



SOME METHODS TO EVALUATE CREW ACTIVITY IN HELICOPTERS

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SOME METHODS TO EVALUATE CREW ACTIVITY IN HELICOPTERS

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SUMMARY

While the knowledge of helicopter dynamics, structures and systems has increased and led to a steady improvement in the performance of helicopters, our understanding of the man in the system is still somewhat limited.

With the older, slower, less complex helicopters, the crew have usually been able to cope with their tasks, even if at some cost to themselves. The stage has now been reached where the pilot and crew are being required to perform more and more difficult tasks with increasingly complex equipment. Only if this equipment is carefully matched to the man's requirements and his tasks are designed to be within his capacity, will the future helicopter systems reach their full potential.

By investigating human factors problem areas now, they can be identified and prevented from being repeated in future helicopters. Some ways in which the present shortcomings can be highlighted are by Cine filming, "Eyemark" and voice recording of helicopter crew during typical operational conditions. Existing hardware shortcomings can also be determined by conducting structured interviews and using other subjective methods with the operators of current equipment. Questionnaires submitted to operators have proved to be very effective in extracting useful data, if performed in a scientific manner.

Frequently there would appear to be little communication between manufacturer and customer once the hardware is in use. The operator's complaints will become meaningful if the designer and manufacturer are shown how their products are actually used. It will then enable action to be taken to prevent present shortcomings from being perpetuated in future helicopters.

INTRODUCTION

Once a helicopter is in production there seems to be little feedback of its human factors shortcomings - or its benefits - to the airframe or equipment manufacturers. This is due to inadequate communications channels, apathy and the very adaptiveness of man, in that he can usually find a way round a problem. In the past this has usually been acceptable, but the situation is now being reached where the man is at the limit of his capacity. Both the man's and the machine's capabilities need to be optimised and integrated with one another. Before this can be done it must be found out how man copes with the present situation and what are the current inadequacies. A number of techniques are available to help this to be done, ranging from activity recording on film or tape, physiological measurements and subjective evaluation during in flight operations to simulation and synthesised time analysis.

CREW ACTIVITY RECORDING

To gain an impression of helicopter crew activity and crew problem areas, it can be useful just to fly with the crew on an operational sortie and to observe events. However, this has the disadvantage that the observer can record only subjective impressions of what he is looking at, or listening to, at that particular moment. It gives a somewhat biased qualitative measure but yields no quantitative information.

One method by which these shortcomings can be overcome is that of cine filming. For a number of years^{1,2}, cine film records of helicopter pilot activity have been taken and analysed for several different types of UK service helicopter. These films provide a permanent record of pilot or cockpit activity. By careful analysis, crew head and hand movement records can be compiled which yield quantitative data and activity patterns for different flight conditions. Figure 1 shows the observer with the hand held fish eye lens camera filming a Gazelle pilot. Figure 2 is a "still" taken from a frame of the cine film record.

Since much of the information required by the pilot is obtained visually, it can be argued that study of eye movements or scanning patterns may indicate the difficulty of the task being performed at the time. Experience has shown this to be true, and Figures 3 and 4 show typical pilot's head activity patterns for Cruise, Low Level and "Top of the Earth" (NOE) flight.

These figures clearly demonstrate how activity patterns change as flight condition related task difficulty increases. During the relatively undemanding cruise condition at 700 feet above ground level (agl), Gazelle Pilot B tended to spend long glances of several seconds out to the front with shorter ones, of a second or so duration, to the left, right or inside the cockpit. In this phase of the flight, the average length of glance was found to be 3.3 seconds. During low level flight, where the same Gazelle pilot flew lower at about 100 feet agl (but remained well clear of ground obstructions) the flying task was still relatively undemanding and a very similar scanning pattern was produced. Surprisingly, Pilot A flying a much larger Wessex also produced an almost identical scanning pattern for low level flight as Gazelle Pilot B, Pilot A had an average scan time of 2.9 seconds.

