possible to test subjects at their point of maximum anxiety. It is hoped, using Army trainee parachutists, to repeat these studies with the test given closer in time to the actual jump. Meanwhile, the pattern of anxiety during the week preceding the jump and during the jump itself is providing valuable information on coping behaviour of both novice and experienced parachutists. Since we have personality tests on the jumpers, we should also be able to study the relationship between temperament and mode of coping with a fearful situation.

5.3 Diving research (Baddeley, Godden, Lewis, Logie)

In addition to concluding our work on the role of the underwater context in memory (89; 91) we took part in a Department of Employment funded project on the selection of trainee divers. This was carried out jointly with the University of Stirling: the Unit's concern has focussed on an analysis, based on divers' logs and interviews, of the job of a North Sea diver (90). This provides a much-needed background for studies of diver performance under more controlled laboratory conditions. Our own work in this area has been in collaboration with the A.M.T.E. Physiological Laboratory at Gosport, where divers have been exposed in a dry pressure chamber to

conditions equivalent to a depth of between one and two thousand feet of sea water. Our role in these trials has been to monitor the divers' performance. We detected a decrement in several tasks at pressures exceeding one thousand feet of sea water. Data from sleep diaries and subjective ratings of alertness and anxiety suggest that the decrement is probably due to the oxy-helium breathing mixture, and is not a secondary effect of fear or sleep loss (118). This work is continuing using Tri-mix, a helium-nitrogen-oxygen mixture which has been claimed to reduce the narcotic effects of oxy-helium. In the one dive so far studied this claim was clearly not supported: very marked performance decrements were found (22 U). We plan to continue to collaborate with A.M.T.E./P.L. on this project.

5.4 Psychological wellbeing of telephone switchboard operators (Brown, Wastell, Wilson, Copeman)

Operational research within British Telecom (formerly the Post Office) and earlier A.P.U. studies (52) indicated that trends in telephone switchroom design were having an adverse effect on the attitudes and productivity of operators. This evidence was supported by an M.R.C. funded study (262) of the social factors determining operators' attitudes towards their job. A subsequent psychophysiological field study of individual task performance (53) established that operators of modern 'cordless' switchboards were less productive and less responsive to diurnal fluctuations in call-traffic load than operators of the earlier 'cord' boards but that no differential stress effects were exhibited on the physiological indices measured.

A factor analytic study of operators' self-rated mood throughout their working day revealed that a factor termed 'well-being' was associated with this measured difference in performance, although a second self rated factor, termed 'competence', was not (230).

A further field study, now nearing completion, was conducted to establish where, in their call-handling procedures, cord board operators are able to achieve their greater efficiency. Discussions are in progress with the Human Factors Division of the British Telecom regarding collaborative research designed to validate the remedial measures suggested by these A.P.U. studies. Any results should have a general application to a wide variety of queue-serving tasks where technological developments, introduced on cost criteria, threaten the quality of service provided to the general public.

6. MEMORY

Short-term and working memory (Baddeley, Hitch, Hull, Lewis, Morton, Ottley)

The concept of a short-term working memory has continued to be a -teful one. Recent work has presented the case for the visuo-spatial scratch pad, a system responsible for visual imagery (21) and has explored in further detail the articulatory loop, a concept devised to reflect the role of subvocal speech in memory. Recent experiments iave shown the need to distinguish between the process of articulation iCMI_f which is responsible for word length and articulatory suppression effects, and the subsystem which feeds the process of articulation, which is responsible for the influence of phonemic •ailarity on memory. He hope in future to explore the question of .-ether this subsystem is one involving a "deeper" articulatory code which is not subject to disruption by articulatory suppression, or one representing some form of auditory memory (20 U).

The component of working memory most difficult to study is the central executive. We continue to use a strategy of attempting to split off from this central core subsystems which can be analysed separately. In addition to a possible auditory imagery system, it seems likely that we shall be able to identify a verbal memory component which is capable of holding speech-like material without subvocalisation, and with relatively few attentional demands. It appears to be the case that only when this system becomes overloaded does it make heavy demands on the central attentional system (13). Further research in this area will pay more attention to the microstructure of performance when subjects are required to carry out two tasks simultaneously.

Experiments have been carried out on the characteristics of a stimulus suffix which make it effective as a disrupter of immediate memory. First it has been shown that the set of suffixes used in an experiment can affect the size of the suffix effect (166 U). Secondly it has been shown that certain acoustic manipulations of the suffix can lead to a reduction in its effect. This has led to the idea that an early analysis may allow sounds to be classified as 'speech' or 'non-speech' sounds. Precise periodic regularity, for example, is more characteristic of non-speech sounds (158).

A series of experiments (17) has used words of varying length as suffixes and prefixes. Results suggest two effects, a suffix effect of the type studied by Morton et al which is maximal with short suffix words, and affects the last memory item, and a separate effect which is maximal with long suffix words. This effect, influences the retention of earlier items and appears to reflect the temporal decay of a short-term memory trace.

6.2 Psycholinguistics and memory (Barnard, Dennett, Long)

One of the aspects of our recent work on language and memory includes the development of a model of question-answering. This attempts to account for variations in answering behaviour to logically equivalent questions. Initial ambiguities in interpreting questions are resolved by relationships between the structure and content of an incoming question and its referring memory representation (26 U). A new approach to short-term memory has also been developed which seeks to link classic memory phenomena to the operation of an understanding mechanism. This is modelled in the form of a multiprocessor organisation for a set of functionally independent processes for understanding, representing and producing language (27 U).

