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Pilots' Performance in Changing from Analogue to Glass Cockpits

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Abstract

This article discusses the problems of pilots' performance when displaying the flight and navigation data changes from an analogue to a glass cockpit depiction. We have focused the research activities on the performance of pilots who have flown less flight hours (approx. up to 100 flight hours) only with an analogue display, in their short aviation career, or who were absolute beginners and had only basic experience with instrument flying. The task of the research is to confirm a hypothesis that display changes will have less negative impact on pilots' performance if a new training and practice method using flight simulators precede the changes. For measuring the performance of pilots we have created two methods: precision of the piloting techniques and power load level. Research flights were conducted on a flight simulator and on a real aircraft. During the research, two groups of pilots were being compared. The first group of pilots completed the display changes according to current procedures and the second group of pilots according to the new training method. This article presents the research methodology and the results of measurements.
KEY WORDS: *pilot, pilotage, human performance, aircraft, cockpit, simulator, stress, workload*

1. Introduction

This paper is considered for an output of a project named as "Research on pilots training methods by utilization of flight simulators". ITSN project code is 2622022016. The project was cosponsored by EU funds and carried out by Education training & consulting company (ET&Cc) in cooperation with The Faculty of Aeronautics of Technical University in Kosice (LF TUKE).

A strategic goal of the project was characterized as a research of the security increase in civil aviation realized by ET&Cc. The research process utilized an effective cooperation with a research and development institution of LF TUKE and a follow-up implementation of the findings into commercial environment [9].

After analysing current simulation trainings for pilots it proves that the display transmission of basic flight data, navigation data and engine outputs on a cockpit displays have an influence on pilots performance. There are pilotage techniques effected and those are introduced in forms of deviations on an actual airplane position and actual flight trajectory off standard flight and navigation parameters [10]. Current trends in display of core flight, navigation and engine data on airplanes instrument board is heading to a consistent switch from the standard analog ones to glass cockpits. On principle, later ones can considerably change the display concept of outputs needed for pilotage and aircraft navigation.

It was anticipated that data display has different influence on various pilot categories and depends on pilots trainings, number of flight hours, career time and etc. Some the most significant influence on pilots performance resulting from data displays transformation were hypothesized for following combinations:

- switch from analog to glass cockpits and its influence on analog cockpit flown pilots;
- switch from glass cockpits to analog and its influence on glass cockpits flown pilots;
- cockpits desk switch to any of above displays and their influence on any cockpit flown pilots. However, the switch is enforced with some long term perspective.

Following up analysed outputs, hypothesis were designed for the project research. The hypothesis represents new knowledge in below areas:

"Following up analysed outputs we anticipate that transformation of an airplane cockpit from analog to glass one has a negative influence on pilots performance. This refers to pilots who during a short pilot career had analog cockpit experience only, flew less flight hours (app. up to 100 flight hours) or they are novice and have only basic experience with instrument flights"

This pilots category will form 1st test sample and called as beginners. We assume, prior to the display change, the new training method will be passed then the switch will allow for less negative impact on the pilots performance [10].

During the research, the influence on pilots performance after the transmission of flight and navigation data display was assessed by measuring of a precision on pilotage technique and pilots workload. The pilot workload level was defined for the project use as a deviation of defined psycho-physiological pilot parameters off earlier defined designator parameters for the same pilot.

Measuring pilots performance by measuring of workload level and stress factors on pilots has already been attracting time long attention. Most of studies in this research area have been dealing with a psychological load on a flight crew. Various studies admitted that increasing the workload level might result in a faulty perception, lack of attention or weak output data processing. Mentioned workload factors gives a negative influence on the safety in civil aviation. Today´s statistics show a fact that the human factor plays a key role for airplane crashes.

One of 1st studies were carried out at an air base in Arizona in 1977. The study was focused on stress producing factors and their influence on pilots training. Their experiment followed up studies which confirms the stress factor on pilots behaviour changes and culminates in faulty pilot decisions. Some similar studies proved evocation and presence of a stress in piloting, respectively in simulator training. [1, 3, 6, 7].

Another study focused on evaluation of stress and its factors on any professional duty performance. A variety of daily life factors were considered among others interpersonal relations, family matters, life style etc. Research findings proved an urgency for programmes of the stress control and stress resistance which will lead to operational improvements of crew performance [8]. In Wilson and Fisher study we find measurements variety of pilots physiological parameters which define stress load at certain flight sequences. The study was dedicated to forming appropriate physiological parameters and their combinations for detecting pilot conditions at certain flight phases (a level of pilots workload).