Figure 4 shows typical NOE head activity patterns from one Sioux and two Scout Pilots. NOE flying is far more demanding, requiring the pilot to fly as low and as fast as possible, flying between obstacles rather than over them. These activity patterns are very similar, despite the different pilots and different helicopter types. However, these patterns are quite different to those for low level or cruising flight. The NOE patterns are typified by frequent short glances outside and inside the cockpit, averaging 1.6 seconds.

Other typical patterns (but different to the Cruise or NOE patterns shown here) have been found for other phases of flight such as operations in and out of wooded clearings and restricted areas³.

Table 1 summarises the % times spent looking inside and outside different helicopter types by RAF, RN and Army pilots for various flight conditions, all of which have been recorded on cine film.

TABLE 1 Percentage head activity times for 8 pilots in 6 types of aircraft for different flight tasks or conditions, derived from cine film analysis.

Task/Pilot	Left	Radio	Map	Inst	Front	Right	Total Out
<u>CRUISE</u>							
Wessex Pilot A	10	0	0	13.6	59.7	16.7	86.4
Gazelle Pilot B	17.5	2.0	1.6	5.2	57.7	16.0	91.2
Scout Pilot G	32.8	0	0	18.4	44.4	4.4	81.6
Scout Pilot E	13.8	10.4	7.2	18.4	37.7	12.5	64.0
<u>LOW LEVEL</u>							
Wessex Pilot A	15.6	0	0	5.5	72.7	6.2	94.5
Gazelle Pilot B	15.3	0	0	3.9	76.2	4.6	96.1
<u>NAP of the EARTH</u>							
Scout Pilot C	9.1	9.0	6.6	5.5	55.8	14.0	78.9
Scout Pilot D	20.7	0	9.6	5.7	51.6	12.4	84.7
Scout Pilot F	17.1	4.6	7.8	5.4	51.9	13.2	82.2
Scout Pilot E	9.3	11.1	10.8	4.6	51.2	13.0	73.5
Sioux Pilot E	3.8	0.5	5.7	8.5	51.9	29.6	85.3
Beaver Pilot H (F/W)	12.5	0	10.3	6.9	57.0	13.3	82.8
<u>HOVER in CLEARING</u>							
Scout Pilot G	36.1	0	0	6.1	43.7	14.1	93.9
Puma Pilot A	3.9	0	0	5.8	76.6	13.7	94.2
Wessex Pilot A	5.6	0	0	0	26.9	67.5	100.0

It can be seen from the table that a considerable amount of time is spent by most pilots looking inside the cockpit. For example, at NOE height it was expected that a pilot would spend virtually all of his time looking outside the cockpit to detect and avoid trees, wires and other potential hazards. The figures above indicate that Army helicopter pilots spend about a fifth of their time looking inside the cockpit during NOE flight. The reasons for this are that the pilot flying NOE is constantly scanning his instruments to check engine performance etc to detect engine and system changes which might be the precursor of failures. If the pilot has no crew to help him, he may be map reading and changing radio frequency. At very low level the view ahead may be only a few hundred metres or less. This requires repeated checking of the map with the identifiable ground features in view. During cruise at several hundred feet agl, the pilot's view is for kilometres rather than metres and he can identify his position on the map relatively quickly. Similarly, at low level the radio may be masked by ground features and this will require additional tuning or frequency changing. This will result in more time being spent looking inside the cockpit than would be so at higher altitudes.

Thus, cine filming of pilot's activity patterns can provide some useful general objective data and can highlight areas where improvements are required to improve the operator equipment interface. However, it is a relatively inaccurate method of investigating pilot scanning patterns. A more precise method is that of the Eye point of regard or "Eyemark" camera.^{4,5} This method uses a corneal reflection technique. The image of a small light source, mounted on the head close to the

pilot's eye, is reflected from the cornea onto a half silvered mirror positioned in front of the eye. The movement of the reflected image is recorded via a lens system by a TV camera onto a video tape recorder. The forward view in front of the pilot's head is also recorded on the same optical system. Thus, a picture of the scene in front of the head is obtained on which is superimposed the image of the light source showing the point of regard of the pilot. Subsequent analysis of the video tape enables the calculation to be made of the precise amount and number of times that the pilot looks at particular instruments, or exactly where outside he is looking during flight.