Work initiated some years back on the analysis of telephone conversations has resulted in the availability of a large corpus of natural telephone conversations. Work based on this corpus (31) examined the temporal structure of natural conversations and indicated that the management of conversational turns is not necessarily impaired by the absence of visual clues as has often been inferred on the basis of more artificial laboratory studies.

A new project has also been started to extend the work on both comprehension and question answering. The former component focuses on text comprehension and the part played by pronouns in the integration of information in texts. The question answering component, like the work cited above, is focussing on the relationship between the structure and content of incoming questions and the structure of the information about the text as it is represented in memory. The work is carried out using computer-presented sentences. The work will also examine issues pertinent to future developments of the use of computer-based systems in the automated office of the future.

6.3 Memory for faces (Baddeley, Simmonds, Woodhead)

We have continued to look for ways in which face recognition might be improved. By analogy with verbal memory, we predicted that a deeper and more elaborate encoding of faces would lead to better subsequent recognition. Unfortunately, accompanying faces with further details of the person's character and lifestyle had no effect on performance, a result that was disappointing from an applied viewpoint (25 U; 274) but theoretically interesting (11 11). A feature which did prove to influence subsequent recognition was the pose of the original photograph. Three-quarter views are consistently better than frontal or profile poses (25 U; 275). Since this is inconsistent with current practices (e.g. passport photographs, police Wanted notices), it is proposed to investigate it further using a more realistic situation involving presentation through the local press, using the response of the general public as a measure. Finally, we have found consistent individual differences in ability to remember faces, indicating the feasibility of selection tests for good recognisers (276). People who are good at remembering faces were also good at remembering paintings, but did not differ in verbal memory. This result suggests separate visual and verbal memory systems, but no separate component within the visual system specialised for remembering faces (277).

6.4 Memory in everyday life (Baddeley, Bekerian, Lewis, Harris, Wilkins)

Although the last 20 years has seen an enormous amount of research on the psychology of human memory, this has been largely confined to laboratory studies, typically of verbal material. It is important to assess the extent to which these results can be generalised outside the laboratory. Investigations have included work on the role of memory in retrospective surveys (5; 19), work on the ability to recall emotional events (35 U), memory for conversations (36 U) and an evaluation of a saturation advertising campaign (37). This involved an attempt by the BBC to acquaint the public with changes that were to occur in the assignment of radio programmes to particular wavelengths. Despite the fact that our subjects would have heard this information over a thousand times, their ability to recall it, or to reproduce it on a display analogous to a radio dial, was appallingly bad. This result reinforces laboratory studies which indicate that mere repetition does not guarantee learning.

6.5 Memory aids and remembering to do things (Baddeley, Harris, Lewis, Nimmo-Smith, Wilkins)

Previous psychological work on memory aids has concentrated on the effectiveness of classical mnemonics in improving performance on laboratory tasks. Two interview studies (99; 100) revealed that memory aids reported to be used most often are not mnemonics but external aids such as diaries. Also these aids were more often used as prompts to remember to do things than for mere information storage. Consideration of the different types of prompting aid used, with their various advantages, points to a number of effectiveness criteria against which such aids can be judged and which help in constructing new ones (99; 101).

We began the investigation of remembering to do things by re-queuing people to activate a miniature event recorder at a succession of prearranged times over the course of the week (245), a task similar to the regular taking of medication. We compared a group of subjects who performed well on a verbal memory task with a group who performed poorly. Those with good verbal memory performed less well, indicating that remembering to do something is very different from memory as measured by conventional verbal tests.

These provocative results have been followed up in two ways. First a detailed study of the way in which people observe a clock before responding at prearranged times has revealed that the forgetting of a planned action may be quite rapid (103 U). Secondly, a collaborative study has been set up with local geriatricians to monitor the ability of elderly patients to take medication as prescribed. Two aids are being compared, one a compartmentalised pill container, and the other a booklet.

6.6 Closed head injury and memory (Baddeley, Harris, Sunderland)

Memory difficulties are among the most common complaints from patients who have suffered severe closed head injury. Previous research has also shown closed head injured patients to be impaired on certain objective memory tests. In our first study we have been investigating the relationship between the everyday memory problems reported by patients (or observed by their relatives) and patients' performance on conventional memory tests. Data collection from over 100 subjects is now complete and analysis is under way. We are finding interesting inter-group differences in both objective and subjective measures of performance and interesting relationships among the various measures.

Our future plans include studying whether objective tests given just before discharge from hospital can predict later memory problems (a year post-injury), as assessed by a postal questionnaire that we are currently developing.

6.7 Amnesia (Baddeley)

Research in this area has been limited by a lack of suitable patients. The last few years have however seen a growing consensus of results in this area which has allowed the formulation of a "minimal model" (7) together with a reformulation of the theoretical problem. At present progress in this area seems to be constrained primarily by our inadequate theories of retrieval in normal memory. An extension of the scope of such theories in ways which should bear on our understanding of amnesia has been suggested (11 U).

6.8 Management of memory disorders (Harris, Sunderland)

We have conducted an informal survey of British rehabilitation units and other medical departments thought to be involved in the management of memory problems following brain damage (102 U). This revealed (a) considerable interest, coupled with a lack of expertise or training and (b) a desire for more information, contacts and research on this topic. As a result of the survey we are planning a meeting of interested researchers and clinical staff to exchange information, discuss future research, and decide what else should be done to help clinical staff.

6.9 Theoretical work on long-term memory (Baddeley, Bekerian, Hammersley, Morton)

An attempt was made by Baddeley to fit the results from a series of recent applied memory studies into the framework provided by the currently dominant views of human memory, namely Craik and Lockhart's Levels of Processing Hypothesis, and Tulving's Encoding Specificity Principle. Data were taken from the Unit's work on context-dependent memory in divers (91), memory for faces (274), amnesia (7) and word finding in aphasic patients. A paper pointing out the shortcomings of the Levels of Processing Hypothesis has already been published (1), while a later paper suggesting modifications to this and to the Encoding Specificity Principle is in preparation (11 U).

