METHODS IN DISPLAY DEVELOPMENT

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Abstract

Current and future helicopter missions are placing emphasis on assimilation of information by the crew. Flexible electronic displays are now available, so that almost any display format can be produced. The current project explores the options of information display and aims to produce a suite of formats which will use the CRT technology to best advantage. This paper describes the methods used to develop helicopter dipslay formats for future use, under contract to RAE Farnborough.

Original format concepts are generated by psychologists, working from first principles of perception, and also by operational Service Pilots and Test Pilots during group sessions. These formats are then subjected to a rigorous three stage process of evaluation and modification. The formats are progressively assessed in static, animated, and fully simulated forms. Assessment trials are conducted as formal, controlled experiments, involving the measurement both of subjective reaction, and objective performance data. Statistical analysis of data is performed to identify real performance effects as distinct from random variations.

Introduction

Current and future helicopter missions are placing greater emphasis on assimilation of information by the crew. The information can comprise a wide range of flight and mission parameters. Under high workload conditions, the pilot has only a short time in which to react to complex information, which may include tactical threats or flight critical warnings.

Flexible electronic displays are now available, both for instrument panel and helmet mounted application. This has introduced a new genaration of problems in the development of display formats, because almost anything is possible.
From a psychological view, traditional electromechanical layouts are not an ideal means of information transfer to a human operator. Each separate indicator requires foveal vision for precise reading. This forces a serial mode of processing that is detrimental to human performance under conditions of high stress and information overload. Several approaches have been considered to overcome these problems. Head Up displays attempt to bring more information into the fovea. 'Object' displays can be used to compress information.

Currently, the formats presented on these display heads are little more than electronic mimics of traditional electromechanical instruments. At Westland, a comprehensive research programme is underway to develop new kinds of display format which will take full advantage of advanced display technology. The formats are intended to reduce pilot workload and maximise mission performance. The programme addresses systems, tactical and primary flight displays for head down presentation, plus helmet mounted display formats.
In the past, formats have been designed by engineers, and assessed by pilots in an informal, subjective way, highly dependant on the idiosyncratic preferences of the individual. This has led to a high number of iterations, conservative format designs and under-utilisation of technology with no gaurantee that all pilots will perform well using the display.

There is a need for a more thorough, scientific approach, which explores the best methods of data presentation, unconstrained by obsolete technology. This requires creative input from a wide range of sources, and structured assessement using a large number of pilots.

Under contract to RAE Farnborough, a large scale study is being carried out at Westland to develop new helicopter display formats.

Format Generation Method

Original ideas for new display formats have been contributed by diverse sources. These have included operational pilots from all three Armed Services (Navy, Army and Air Force), Test Pilots from the Armed Forces, industry and RAE, an independent Industrial Designer, a University Psychology Department, and psychologists and engineers from industry.

Pilots from the Armed Forces produced formats for HMD and CRT primary flight displays.

Contributions from the Armed Forces were obtained during one day visits to establishments. In each case, 12 operational Service pilots were thoroughly briefed on the aims of the project. Existing 'state-of- the-art' display formats were discussed. The pilots then worked in groups of three or four, to generate a new format idea for a given application. Each group worked towards a different aim, eg an HMD format for NOE flight, or a fuel usage format to be displayed head down, etc. Group effort on the format continued for an average of 2 hours, followed by a break. One representative from each small group in turn then presented their format idea to all 12 participants, explaining each element, and the rationale behind the design. The format was discussed by the whole group, and in some cases modified, until all participants agreed that the format was at least acceptable. This format was then recorded in detail, including a written description of the mode of operation of every element.

Industry Test Pilots produced formats for HMD Primary Flight Information

Contributions from industry Test Pilots were requested by written briefs, and were prepared individually over a period of weeks. Their briefing suggested that they began by listing all of the instruments which they considered to be absolutely essential for a helmet mounted presentation. They should then consider how each instrument could be best represented, and finally arranged these elements into a complete format. Test pilots who endeavoured to use this method reported that when they constructed a format which included all of the information which they had listed as essential, it was so overcrowded that they would not have been able to view the outside world behind it. They also discovered that when the individual elements were combined into a complete format, the criteria by which they are evaluated may change, eg it is important that the elements are noticeably different from each other. Therefore the Test Pilot subjects went through a number of iterations before their format proposals were submitted.

The Industrial Consultant produced formats for HMD and CRT Tactical displays.