The more detailed "Eyemark" activity chart obtained for a Gazelle pilot during low level and climbing flight is shown in Figure 5. Glances of less than a tenth of a second have been recorded for helicopter pilots during peaks of high level activity by this technique. The "Eyemark" camera has revealed similar but more detailed and sensitive visual activity patterns than has the simpler cine filming method. However the "Eyemark" is a much more costly and difficult technique to use and gives no indication of pilot manual activity in the cockpit, as does the cine film.

Visual activity recordings can be supplemented by tape recordings of the intercom during flight. These not only aid in the analysis of the visual record, but can also give an indication of pilot and crew workload. Voice recordings can directly inform the observer of the task difficulty by their content, or in certain situations, by their quantity and frequency of occurrence. For example if the pilot is constantly having to use his radio or intercom, it is an indication that his flying task still allows some spare mental capacity to take on verbal tasks. If these secondary tasks are then interrupted and the pilot temporarily ceases speaking, it is likely that the primary task of flying has increased in difficulty and the secondary verbal task has had to be dropped. This method of detecting a high workload in a flight situation was the starting point of an investigation of a non intrusive method for detecting pilot stress. It relies upon changes in the speech spectrum to indicate mental stress of pilots and Air Traffic controllers and is currently under development at Farnborough^{6,7}.

Thus, some indication of the problems of existing helicopters and their systems can be obtained by recording overt crew activity and can give some measure of workload. This does not, however, give the complete answer and subjective evaluations can often provide complementary data. Questionnaires, subjective ratings and structured interviews are some of the methods by which this additional information can be acquired.

QUESTIONNAIRES AND INTERVIEWS

Correctly designed questionnaires, if used sensibly, can yield information which would be difficult, if not impossible, to obtain by other methods. As mentioned above, once a helicopter or its equipment has been designed, manufactured and delivered to the operator, there often is little feedback of information to indicate either its faults or merits. A carefully designed and administered questionnaire can sometimes provide this feedback link, to the ultimate benefit of both user, manufacturer and R&D authority⁸.

As stated by Howells⁹, equipment designers tend to consider the use of such subjective methods as interviewing or questionnaire techniques only as a last resort when it has not been found possible to measure or quantify the performance of the equipment. In terms of the normal academic and professional training of designers this is understandable so that if the designer has to resort to using some form of subjective assessment, the results are often disappointing to all concerned.