The concept of headed records has been developed by Morton, Bekerian and Hammersley (following on from work by Norman and Bobrow) to provide a framework for discussing natural memory and its limitations. The record is considered to be the basic unit of memory. The framework is unusual in postulating that individual records have no direct interconnections, hence departing from the currently dominant view that memory is based on an associative network. It is further postulated that records cannot be directly addressed, a major difference from other theories of memory, and that they are unmodifiable and essentially free from decay. Records are accessed from headings which may include a subset of information from the record but could also include other information, such as the emotional state of the individual at the time of laying down the record. The headings themselves are addressed from a description which is constructed from information currently available to the appropriate mechanism (which we call the characterised (157 U)).

Morton et al use this framework to account for a variety of natural memory phenomena and to treat a number of standard experimental paradigms, in particular work relevant to the effects of the form of questions on memory for events. Experiments have been carried out on memory for films and stories (92 U), conversation (36 U) and emotional events in an individual's history (35 U).

7. COGNITIVE SKILLS

7.1 Arithmetic (Hitch, Young)

A series of experiments by Hitch (107; 108) explored the role of information storage in working memory in performing mental arithmetic. They showed that the forgetting of both initial and interim information was a potent source of errors. A memory decay model was shown to provide a good fit to the data.

Using an approach based on "Production Systems" (i.e. rule-based information-processing systems) Young has been concerned with the errors in children's written subtraction, showing that they can largely be accounted for by the omission of individual rules from a correct production system (307). This work is continuing in collaboration with T. O'Shea of the Open University. At present, data on the real-time performance of subtraction are being gathered in the classroom, the aim being to provide information about changes in the skill at the time that a new rule is being acquired. A future direction for the theoretical analysis is to model the way in which children's experience with various concrete representations of arithmetic—such as Dienes blocks, abacuses, or counters—affects their skill at written arithmetic and their more abstract understanding of number.

7.2 Language

7.2.1 Word comprehension (Marcel)

The backward-masking technique developed by Marcel has been extended to investigate how polysemous (multi-meaning) words are understood. These studies (130; 131) suggest that both meanings of such words (e.g. PALM) are automatically accessed unconsciously and that verbal context serves to select that meaning which will be apprehended consciously.

7.2.2 Word retrieval in aphasia (Morton, K. Patterson, Purell)

The studies of acquired dyslexia and dysgraphia described above are proving enormously fruitful in the framework of theoretical cognitive psychology. From a more practical or applied point of view, we have been assessing the efficacy of certain techniques used by speech therapists to assist word retrieval in aphasic patients. When a patient cannot find the name of something which he wants to say (e.g. "sugar"), speech therapists commonly attempt to improve the patient's performance in one of the following three ways:

- (a) The therapist says the word and asks the patient to repeat it.
- (b) The therapist gives a partial phonemic cue for the word, e.g. "sh" or "shu".
- (c) The therapist gives a sentence context for the word, e.g. "I like my tea sweet; please may I have some ?"

In a research project funded by the DHSS, we have designed tests to evaluate these three techniques. Studies of the first two are complete (176). The results are quite clear, if a little disheartening: we have confirmed that repetition and phonemic cueing are successful at the time of application, but we have found no evidence for any long-term benefit from these procedures. The third study on contextual cueing, plus a few individual case studies involving intensive exposure to repetition and phonemic cueing, are planned for next year.

7.2.3 Philosophy of psychology (Morton)

Many theories of psychology and language appear to be confused in their aims. In particular there is a tendency to try to find biological accounts of psychological phenomena. Morton, together with Jacques Mehler (of C.N.R.S., Paris) has critically examined some of the current trends. They see little reason to suppose that there are significant biological constraints on psychological theories (143 U; 154; 155). Attempts have also been made to explore, from a phylogenetic as well as an ontogenetic viewpoint, possible relationships between language-specific mechanisms and more general cognitive functions (153). The possible relationships between models and data have also been studied.

7.3 Reading

7.3.1 Psychological units in reading (McKenna)

Letter detection tasks can be used to indicate the way in which words are psychologically represented. A series of experiments by McKenna suggests that the stem of a word such as "waiting" (i.e. wait), is represented in a different way from its suffix (ing). This finding relates to certain neurological reading disorders in which patients show preserved reading of word stems but impaired reading of affixes (171; 214).

By using tasks in which it is necessary to process every letter (typing and handwriting) McKenna has shown that the suffix is processed separately from the stem, but as a unit. Future research will attempt to determine whether the unitisation proceeds directly from the word or whether the context directs this process.

7.3.2 Translation of print to phonology (Marcel, Kay)

It has commonly been supposed that phonological representation of alphabetic written language may be achieved by non-lexical grapheme-phoneme rules. An examination of the oral reading of single words by Surface Dyslexic patients and normal beginning readers by Marcel (129) casts doubt on this. A new theory has been proposed whereby the orthography of both words and nonwords is segmented lexically and orthographic segments are pronounced by analogy with their occurrence in known words. A series of experiments on normal adults supports this view and undermines the classic "two-process" model (116).

7.3.3 Phonological awareness and literacy (Marcel)

An important factor in learning to read and write alphabetic scripts is the reflexive awareness that our own speech can be segmented into phonemes. Marcel (126) has suggested its importance in both the initial teaching and clinical breakdown of reading. In a joint project with Halliday of Manchester University, he is investigating both the relationship of phonetic segmentation with reading problems and efficacious methods of initial teaching and remediation.

