COCKPIT AND HUMAN FACTORS

INSTRUMENT SCANNING IN NEW COCKPITS

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1. INTRODUCTION

1.1 In the frame of the studies conducted in the Human Factors Research Department of AIRBUS / AEROFORMATION as well in the area of fondamental research than applied research for training, an oculometric study of the visual scanning has been made in A310 and A320 full flight simulators, during ILS and VOR/DME approaches.

The primary objective was to determine if the research and acquisition of information was made in an identical or different manner related to the fact to be in an :

- A310 with cathodic ray tubes of 6 inches one above the other (Primary Flight Display above Navigation Display) and with classical electro-mechanical instruments, as speed indicator, altitude and vertical speed, VOR and ADF indicators.

- A320 with only two cathodic ray tubes of 7 inches, located one at side of the other, and including all the information necessary for the flight.

Following the results, the aim of this study is to obtain an improvement of the pedagogy (transition from a classical "steam gauges" cockpit, or semi-classical cockpit, to a full glass cockpit) and if necessary to make some recommendations on ergonomy.

1.2. For that we used the technical means of oculometry and we worked in close collaboration with the specialists of the PRODEC laboraty on the French Rouen University ; they have insured the practical realisation of the measures and the writing of a report on the pure oculometric point of view. AEROFORMATION has provided the bringing into operation of the simulators and the cooperation of the subjects participating to the experimentation (simulator instructors, test pilots, instructor pilots, and at the end participation of an A320 Air France Captain) ; we have also fixed the flight profiles, participated to all the measure's sessions, the processing of the records, the preparatory meetings for the final report, and the writing of the general final report.

2. EXPERIMENTAL DEVICE

2.1. We used a Japanese oculometer, NAC 5, normally used by the PRODEC laboratory. It is made of a sort of helmet weared by the subject on his head, including :

- a video lens recording the scene in front of the subject

- two infra-red leds sending on the cornea of each eye luminescent ray that is reflected by the cornea, and that incrust on the general view, a cross pointing the place where the eye of the subject is focused.

In the simulator it has been possible to equip both pilots with this device, and to place all the material necessary to follow in real time the good recording of the session.

2.2. This system has a certain number of limitations that are interesting to know in order to understand the choice of the sequences of flight and the limits of the results.

- In order to avoid that the calibration of the NAC 5 (initial setting of the cross on definite points looked by the subject) lifts with time, it is necessary that the helmet be firmly tied on the head of the subject. So after a certain time it is boring and tiring for him and it is mandatory to stop the experimentation. So we have been obliged to record rather short phases of flight, no more than 10 minutes, and finally we have selected two types of approaches, an ILS and a VOR/DME, each having a duration of no more than 10 minutes. The interest of the approaches is that they are typical of a high workload period and require a good crew coordination, very interesting to study.

- The data processing is made manually, frame after frame, so it is very long ; it represents roughly 8 hours of work for 1 minute of recording, including the necessary cross-check.

- And finally we know that it is not because the eye is spotted on a point that the subject takes only the information placed on this point ; he can work with "peripheral" vision and catches other information, or have a second of rest, or to be distracted. So after each session it is necessary to show the movie to the subject, and he makes his comments, he verbalizes his intentions, he explains his strategy.

3. METHODOLOGY

3.1. For this first phase of our study we worked with subjects that are, or have been, Captains, acting as standardized crews, using the AIRBUS standard procedures. The pilot in the left seat was the Pilot Flying (PF) and the pilot in the right seat was the Pilot Non Flying (PNF). We worked with 6 simulator instructors, 2 instructor and check pilots, 2 test pilots, 1 Air France A320 Captain.

3.2. We have selected on each CRT the "zones" interesting for the information needed for the flight, so that the person in charge of data processing is able to plot the good area.

We have defined 25 zones in A310 and 24 in A320.

For examples : speed, speed trend, altitude, vertical speed, FCU, FMA, etc...

3.3. As written before we have studied only two types of approaches ILS and VOR/DME and we have never introduced any failure of systems or bad meteorological conditions, to avoid too many different parameters, and have a common basis of comparison for all the approaches.

4. GENERAL RESULTS

4.1. Taking into account the statiscally speaking low numbers of subjects it was very important to judge the validity of the results, using the current tools of statistics.

The first criteria is the "inter subjects" stability, that means to check if in a given situation, the different subjects give the same priority to the different zones.

In other words we must know if even with the individual differences observed between the subjects, they put the same hierarchy in the different zones of interest. This study is made through the criteria named W of Kendall, computed on the duration and the frequency of study of the zones and their mean average.

Through this study it appears that within a given situation, all the subjects are stable in regard of the above criteria.

That means that as well as in ILS than in VOR/DME the hierarchy of the sources of information is reproduced for both types of aircraft (A310/A320/and both roles in the cockpit (PF/PNF)).

4.2. Another interesting result is that the time devoted to the different zones, so to the various instruments and/or sources of information, is proportional to the number of consultations made in this zone.

5. <u>DETAILED RESULTS</u>

5.1. <u>One airplane, one approach, five pilots</u>

The first part of this presentation will be related to the A320, to an ILS approach, with five different pilots, all seated on the left hand seat and acting as pilot flying. Obviously, they all have a common "anchoring point", that means the zone around which they organize their visual pattern, and it is the Flight Directors bars ; this is very interesting because they are a synthetic representation of a lot of information, so it is extremely important to use them to have the "big picture" of the situation.

Otherwise, we have seen that around this common basis they develop different visual strategies.