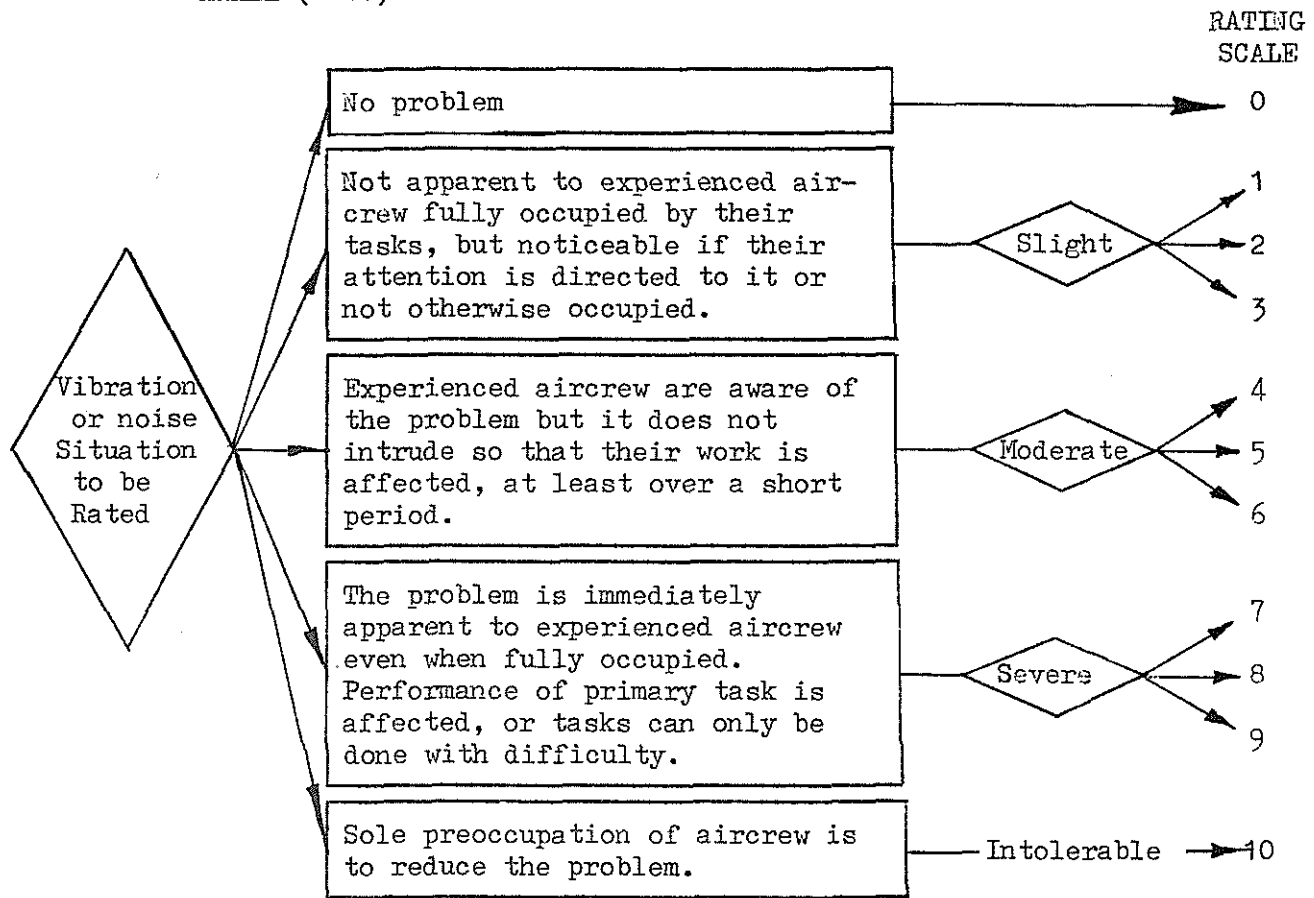
Perhaps unknown to many designers of aircraft systems, persons engaged in certain fields of research and areas of study, such as clinical psychologists and even market researchers, often possess no other tool other than some form of systematic subjective assessment. In the hands of such practitioners, it is often a far more systematic and precise tool than when used by an equipment designer who lacks an appreciation of the various rating scales, checklist techniques etc available. In the field of aerospace R&D, it is usually possible to find a specialist with experience in the use of such methods and it is advisable to seek such professional help if available¹⁰.

For a questionnaire to stand any chance of success a number of stages must be followed. Usually an initial study must take place, with visits to part of the population who will receive the final questionnaire. These visits will help to ensure that the correct questions are asked in a form which is readily understandable by the population concerned. All too often human factors engineers ask questions in their own jargon which are either ambiguous or misunderstood (or both) by the recipient. On the other hand, if questions can be phrased in the recipient's terminology it shows that the latter is not dealing with someone completely out of touch with reality but with someone who has made some effort in trying to understand the user's problems and who is open to suggestions. At this stage in the design of the questionnaire, the means of analysis should be considered. All too often the questionnaire analyst is confronted with a mass of almost unclassifiable and meaningless data which cannot be correlated with other data. The correctly designed questionnaire will yield data that can be quickly and simply extracted and, if necessary, processed by computer and correlated with other data. This can be accomplished by the use of forced choice questions constructed around a decision tree.