In addition, the way in which phonological awareness is related to spelling has been explored in groups of children, adult illiterates and aphasic patients whose speech perception and production appears to rely on an inadequate acoustic code (128).

7.3.4 Phonological coding in fluent reading (Baddeley, Eldridge, Lewis)

The rate of subvocalisation in fluent adult reading was studied by requiring subjects to produce an irrelevant utterance, e.g. the word "the", continuously while reading and comprehending sentences (4; 18) and prose (14). We found our subjects able to read and comprehend simple sentences with no apparent impairment. With more complex passages they read equally rapidly, but are more prone to miss errors in the text, indicating that subvocalisation may operate as an optional checking mechanism in fluent reading. Evidence that subvocalisation is not essential for phonemic coding comes from studies in which subjects were required to judge whether pairs of words rhymed or not. They were able to do this while suppressing articulation, with no marked loss in either speed or accuracy. It is suggested on the basis of this result that subvocalisation may be supplemented by an auditory image which may play an important role in reading.

7.3.5 Acquired disorders of reading

Deep dyslexia (Baddeley, Lewis, Marcel, Morton, K. Patterson, Shallice)

Morton and Patterson (158) have attempted to provide a comprehensive theoretical account of the pattern of deficits observed in deep dyslexia, based on Morton's logogen model of the processes of recognition, comprehension and pronunciation of written words by normal readers. Shallice in collaboration with Dr. E.K. Warrington of the National Hospital, has also developed a general model of the central acquired dyslexias, in which deep dyslexia is viewed as a mixed syndrome which can arise from varying combinations of more basic syndromes (214). For example, Shallice and A.K. Coughlan (of the Wolfson Rehabilitation Centre) have conducted a case study on deep dyslexia which has established that the deficit can arise from a modality-specific deficit in attaining the meaning of abstract words together with a deficit of the phonological reading route (213).

In the past, major interest in this syndrome has centred on factors such as semantically related errors in reading (e.g. protein » carbohydrate") and the major influence of word imageability or concreteness on reading performance. Recently, however, Morton and Patterson have turned to analysis of some of the more syntactic/grammatical dimensions of the syndrome.

(1) They have investigated whether grammatical function words (like of, on, with, her etc.), which the patients have grave difficulty in reading, are comprehended (157 U). The answer is:

(a) At least the more meaningful function words (like on and her) are well understood by a deep dyslexic patient. Therefore the reading deficit does not 'reduce' to a comprehension deficit, since even these rather meaningful function words are poorly read.

(b) Such words may be reasonably well understood in isolation; but the patient is unable to use word order or relational information to construct the meaning of a whole message. Thus he knows that on means something to do with top or above; but given the sentence The magazine is on the book, he cannot work out which object is on top.

(2) Patterson has also been investigating effects of the morphemic structure of words (mostly involving affixes like -ed, -er, -tion, etc.) (171). Like function words, these affixes cause grave difficulties for deep dyslexic patients in reading aloud. Experimental questions have addressed patients' knowledge of correct inflectional and derivational forms (e.g. ability to judge that fearest and quickly are legitimate words whereas fearest and passly—while composed of real root morphemes and real suffixes—are not) and their ability to select correct derivational forms of words to fit in sentences.

Baddeley and Lewis, in collaboration with T.R. Miles and N. Ellis of the University of Wales, Bangor, have tested the recent claim that developmental dyslexic children reveal a syndrome closely related to deep dyslexia. The reading of developmental dyslexics resembled that of normal but younger children rather than that of deep dyslexic patients (15).

Phonological dyslexia (K. Patterson, Shallice)

A major question about normal adult reading, to which the study of deep dyslexia has been considered relevant, is the following: are printed words generally (or indeed ever) translated into a phonological representation in order to be recognised and understood? A syndrome of acquired dyslexia described for the first time in 1978, phonological dyslexia, addresses this question even more directly. A normal reader will easily know how to pronounce a new word, such as a surname he has not seen before (e.g. Doob). A phonological dyslexic patient cannot do this (173; 214). Oral reading of familiar words, however, is almost normal in such patients. There are three important implications to be drawn from this research:

(a) If a severe impairment to phonological coding engenders such minimal disruption in a patient's reading, then it is very unlikely that such coding plays a critical role in normal reading.

(b) Theoretical accounts of deep dyslexia have sometimes proposed that symptoms in that syndrome (such as semantically related errors like anxiety* "nervous") might be attributable to the deep dyslexic's loss of phonological coding ability. If phonological dyslexic patients show the phonological impairment but not the other symptoms, however, then the hypothesised causal relationship becomes untenable. Thus we are advancing in our notions of how symptoms relate to functional components of the system.

(c) There is one deficit in reading individual words shared by phonological and deep dyslexic patients: a difficulty with grammatical morphemes, especially bound morphemes (affixes) and possibly also free morphemes (function words like *of*, *at*, *with*, etc.). Patterson (173) has suggested that this feature might be attributable to the phonological deficit.

Letter-by-letter reading (Kay, K. Patterson, Shallice)

Patients with this disorder, as the designation implies, read a word by identifying each of its constituent letters in succession. Time required to read a word is thus enormously slow and a monotonic function of word length. In the framework of our developing process models, we ask the following question: is the actual mechanism or process which allows normal readers to recognise words, deficient in these patients, as argued by Warrington and Shallice (225), or is this mechanism intact but forced to accept abnormal input from a preceding Stage of visual analysis of the written word, as argued by Patterson and Kay (175 U)?