The industrial design consultant was subcontracted and worked independently, after a thorough briefing and discussion. His extensive experience in the defence industry formed a useful basis, because the requirement was to represent tactical information from both HMD and CRT displays.

The University Psychology Department produced formats for CRT systems displays.

The undergraduate psychology students were briefed on the information to be displayed, and the main criteria by which it would be evaluated, eg readability, attention getting, minimum likelihood of confusion. The students then worked on producing formats from the first principles of information presentation, without experience of conventional formats for the display of this information.

Established principles of psychology show that global features of a complex, integrated display are processed more quickly than details of separate items of information. Spatial proximily makes it more likely that items of information will be processed in parallel (quicker than serial processing) but this will not necessarily occur if the items are perceived to be unrelated. One technique for integrating data both spatially and in terms of meaning involves the use of 'object' displays.

In an object display multiple data are combined as attributes of a single object (eg a polygon) for operators who need to combine information from multiple data in order to make a single decision.

Many simple and well proven rules were also applied, eg displays which are used frequently should be located centrally; displays which are sampled sequentially should be located close together; important displays should be the most salient.

They then conducted a comparative evaluation and submitted their best designs to the study.

The format generation process produced in excess of fifty original formats. In order to identify the most promising examples for further development, the formats underwent an evaluation process.

Evaluation

A three stage process of evaluation and modification was adopted. Each stage served as a 'filter' to select those formats with sufficient merit to justify further development. The three stage process is progressive, becoming more thorough and realistic (and therefore more expensive and time consuming) at each step. Every stage used both objective performance measures and subjective opinion to assess each format.

Measurement of both sujective and objective data has several advantages. In the past, pilots have subjectively assessed two formats to have equal merit, but make many more mistakes using one particular design. If purely subjective methods are used, this will not be detected. Objective measures used alone may show which formats have merit, but cannot show why, or how they can be improved. This dual data collection methods is also useful, in that when a test mission is repeatedly flown with different formats, the pilot will tend to use one of two strategies. He may keep his effort at a constant level - in which case the variation in format merit should affect his objective performance. Alternatively, he may attempt to maintain performance at a constant level, which will be easier with good formats than with poorer examples. In this case, variation in merit will be apparent in the subjective measures.

This empirical method of development produces suites of display formats which will benefit real mission performance. It also identifies good and bad features of display elements to support modification, and future design work.

Static Evaluation

Each of the original format concepts was plotted on a computer grahics package (Pluto-designer) to produce a paper hardcopy in standardised form. The evaluation was carried out by representatives of the pilot groups who had originally generated the format ideas. This involved two pilots from each of the armed services, two test pilots from RAE and two from WHL. The assessment procedure lasted, on average, one hour per format. Since there were more than fifty formats to be assessed, not every format was seen by all pilots.

The subjective assessment was conducted first, to fully familiarise the pilot with every element of the format.

This began with a briefing. Then, each individual instrument was assessed in turn. The pilot considered the instrument on each of the following criteria:

- Inclusion: he rated the extent to which the information given by the instrument should be included in the format (irrespective of the way it was presented in this example), by selecting one of four ratings: i) unnecessary, ii) useful, iii) desirable, iv) essential.

- Form: he rated the form in which the information was presented (eg strip gauge, digital readout, dial) by selecting one of four ratings: i) unacceptable, ii) acceptable, iii) good, iv) ideal.

- Position: he rated the position of the instrument on the format layout (ratings as for 'Form' above).

- Mode of Operation: he rated the logic by which the instrument functioned (eg non-linear scaling, symbols which are present or absent according to the value of system parameters, etc) (ratings as for 'Form' above).

- Colour: he rated use of colour in the instrument (ratings as for 'Form' above).

- Core/Selectable: he rated whether the instrument should be always present (core) or selectable ie to be selected either manually by the pilot, or automatically by the aircraft systems ratings were simply i) core, or ii) selectable.

Finally, the complete format was rated as an integrated whole.

The objective performance assessment was conducted using a controlled exposure tachistoscope. This device presents the format to the pilot for one second only. The pilot was given a written description of a flight envelope, indicating maximum and minimum values for major parameters. Examples of the format were presented to the pilot for one-second exposures. The pilot then rated the flight regime shown by the values on that format as being inside or outside of the flight envelope specified. The procedure was then repeated for a second set of examples of the same format shown in monochrome, to asses the value of colour coding. Formal non parametric statistical procedures were used to analyse results.

This evaluation procedure is structured, so that results from different sources can be compared directly. It has the advantages of being portable, inexpensive, and relatively quick, such that large numbers of ideas can be evaluated by a wide audience with minimum resources.