The following A&AEE Scale is an example of a decision tree based on the Cooper-Harper rating scale. It was used by Howells¹¹ to evaluate noise and vibration levels in Sea King helicopters.

Example 1

A&AEE (0-10) SCALE FOR SUBJECTIVE PROBLEM ASSESSMENT



The ratings from different crew members in several different helicopters were compared with objective measurements of noise and vibration for the purpose of determining those aspects of the cabin environment that degrade comfort and performance the most.

An example of a forced choice question which was used in a helicopter seat evaluation is shown below:

Example 2

Please rank the following factors in terms of how you assess they would improve operational comfort:

(Accepted that present primary controls cannot be altered)

- Adjustable rake
- Better seat covering material
- Foldable arm rests
- Improved vertical seat adjustments
- Improved F/A seat adjustments
- Lumbar support
- Seat pan contouring
- Thigh support
- Vibration isolation
- Other

This type of question forces the user to respond with a finite, but likely list of alternative replies. The questioner is then able to group the data into meaningful separate categories for analysis or final correlation with other data. (There is little point in collecting a mass of data from a questionnaire if it cannot be broken down, analysed and used in a meaningful way). Even if the questionnaire has been designed to ask the correct questions in the right way, such that the responses can be readily analysed, it will not achieve its potential if it is poorly administered.

A questionnaire needs to be distributed personally with an explanation of its purpose. Another problem often encountered is that the equipment user has been complaining for years about its shortcomings but nothing has been done to improve it. If a questionnaire arrives without explanation, the user may doubt if it is worth bothering to complete it as nothing has happened in the past. If the questioner is available to explain that the user's objections to the equipment have not reached him, and that this is an attempt to remedy the situation, his chance of receiving completed questionnaire will be very much improved. The distributor should be available to help anyone who still has difficulty in understanding any of the questions. Similarly there should be someone detailed to collect the questionnaires when completed and to return them to the originator.

Frequently there are complaints that a very low proportion of completed questionnaires have been returned. This is usually due to some or all of the following reasons as follows

- 1 Questionnaires were sent to a Unit by post for distribution without any personal contact by the originator.
- 2 No explanation was given of the purpose of the questionnaire.
- 3 The questionnaire was ambiguous or poorly designed.
- 4 There was no one to collect the completed forms.
- 5 The Unit has already received a number of poorly designed questionnaires recently and is getting bored at completing them.

Ideally questionnaires should be designed and administered in such a way that they meet the following criteria.

Questionnaires:

- a. Should provide feedback of equipment faults and merits.
- b. Purpose must be explained to the recipient.
- c. Should ask questions that can be understood by the recipient.
- d. Should be designed to yield useful and correlateable data.
- e. Should use forced choice questions whenever possible.
- f. Should be collected when completed.

If the above criteria are observed then questionnaires can provide the equipment designer with information which is invaluable and often unobtainable by other means.

Even with a well-produced and administered questionnaire, difficulty is sometimes encountered with, for example, pilots who are quite willing to discuss equipment, etc but uneasy at writing comments down on paper. For this situation the structured interview might offer the best approach. The same procedure should be followed as is required for a questionnaire except that the subjective responses are recorded by the questioner rather than by the subject. This technique has been used successfully on several occasions by Howells^{9,11}. The procedure used was for the helicopter pilots to read through sequentially structured general questions which led to forced choice branching questions. Having done this and registered the preferred choice category the pilots went on to explain verbally the detailed reasons for so choosing. The verbal response was then noted down by the questioner or discussed in greater detail for clarification. Sometimes, if no objection was raised, the dialogue between pilot and questioner was recorded on tape for later analysis.

This technique of a structured interview was developed initially for a trial to supplement radar plots of a helicopter's position during an evaluation of a helicopter guidance approach aid. It was found to be acceptable to the test pilots concerned and yielded information of both sufficient generality and detail for use by the equipment designers. The latter were able to assess more fully the system performance than they had previously, by reference to radar records alone.