Of interest in many interrelated disciplines is the extent to which representation of language in the brain is typically (for right-handed people) lateralised exclusively to the left hemisphere. Although speech production is widely thought to be the sole province of the left hemisphere, there is more controversy regarding comprehension. Patients showing letter-by-letter reading usually have well-localised left-occipital lesions; yet recent extensive investigation of at least six such patients reveals almost no evidence of comprehension of written words despite an apparently intact right hemisphere (175 U; 225).

Surface Dyslexia (Marcel, Shallice)

Work at the National Hospital by Shallice and McCarthy in collaboration with Dr. E.K. Warrington has led to the first detailed study of a "pure" case of surface (or semantic) dyslexia; it produced support for a particular model of the operation of the phonological route in reading. Their analysis fitted well with a more general 2-route model of the central acquired dyslexias for which they had previously provided evidence (214).

Marcel has re-analysed the oral reading of surface dyslexic patients. Contrary to standard accounts, it was shown that patients show several pronounced lexical effects in their reading. This has led to a new account of oral reading in normal people (129) which has gained support from further experiments (116). This model eschews non-lexical grapheme-phoneme rules and relies on the lexicon to segment orthography and retrieve phonology by analogy.

Acquired Dysgraphia (Shallice, K. Patterson)

Work on writing and spelling disorders has shown that a 2-route framework analogous to that developed in recent years for analysis of the acquired dyslexias can be applied to the dysgraphias. The syndrome of phonological dysgraphia, involving a specific deficit to the phonological route, has been described by Shallice (212) and the syndrome of surface dysgraphia, involving reliance on the phonological route, by Patterson and Hatfield (174 U).

7.4 Control functions of the frontal lobes (McCarthy, Shallice)

Shallice has been involved in collaborative work at the National Hospital involving three group studies on the cognitive effects of frontal lobe lesions.

(i) In collaboration with J. McCill: A series of 90 patients with localised lesions were tested in 1976-78 in an experiment designed to contrast two explanations of frontal memory difficulties— Milner's hypothesis of a time-tagging problem and a planning/ strategy deficit hypothesis. The results, which are being prepared for publication, primarily support the latter position.

(ii) A series of 130 neurological patients were tested by Shallice and McCarthy on tasks involving planning skills. One is a problem-solving task related to the Towers of Hanoi; the other is based on directed forgetting.

Although not all of the patients¹ lesions have yet been adequately localised, it appears on preliminary analysis that both tasks are especially sensitive to left frontal lesions.

(iii) In collaboration with E.K. Warrington and L. Oldfield: A battery has been developed of ten tasks suitable for clinical use and on which there is some evidence of sensitivity to frontal lobe lesions. A series of 120 neurological patients were tested in 1978-80. It is intended to assess which tasks have most clinical value in the diagnosis of frontal lobe impairment and to determine whether frontal deficits cluster.

It is planned to continue work on frontal lobe functions in three main ways: -

1. By analysing the cognitive processes involved in look-ahead problems in more detail. A preliminary analysis indicates that such tasks are especially sensitive to left frontal lesions.

In a further series we would hope to be able to isolate the difficulty more precisely.

2. By attempting to produce a theoretical account of frontal lobe disorders in terms of the distinction between planning and execution systems used in some artificial intelligence programmes.

3. By single case studies of particular frontal syndromes. These are at present being planned in collaboration with Dr. M-F. Beauvois and Dr. J. Derouesne of INSERM, Paris.

8. COGNITIVE ERGONOMICS

8.1 Design of information (Barnard, Threlfall, Wright)

This is an area in which the Unit has been active for a number of years. Our recent concern has been with devising procedures that will allow the research findings from our own and other work to be applied to practical design problems (290). What is required here is an "applications theory"; such a theory should summarise existing knowledge and direct further research, while offering the practical designer a set of procedures for evaluating existing designs, and methods for improving them (286). An adequate theory will inevitably be complex, requiring designers to have access to expertise in a range of disciplines including behavioural research (294). However, we have already shown that such an approach (a) has more power and generality than such empirical design tools as readability formulae (292) and (b) provides useful guidelines for materials as varied as manuals, forms, tables and narrative prose, as well as the range of new technologies that are currently developing (285; 288; 289).

Research into the psychological factors influencing ease of understanding written materials has shown that people's expectations are crucial. Inappropriate expectations lead to errors in use of tables (300) and the inaccurate completion of forms (30). It is therefore critical that the writer should bear in mind the knowledge and expectations of the reader, a fact that applies to materials as diverse as medical trial forms (299) and legal language (291). Nevertheless writers have difficulty incorporating such advice into their own writing style (297 U). Hence the importance of understanding the process of writing (287). We are therefore developing a research programme which has begun by examining people's editing skills (297 U). The programme will go on to study the contribution of the writer's memory and knowledge structures to the writer's organisation of ideas, and will examine the effect of the communicative task on the expression of these ideas.

8.2 Man-Machine communication

8.2.1 Pictographic instructions for equipment (Barnard, Hull, Marcel)

This project has examined how people understand and follow pictographic instructions for using equipment. In the first phase experimental work concentrated on the structural segmentation of sequences of pictograms. Although structural factors proved to have significant influences on performance, other factors emerged as important contributors to understanding and equipment use. They included (1) people's conception of both the equipment itself and the task in hand; (2) their strategies of combining equipment operation and instruction usage and (3) their assumptions about graphic representation and communication (135; 29). These factors are being investigated in a second phase of the project, which has received further support from British Telecom. This work is part of the Unit's broad interest in Man-Machine Interaction, but also has theoretical relevance to the relation between tacit and conscious knowledge as well as to the processes underlying the planning of actions.