When the static evaluation was complete, the most promising 20 formats to proceed for animated evaluation were selected based on both pilot acceptability and objective performance measures. A format whose results were universally good would be preferred to a format with variable results, eg rated ideal by some pilots but unacceptable by others. The formats which were selected for further development were modified in accordance with pilot comments before proceeding for animation.

Animated Evaluation

The animated evaluation was carried out on a fixed base simulation at WHL. The cockpit provides a full set of flying controls, 3 head down CRT's in an instrument panel; a large monitor head up showing a CGI outside world on which helmet mounted display formats can be overlaid. These HMD formats do not move with the pilots head but remain in position, as a fixed wing HUD would do. This is not ideal for HMD evalution but provides an inexpensive means of flying animated formats.

General Procedure

Each format type is assessed in isolation. Evaluation of all format types followed the same general procedure:

i) Briefing:

The format will be explained to the pilot in detail. Each element will be identified, and its mode of operation described.

ii) Familiarisation:

Free flying time will allow the pilot to familiarise himself with the simulation, and the display format (animated). This will take place on a separate 'Practice' terrain. No datalogging is required.

ii) Practice:

Flying on the test terrrain the pilot will practice the tasks which will be used during the test sequence.

iv) Test:

For each format type, there will be standardised test procedure, consisting of a sortie containing specific stylised tasks. Objective peformance measures, and strucutred subjective responses, are recorded.

v) Debrief:

Discussion and general comments on the format.

The test procedure consists of a mission which the pilot flies through a purpose built test terrain. The mission consists of a series of tasks. These appear as a continuous mission to the pilot, but for the data-logged software and trials analysis the tasks are considered to be completely spearate. Each task is designed to assess a different part of the display format - either an individual instrument, or the co-ordinated use of certain groups of instruments.

Throughout test sequences, all major flight parameters are recorded. For every task, there is a primary objective measure, which tested the extent to which the pilot was 'successful' at flying that task. For example, if the criteria was to fly a particular manoeuvre 'as fast as possible', then the primary objective measure would be 'time'. However, it is not adequate to record the primary measure alone because, for example, in an effort to achieve the main criteria, they may sacrifice other aspects of the task, eg, fail to maintain the correct height or ground track. Since it is easier to achieve the main criteria on those occasions when not attending to other aspects, this would give the false result that the formats used on such occasions were superior. Therefore, all other relevent flying parameters were monitored throughout each task. Provided that each parameter was maintained within proscribed maximum and minimum limits during the task, it was not logged and the results from the primary objective measure were considered valid. This procedure ensures task standardisation across all formats. If any parameter strayed outside the permitted limits at any time during the task then that task was abandoned as non-valid, and repeated. (In practice, this seldom occurs).

Trials are ongoing, but once the data collection is complete, formal statistical techniques will be used to compare results of different formats for each individual task, and total results for the overall mision. Comparison of results for each task may indicate the merits of particular instruments/ configurations for specific applications and this information will be used to improve seleted formats before they proceed to simulation. Comparison of results between formats are tested for statistical significance.

After each mission flown, a subjective assessemnt of each format was carried out. This procedure was identical to the subjective assessment of the formats in static presentation, but with one additional criteria relating to movement.

A different set of tasks were flown to assess each different format type. As an example, HMD primary flight formats wre assessed as follows:

Test Procedure for HMD Primary Flight Formats

i) Briefing

ii) Familiarisation (Practice Terrain):

For the first occasion when the pilot uses the simulation, 5 mins flying the simulation with no displays, (except the 'outside world' terrain). On each occasion, 5 mins further flying with the helmet mounted display (HMD) format superimposed on the outside world. The pilot may be asked to read values from the HMD during this time, to ensure correct understanding. No head-down displays are presented.

iii) Test Sequence (Test Terrain)

Throughout the test sequence, the HMD format will appear superimposed on the ouside world display. No head down displays are presented. The test sequence will be flown once for practice, then the second time as a test with performance recorded.

Tasks are as follows: (primary measures shown underlined)

T1 Hover at 15 ft, with heading of x°, (measure groundspeed, height, heading).

T2 Transit from hover to forward flight, with a nose down attitude of 7°, to 150 kts, 500 ft. (Measure attitude, airspeed and height).

T3 Turn right onto a specified heading, with a bank angle of x°, (measure bank angle, sideslip, height, speed).