Since this use of the structured interview, it has been usefully employed in the evaluation of helicopter seating and helicopter workload studies. It would be equally applicable for assessing electro-optical aids and other equipment for helicopter use.

In general, if performed in a sensible manner, subjective techniques using questionnaires or interviews can yield much information which is unobtainable by other objective measurement techniques. It can also give the designer insight into why objective data result in the way they do. More important, subjective information provides the feedback link between the equipment operator and the designer, manufacturer and R&D authority.

CONCLUSIONS

There is no simple or unique way in which a helicopter or its systems can be designed to have acceptable human factors aspects with the crew as an integral part of the overall helicopter system. Some of the major pitfalls may, however, be avoided if note is taken of present helicopter shortcomings (and advantages). Often these go unnoticed by all but the operators. If current helicopters are systematically studied there is a good chance that the manufacturer can be made aware of the shortcomings so that they are not repeated in future designs. This can be accomplished by methodical evaluation using crew activity recording techniques and by the use of carefully prepared and administered subjective investigations.

Until recently, investigators have tended to be polarised towards either subjective evaluation using questionnaires or objective measures. Rarely have both objective and subjective measures been used simultaneously. Only by using various subjective and objective measures together will the full picture of the helicopter user and his requirements be built up and better future designs be ensured.

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FIG 1 Gazelle Pilot B being filmed by observer with hand-held fish eye lens cine camera.



FIG 2 Frame from fish eye camera film showing Pilot flying NOE and operating badly positioned radio.