8.2.2 Conceptual models and cognitive skills (Young)

Young has used a Production Systems approach to investigate users' conceptual models of interactive devices, such as computer text-editing programmes or pocket calculators (304). By analysing several different designs of calculator it has been possible to make explicit the models implied by the calculators' behaviour, and from these to derive predictions about the users' performance (305). Complexities in the model, for example, give rise to corresponding difficulties in the use of the device. The models are of at least two different sorts, and this, together with their concreteness and tractability, has served to elucidate the rather confused notion of "conceptual model" itself (306 U).

These ideas have application in a project being carried out for British Telecom on accessing structures in viewdata. Two aspects of the Prestel system are being examined. Work is now in progress examining the difficulties in terms of the mismatch between the user's conceptual model of the topic area (or of Prestel itself) and the model assumed by the information designer. This investigation will be extended to study the difficulties encountered when browsing through large networks of information, in particular to examine the factors that determine whether the user remains oriented or becomes "lost".

To help with both the calculator and the viewdata studies, we have designed and built a force-sensitive platform for recording keypresses, which we hope will be of some general utility. Advice is currently being sought on the possibility of patenting and/or marketing this device.

8.2.3 Man-computer interaction: the IBM project (Barnard, Hammond, Long, MacLean, Morton)

A substantial part of the Unit's recent work on human-computer interaction has been carried out under a collaborative research project with IBM (1977-1980). The first research project concentrated on the use of interactive systems by "casual" users - people such as town planners, engineers, or accountants, who have little or no formal training in computing. The initial emphasis of the work was to explore a methodological framework for research in this new area. The proposed framework makes use of a variety of conceptual tools and empirical methods (159). In an attempt to explore the problems, a study investigated the effects of introducing a new interactive computer system into the working environment of a large local authority. This study revealed many illustrative problems as well as some of the beneficial effects of computerisation (94 95; 122). A more, detailed observational study was also carried out to document, identify and classify the types of

difficulties encountered by users attempting to solve problems interactively (96; 97; 98). These observational studies served to help identify underlying factors which could usefully be studied in the more controlled environment of a laboratory which permits the systematic variation of interactive dialogues. So far we have investigated the structure of command sequences, focussing on the consistency of this structure and its compatibility with natural English. We have also studied effects of the design of information displayed on the terminal (28). The confusability of the names for commands and the conceptual difficulty of the user's task have also been shown to influence ease of use (93). Other studies in the series have examined relationships between instructional information and the structure of the dialogue, the influence of the phrasing of "questions" to be solved and the extent to which users have a constrained or free choice for ordering elements within a computer command sequence. The research has also explored the factors which influence the design decisions made by professional programmers when developing interactive languages for "casual" users. The picture which is emerging from the results is a complex one. The usability of interactive systems is clearly determined by a multiplicity of variables whose specific influences require careful conceptual and empirical evaluation. Adequate, but simple guidelines for system designers are likely to be difficult to establish and validate, and we may have to explore more sophisticated routes to designing truly usable systems. The progress made on this first collaborative project was sufficient to encourage IBM to extend and expand their support for the Unit's work in the form of a new three-year project. The aims of this new project are to build on the body of empirical findings obtained in the earlier research, both by examining a broader range of interactive systems in use in industry and by continuing the laboratory studies of specific variables underlying interactive dialogue. In addition, we hope to develop further theoretical techniques for analysing human understanding in this kind of complex task environment.

8.3 Perception and decision in transport systems (Brown, Copeman)

During the past three years, effort devoted to this project and to the T.R.R.L. contract on "Drivers' Attitudes and Behaviour in Relation to Road Traffic Offences", has been largely confined to the modelling of road accident causation, using the wide variety of data available including those collected during earlier T.R.R.L. contract research on experiential and exposure factors in accident liability (e.g. 64). Given that the vast majority of road accidents result from mismatches at the interface between the individual and other components of the traffic system, attention has been concentrated on the risk incurred when certain types of individual, or certain groups, encounter specific traffic conditions. This approach keeps open the remedial options of improving driver behaviour or reducing traffic system demands.

A model of the differential development of perceptual-motor and decision skills has been used to explain the experiential effects observed in road accident statistics (48; 51). Decision theory has been used to model traffic offending (49) and to demonstrate the individual's problem in balancing costs, which arise mainly from factors intrinsic to the traffic system, against payoffs, which relate largely to extrinsic factors. Evidence for the effects of speed stress on individual drivers and on traffic flow has been reviewed (45). Psychological understanding of driving fatigue and its prevention have been reviewed in some detail (42) and earlier views on the compatibility of driver and pedestrian behaviour are questioned (47).

The application of psychological theory and ergonomics research to the design of accident countermeasures has also been reviewed (44; 46). The concept of 'danger compensation' is seen to be particularly useful in explaining why reductions in objective risk arising from road safety measures often produce disappointing changes in accident rates.

Much of the theory and practice recently reviewed under this project has been generalised to provide the initiative for current work on "Individual Differences in Accident Liability".

We now plan to test hypotheses derived from recent modelling of accident liability. This will initially involve the collection of data on experiential and exposure influences in drivers' levels of confidence in their perceptual-motor and decision skills, and the implications for self-imposed demand within the traffic system. Depending on the outcome of this phase, further investigations will explore the potential for training naive drivers in hazard perception.

8.4 Individual differences in accident liability (Brown, Duncan, McKenna)

Following Brown's submission of a comprehensive research proposal to a Working Party of the Environmental Medicine Committee in 1977 the Committee accepted the Working Party's recommendation that: "A high priority should be given to psychological factors in the causation and prevention of accidents, particularly those which lead to remedial and preventive measures, or test the effectiveness of these". The Neurosciences Board subsequently approved a five-year programme of work in this field and two supernumerary members of staff, Duncan and McKenna, were recruited in 1978 to work on selected aspects of the programme.