- Former military pilot on simple seaters, then a short experience on general aviation, now for a very long time simulator instructor, flying occasionally on a light aircraft. He has a very expansive strategy with frequent changes from one point to another ; secondary anchorings are made on ILS indications, on Flight Monitoring Annunciator and a little less on Flight Control Unit ; this is normal because as an instructor in charge of the standardisation of courses, he insists very often on the necessity to use and crosscheck FMA and FCU. In the end of the approach, he his more closely monitoring the vertical speed than at the beginning and he does not use at all the peripheral vision.

- Former navy pilot on heavy patrol aircraft, now simulator instructor but for a shorter time than the previous, and chief pilot of an aeroclub, so flying frequently. His strategy is very economical, the secondary anchoring is on ILS indications, and there is a light anchoring in Navigation Display.

- Former military pilot with a strong experience on tankers, now simulator instructor for a few years. He has a very particular strategy, anchoring on the first half of approach on FMA and less on FCU, then on the second half anchoring on FD bars and ILS indication, then Radio Altitude. This strategy is rather economical in the first half, less in the second.

- This subject is a test pilot, former military fighter, but having acted as an airline pilot for 9 years before joining Airbus. His ocular strategy is typical of an "expert" one, very economical. We must not be abused by the frequent movements from FD bars to FMA because FD bars are in the middle of the Primary Flight Display, and FMA is in the upper part, the distance between them beeing less than 3,5 inches. We observe also the use of peripheral vision that is very economical to have a general view of a situation.
  We have seen this strategy on most of the pilots.

- This subject is an instructor pilot, former military fighter pilot in combat units of very high level, and he has kept from this period the habit to have accurate looks on several points. So, he uses very often the peripheral vision, the altitude , the outside ; in summary he is the exception among the pilots.

5.2. A Crew

Now, we study a crew made of two test pilots, the pilot flying being a test pilot, former military fighter, but having acted as an airline pilot before joining Airbus Industrie, the pilot non flying having been for ten years a navy pilot on heavy patrol aircraft, then for ten years an airline pilot ; they are both flying an A310 in a VOR-DME approach.

We observe a very good complementarity and task sharing between the two pilots ; the PF is strongly anchored on FD bars, monitors the flight parameters speed, altitude, etc... and has a strong use of the peripheral vision, and finally his ocular scanning is rather expansive.
The PNF has a very economical strategy, and uses moderately the peripheral vision ; he cross-checks some parameters with the PF and monitors some others more specifically.

5.3. Permutation of roles

We have studied two pilots exchanging their roles of PF and PNF during two successives VOR-DME approaches on an A310.
Pilot X has been a military pilot, mainly on fighters or light bombers.
Pilot Y has always been a civil pilot, flight instructor on twin propjet aircrafts. Both are now simulator instructors.

First, we found that pilot X has a less economical visual strategy than pilot Y, whatever are their respective positions.
Pilot X had the habit to be on a single seater so, when he acts as a PNF, he has a strong tendency to closely monitor what the PF is doing and his strategy is more expansive as PNF than as PF.

Pilot Y has been instructor for a long time, he is used to the role of non directly piloting crew member, and so at the opposite of pilot X his strategy is more economical when he acts as a PNF than when he is a PF.

Anyway, we have observed that again there is a very good task sharing and complementarity between the two pilots.

5.4. One pilot, two airplanes, two types of approach

We come back now to a pilot acting as a PF in different situations. Generally speaking, he has an expensive strategy, "beaming" from an anchoring point FD bars, just a little bit less used in A320 VOR-DME approach.

Except this common characteristic, he uses secondary anchor points, more or less, related to different types of aircraft or approach :

- ILS indications when flying an ILS, A310 or A320.
- Flight Control Unit is less used in A310, ILS.
- Navigation Display is mainly used in VOR-DME, A320.
- Altitude is mainly used in A310, because on this aircraft, the altitude is not presented on the Primary Flight Display but on a separate classical instrument.

5.5. One pilot, one airplane, different roles and approaches

Finally, we come back to pilot X flying now on A310, as PF or PNF, in ILS or VOR-DME approaches.

For him, whatever are the aircraft and his position on board, his anchoring point is mainly FD bars.

His strategy is not very economical ; interestingly enough he uses widely the peripheral vision, excepted when he acts as a PNF in an ILS on A320, having at this time his most economical strategy and spending a long time reading his documentation.

6. CONCLUSIONS

So, we have seen that around a common behaviour, each pilot has his ocular strategy, related to the aircraft, to the type of approach and to his role in the cockpit.

Through the interviews we have conducted with the participants to this experiment, we have understood that even if this behaviour is not fully conscious, as soon as the pilots see their scanning on a screen, they are able to immediately explain why they do so, and they have a strong memory of what they have looked at, during the approach.

It has been also obvious for us that the presentation of information on CRTs changes the scanning, compared to a classical cockpit with different separated gages on instruments, but that allows the pilot to have a more economical ocular strategy ; with CRTs and with synthetic presentation like the Flight Director, when a situation has been well established, the use of the peripheral vision allows to monitor the flight parameters with a minimum of ocular expense.

Finally, to help pilots having difficulties with the use of CRTs, for any reason, we intend to develop a pedagogical tool, that could be a video showing the visual pattern of an "expert" pilot during different types of approach, with the pertinent comments of this pilot.

We also intend to continue this study, with an other type of oculometric helmet, more easy to wear and more reliable on the stability of calibration, with airline pilots of different ages and qualifications, and in flight, but in this case for obvious safety reasons, only one pilot will be equipped with the helmet.