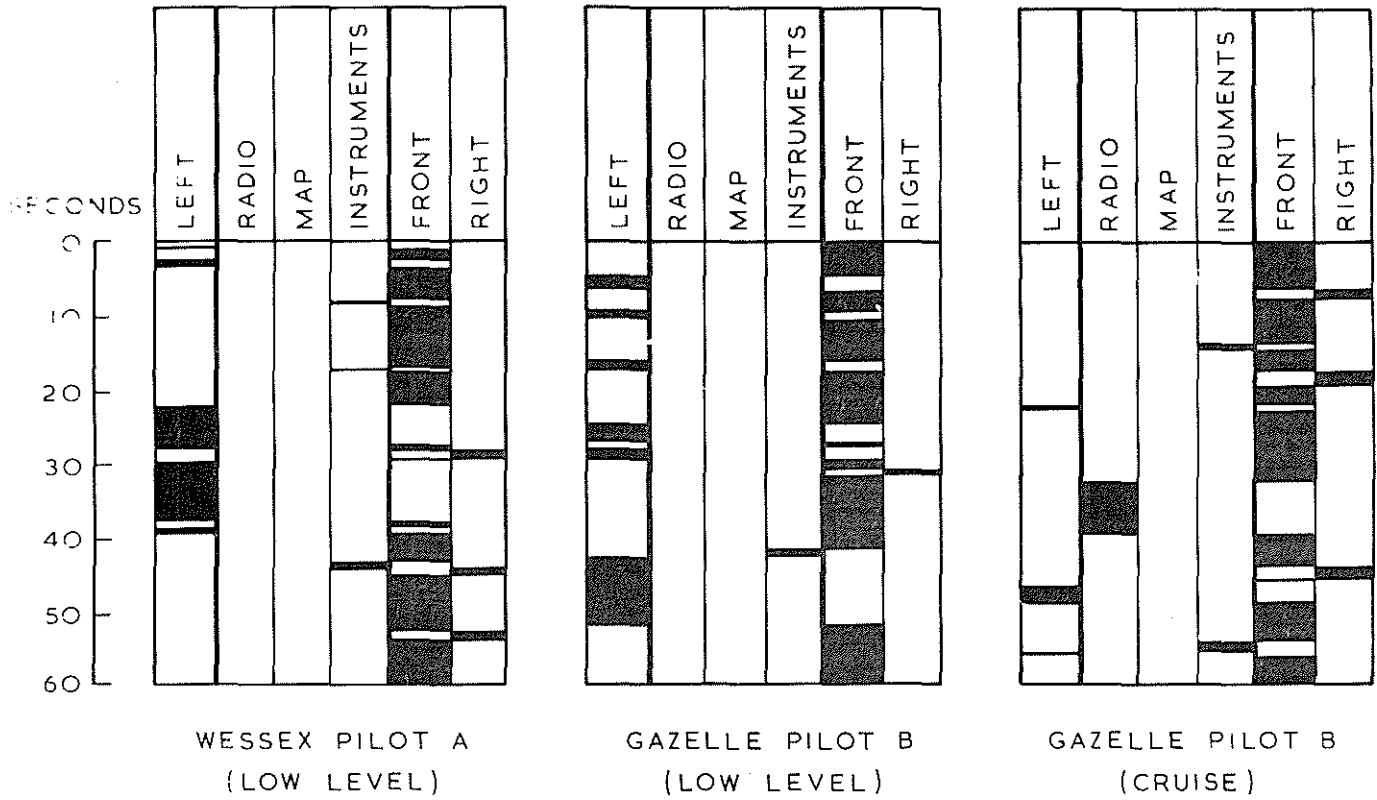


Fig 3 Typical pilot's head activity patterns for low level and cruising flight

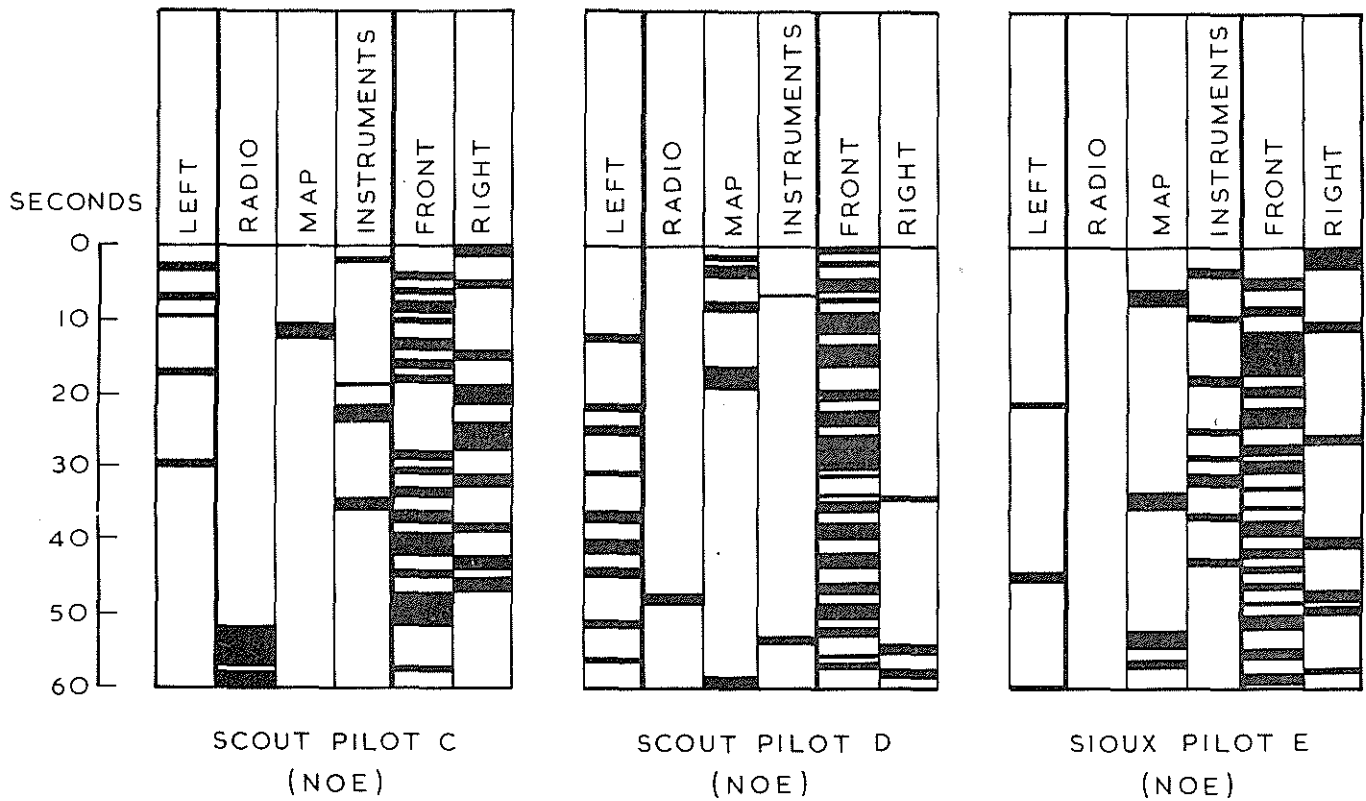