Two earlier applied lines of research, conducted in other laboratories, are being extended and integrated at the theoretical level. The first is the demonstration of an association between selective attention and road accident liability among truck and bus drivers. The second is the association found between 'cognitive style' and performance on a wide range of perceptual and perceptual-motor tasks. Of particular interest is the correlation established between an individual's 'field-dependence' and his performance in real-world situations.

Theoretical interest lies initially in the relationships between field dependence and selective attention, and also between these factors and other individual characteristics, especially those which influence the attribution of causality in behavioural events. A battery of laboratory tests has been constructed to explore some of these issues.

Performance on this test battery is currently being correlated with task performance among three populations exposed to risk of accident. By the kind cooperation of the Transport and Road Research Laboratory, data are being collected from accident-involved and non-involved motorists. The Ministry of Defence (R.A.F.) has generously agreed to the collection of comparable test data among pilots undergoing selection and training. In addition, London Transport has kindly permitted data to be collected among bus drivers at their Training School. These studies will considerably broaden our knowledge of the specific implications of selective attention and cognitive style in the training and practice of perceptual and perceptual-motor skills in dynamic environments.

Once we have completed the collection of data on field dependence and selective attention among trainee drivers, trainee pilots and accident involved motorists, these data will be used to test alternative theories on the causal bases for the two characteristics in question. A planned development of this work is the initiation of

prospective studies among naive driver populations, to investigate the potential for influencing skilled performance and accident liability via special training in attention and perception.

High and sustained levels of attentional and perceptual skill are fundamental to the error-free performance of all sorts of everyday tasks. The consequences of accidents in performance in many of these tasks can be tragic for the individual and expensive for society. It is therefore hoped that this programme of research will continue to receive support beyond its initial five-year term, in order to pursue to successful conclusions the promising leads which have been established to date. In the longer term, a pool of A.P.U. expertise in this field could provide an invaluable source of information on a whole range of accident provoking situations, where individuals and groups within the workforce are exposed to occupational risk and hazard.

8.5 Automated testing (Baddeley, Watts, Williams)

With the development of microprocessors, it is becoming increasingly easy to carry out routine psychometric assessment automatically, without requiring the presence of an experienced tester. It is important that this developing technology be used wisely. The project is therefore concerned with evaluating certain key features of automated testing. Our first study took a series of standard neurological tests and presented them automatically to a range of patients. Results showed that patients were able to respond appropriately to the machine, which provided scores that were broadly consistent with the pattern expected from the location of the patient's lesion. Patients were independently assessed by a neuropsychologist and we are at present relating his evaluation to an evaluation based purely on automated test scores. A second study was concerned with "tailored testing" whereby a standard test is presented automatically, using a programme which selects questions on the basis of the subject's response. This allows the test to be shortened substantially. Subjects were tested on normal and automated versions of the Mill Hill Vocabulary Test and Raven's Progressive Matrices Test of Intelligence. Results showed that the machine-presented version took half as long to administer and in both cases scores correlated very highly with the same subject's score on the conventional test. However while the absolute scores on the vocabulary test were equivalent in the two forms, subjects tended to score less highly on the automated version of the Matrices test. This suggests that automation is feasible, but that population norms based on the conventional test may not be applicable. We are at present attempting to devise a suitable automated memory test. We plan to use samples of elderly patients and attempt to relate performance on the test to subjective reports of memory problems. If a satisfactory test can be developed, it may provide a useful screening device for detecting the early stages of senile dementia.

8.6 Perceptual and control problems in postal and telecommunications systems (Baddeley, Barnard, Brown, Dennett, Hull, Marcel, Poulton, Wright)

This project covers all the research and advisory activities of the A.P.U. under the human factors consultancy agreed annually with the Post Office (now with British Telecom).

Research activities during the past three years have included:

1. Investigations of pictographic instructions, by Marcel and Barnard
2. Studies of the temporal structure of directory enquiry conversations, by Barnard.
3. Experiments by Barnard and Dennett on the comprehension of text, with relevance for viewdata and word processing systems.

4. Investigations by Young and Hull of data accessing structures, with relevance for viewdata in general and Prestel in particular.

Among the advisory activities undertaken within the consultancy agreement, mainly by Brown, but also occasionally by Baddeley, Barnard Marcel, Poulton and Wright, are included the following:

- (a) Ergonomic aspects of data-logging records used by telephone switchboard operators.
- (b) Trials of a computerised Directory Enquiry system.
- (c) Workspace and environmental difficulties encountered by designers of new telephone exchanges.
- (d) Format of the data-logging dockets used by engineers within the repair service.
- (e) Design of user instructions for postage label vending machines.
- (f) Format of artificial speech in recorded announcements.

9. GENERAL METHODOLOGY

9.1 Bias in quantifying judgment (Edwards, Poulton)

A person may be asked to make quantitative judgments on dimensions where he has no familiar arithmetic units that he can use. If so, his judgments are likely to be biased in a number of identifiable ways. The aim of the research is to note that these biases occur, to indicate their nature and estimate their size, and to propose methods for abolishing or minimising the biases (194; 199; 206). A book is being written on this topic.

9.2 Experimental Design (Poulton)

Poulton is concerned by the biases introduced by influential companion conditions included in a within-subjects design. One object of experimenting in the laboratory is to eliminate variables that bias the results in unknown ways. Using a within-subject design reintroduces some of these variables, all neatly balanced for subjects and order, but still capable of biasing the results due to asymmetric transfer (202 U; 203). Poulton plans to continue reviewing the effects of asymmetric transfer in within-subjects designs in different areas of experimental psychology in hopes of dissuading investigators from using such designs, or at least to inform investigators of the risks of bias.