T4 Turn left onto a specified heading, (as for right turn above).

T5 Decelerate to 90 kts, reduce height to 100 ft, (measure attitude, speed, height).

T6 Decelerate to 40 kts, reduce height to 20 ft (measure attitude, speed, height).

T7 Follow an irregular path drawn on the ground at 40 kts, 20 ft. (Measure height, speed, RMS error from centre of aircraft on track of line).

T8 Follow sloping terrain at 40 kts, 20 ft, (measure speed, height, heading).

T9 Fly around trees (or other obstacle) which are blocking the track, and return to it as soon as possible (measure height, time off track).

T10 Fly towards trees (or other obstacle) and decelerate to hover @ 10 ft in front of them, on marked spot (measure time taken between crossing software 'gate' on the terrain and achieving hover for 3 secs within x distance of hover spot, height).

T11 Bob up above tree height to identify some distant ground feature (a large alphanumeric) and return to 10 ft hover, maintaining ground position and exposure time above tree height as minimum (measure ground speed/position, height, heading, time above tree height).

iv) Debrief

Each element of the display will be discussed, and pilot opinion recorded in a structed manner.

For other format types, an alternative mission was used, eg for Tactical Formats.

Test Sequence (Test Terrain)

The test procedure will consist of a mission to attack an enemy target, and return to base. Before flying, the pilot will be told the co-ordinates of the enemy position, and shown a paper copy of his head down display (the battlefield plan). He will be asked to draw his planned route on the paper.

He will then attempt to fly the planned route through the outside world terrain. During this flight the head-down battlefield plan will be displayed. The controller will enter waypoints quickly at the trial operators station of the route to be displayed on the head down plan, during the trial. The primary flight (non-selectable) elements of the HMD will be overlain on the outside world. Steering information will not be shown. When the enemy position is reached, the pilot will attach the target with a missile. This would be extremely simple and involve the pilot pressing a button in the cockpit. The missile would be released and hit the target simply by the virtue of the button being pressed. The route actually taken by the pilot through the battlefield areas would be logged, for comparison with the planned route.

When the target is destroyed, the pilot will select the steering information for the HMD. This will require the operation of a second button in the cockpit. The steering information will direct him down one of three possible routes back to base, selected at random by the simulation. All routes will be of comparable difficulty, and will be defined in software only, ie, they will be not be identifiable by terrain features. The return route of the pilot should be logged, for comparison with the predefined path. This should be an RMS value for deviation from track in X and Y, and percentage of flight time during which the aircraft exceeded the 'safe ceiling' for Z.

Airspeed will be specified to the pilot (eg 60 kts) and should be logged as time spent outside a given tolerance of that value, (eg ± 5kts). Finally, the pilot will land at a helipad; no logging required.
NB. this procedure requires the pilot to operate two 'live' buttons in the cockpit.

Simulated Evaluation

Full simulation has not yet been carried out but is planned for the near future. It will use the full motion based simulator at RAE Farnborough with detailed model board terrain. The most promising examples of primary flight display formats for both HMD and CRT presentation, plus systems display formats will be used.

The animated trials examined formats in isolation, but in the simulator all three display types will be presented together for co-ordinated use. Tactical displays will not proceed to simulation because of system limitations. However HMD formats with tactical elements such as weapon aiming symbology, will be flown.

HMD formats will be presented on a full helmet mounted display worn by the pilot, including a helmet positioning system. Symbol movement (relative to the head, the aircraft or the outside world) to be investigated.

The general plan is to evaluate all possible combinations of the proposed formats in a realistically difficult flying environment. The objective is to discover the best formats for each form of display and to evaluate these formats in conjunction with each other, to study any potentially detrimental or advantageous effects of particular combinations of formats. Evaluation of each combination of formats will follow a similar procedure to that used for the animated trials, although mission tasks will be modified to take advantage of simulation.

Data Analysis

Objective data from all three phases of evaluation are analysed using nonparametric statistical techniques. This type of analysis is uniquely suited to data from trials involving a human operator. It does not assume that the scores under analysis were drawn from a population distributed in a certain way (eg from a normally distributed propulation). Also, it can accept data which is not of true ratio quality, (ie the rank relationship and distance between data points is known, and the scale has a true zero origin). Nonparametric analysis can accept data without a true zero (interval data), and even data where the distance between points is not known, as for ranks (ordinal data).

Tests are applied as appropriate, but most commonly the Wilcoxon, Mann Whitney, Friedman, Spearman and Kendall analyses are used.