Fig 4 Typical pilot's head activity patterns for nap of the earth flight

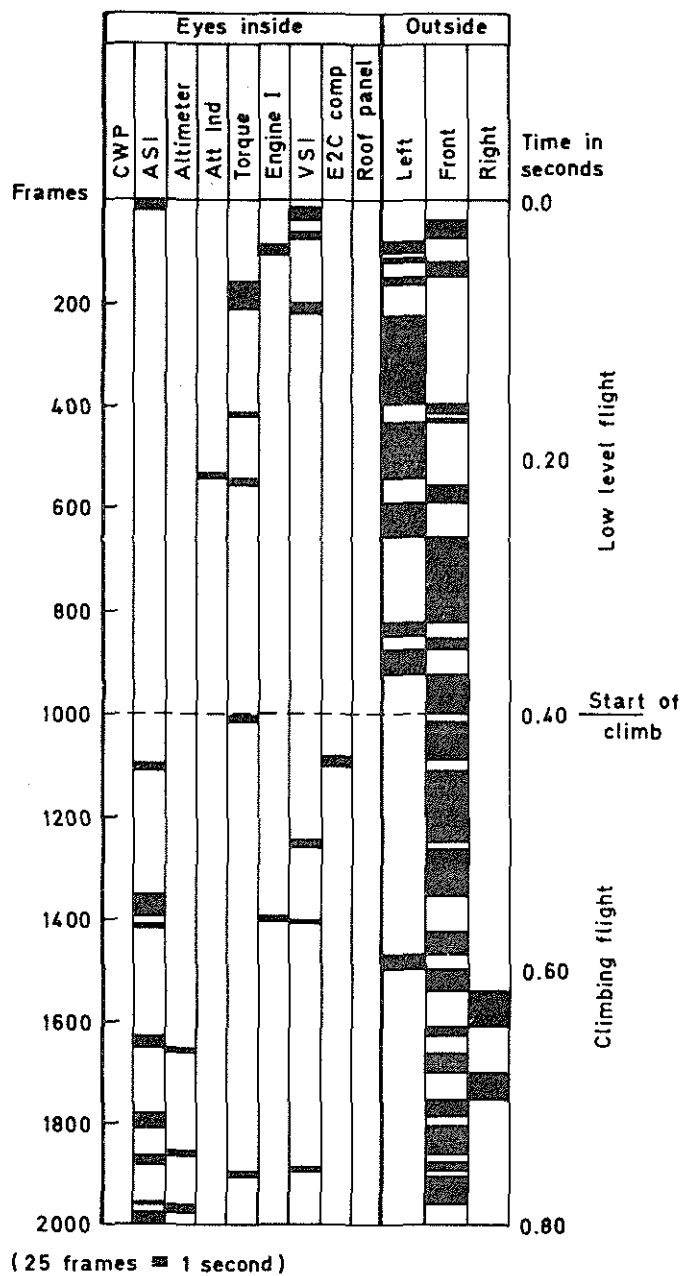


Fig 5 Gazelle pilot's visual activity during low level and climbing flight from 'Eyemark' record