9.3 Neuropsychological theory and methodology (Shallice)

In the last ten years there have been considerable changes in neuropsychological theory. These have mainly resulted from the application of information-processing concepts and the use of an experimental version of case study methods. In two papers Shallice has assessed these changes. In one (211) the increasing integration of neuropsychological theory with cognitive psychology is reviewed. In the other (210) the value of the neuropsychological case study approach for determining the functional architecture of cognition is defended against a number of different types of criticism.

10. PSYCHOPHYSIOLOGY SECTION

The main topics of research are still sleep, stress and performance, evoked brain potentials, and portable performance tests. The emphasis has moved from stress towards sleep in response to an increase in extramural support for our work.

10.1 Sleep (Wilkinson, Campbell, Tilley, Warren, Whitten)

An important part of the Section's work is the recording of people's sleep in the natural setting of their own homes. Three measures are taken, each with some credentials as a measure of the quality of sleep; the physiological record of sleep (electroencephalogram, electro-oculogram, and electrocardiogram), subjective report, and performance the next day. This work allows us to examine the fundamental question of how well they agree, while still responding to issues of current concern. One branch of this research is funded by The Commission of European Communities to study The Effect of Traffic Noise on Sleep in the Home. Work had started by the end of the last progress report and has continued throughout the period of the present one. Fifteen people have been recorded for 16 nights each, all living beside arterial roads having almost continuous traffic all night. The main variable has been to add double glazing to the bedroom windows, reducing the noise inside by about 10 dbA. Significant effects have been observed on all three kinds of measure. Now we are trying to establish broadly the level and spectra of traffic noise peaks which disrupt sleep physiologically, or produce outright wakefulness. We find that people vary greatly in what disturbs them, which underlines the need to follow this study with a more detailed examination of particular groups at risk. Several papers have been published so far (57; 59; 60; 259; 256).

The second study of sleep in the home was upon the Sleep of Shift Workers, a two-year project commissioned by the European Foundation for the Improvement of Living and Working Conditions (216; 220). Important differences were found between sleep during a week on the night shift and sleep during the normal day shifts. Performance on the night shift was also worse than during the day. The men were working a three-shift system, changing shifts every week. Future research, if funded, will examine systems which change either more rapidly or more slowly, including permanent night shift, in order to identify those patterns of working which are least harmful to sleep and performance.

In the laboratory we have examined the effect of one night's loss of sleep, first upon retrieval from long-term memory as a function of the familiarity, or dominance, of the items recalled and second, on "R/S refractoriness", the lengthening of choice serial reaction time which occurs when a stimulus follows too closely upon a previous response. This latter study has led to a series of experiments on this kind of refractoriness in which the variables have been number of choices, amount of practice, and duration of the task. Finally, two reviews have been prepared, one on sleep deprivation generally (257) and another on the relationship between body temperature, performance, and the sleep/wake cycle (258).

10.2 Development of portable apparatus for assessing deterioration in skill (Wilkinson, Houghton)

In the long-term project for producing a battery of standardised portable tests, two new tasks, vigilance and short-term memory, have been added. Both work well, but the short-term memory task appears to be little affected by environmental stress. The Unprepared Simple Reaction Time test (mentioned in the previous progress report) is now used widely and has proved particularly satisfactory on grounds of its sensitivity to stress and the stable plateau of normal performance it provides following minimal practice. Efforts have been

devoted therefore to producing a portable microprocessor-card version of the test which stores reactions times in digital memory (rather than cassette tape) and can analyse data and display results on the spot.

10.3 Event-related changes in the brain as correlates of attention (Wilkinson, Campbell, Allison)

In one experiment now in progress, refractoriness of the evoked potential is being examined as a function of attention to the stimuli concerned. In another, a reaction time experiment, we are attempting to distinguish those event-related changes in the EEC which are due to the response from those due to the stimulus.

Meanwhile the results of an evoked potential study of signal detection have been published (255) and Campbell has completed a study of personality in relation to auditory brain stem evoked potentials (55). Campbell has also contributed two substantial reviews, one on clinical studies of the auditory brain stem evoked potential (58), and the other dealing with the evoked potential correlates of human information-processing (56).

10.4 Effects of environmental stresses

10.4.1 Memory (Millar)

In one of three experiments on memory, Millar examined the hypothesis that noise impairs short-term recall by masking inner speech (144). This was done by varying the ability to rehearse the list to be remembered. The hypothesis was supported, but with reservations. Then he studied retrieval from long-term memory as a function, first of noise (146) and then time of day (147). Performance was found to be best later in the day, unlike that of short-term recall which is thought to be superior in the morning.

10.4.2 Effects of single and combined environmental stresses (Wilkinson, Millar)

Three studies have been carried out in collaboration with outside establishments. At the Hammersmith Hospital, Department of Anaesthetics, we had previously shown that performance of patients was impaired throughout the day following minor surgery in the morning (209). This is thought to be due mainly to the after-effect of anaesthesia. A further study has compared this recovery rate for different anaesthetic agents.

A drug study has been supported by Pharmax Ltd. in which the portable tests of vigilance and reaction time were used to assess the side effects (drowsiness) of a common antihistamine preparation and show how well an ephedrene-based additive could counteract this effect (145). The additive was approved.

In a joint study with the School of Hygiene and Tropical Medicine, the reaction time test was used to investigate industrial pollution (61). Paint sprayers in a boat factory were compared with control workers from the same plant for possible adverse effects of styrene present in the spray.

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