Most studies applied a couple of different parameters for the measurement of psychological and physical load among others heart rate, breath rate, eye blinks, myopotecial temperature, blood pressure etc. [2-5, 8, 11-14]. Parameter outputs were evaluated by different methods of data collections and evaluation by various sensors types application.

Nowadays, there is no stable method for evaluation of the physical and psychical load although the issue of a stress load evaluation in aviation seems to be quite elaborated. Above all, an abstention of methods applicable on different types of aviation positions that can eliminate stress load and performance increase factors is notable.

2. Methodology

The tested pilots group for the research was completed of pilots with a short flying career path, experienced in analog cockpit displays and flew less flight hours (app. up to 100 flight hours), or there were novice only with a basis instrument flight experience.

The sample group represented 20 pilots. The half of the group passed a conversion from analog to glass cockpits after an implementation of the current training standards recommended for the switch of analog to glass cockpits displays.

Another half of the tested group passed the conversion to glass cockpits displays after an implementation of the new training standards recommended for the switch of analog to glass cockpits displays.

Mentioned the new methodology was exclusively designed for this project research. While relocating pilots to the Groups A and B, a special attention must have been paid to an equal separation according pilots´ past flying experience and their performance, the measured findings from previous experiments applied here.

In this paper an influence of flight and navigation data display switch was reviewed by measuring of the precision of pilotage technique and level of pilots workload. The precision of pilotage was in this project defined as a divergence between real flight parameters at certain flight phases off standard flight parameters.

The workload level in this project was defined as a divergence of selected psycho-physiological pilots parameters off defined assumed level of those parameters for the same pilot.

For this research all flight phases practiced by airplanes and flight simulators (pilotage in working zone) were arranged like instrument flights involving some partial utilization of a normal horizon flight. (proportionally app. 80 % instrument flight and 20 % normal horizontal flight)

At the beginning of the research, a theoretical lesson in basis of pilotage was given for the novice group (the lesson time was 1 hour). Next, the group was familiarized with a simple pilotage technique by an analog display flight simulator (the lesson time was 1 flight hour).

The 1st measuring of pilots performance was arranged upon completing the first practice on the flight simulator:

– Through deviations identified in real flight parameters at defined flight phases off standard parameters during a simulator flight equipped with analog display (the lesson time 1 flight hour). Deviations were recognized during:

- rectilinear horizontal flight – a deviation measured in height and flight track;
- horizontal turn – a deviation measured in height, slope, and flight track;
- increasing and decreasing turn – a deviation measured in speed, slope and flight track.

– Contemporaneously by a measurement of the precision of pilotage technique, there were recorded defined psycho-physiological pilots parameters utilized in quantification of pilots workload:

- Heart rate;
- Breath rate;
- Body temperature;
- Body activity (3D actogram);

- Muscle strength.

Followed by a basic training in the pilotage technique by a flight simulator with analog display (the training time was 8 flight hours). The goal of the training was an encompassment of the pilotage and preserving flight standards during a flight:

- rectilinear horizontal flight;
- horizontal turn rotated to defined course;
- ascending and descending turn by keeping defined vertical speed and rotated to a set course.

Upon a completion of the introduction program for flight simulators with analog display, there was exercised the 2nd measuring of pilots performance by a flight simulator with analog display (lasted 1 flight hour)

The 2nd measuring of the performance and all other consequent measurements were identical as the 1st performance measuring. Then a basic theoretical training was provided (lasted 1 hour). The 3rd measurement of pilots performance was executed on-board standard airplane with an analog display (lasted 1 flight hour). Followed by a continuous training of the pilotage technique by a flight simulator with analog display (lasted 3 flight hours) and on an airplane with analog display (lasted 1 flight hour). This experiment phase concerning analog display was completed by the 4th measuring of pilots performance on an airplane with analog display (lasted 1 flight hour)

The next experiment phase allocated pilots into two groups: the Group A (pilot number 1 to 10) passed the conversion training to planes with glass cockpits by application of the current training standards dedicated to the conversions from analog to glass cockpit displays. The Group B (pilot number 11 to 20) passed the conversion to an airplane with glass cockpit display by application of the new training method dedicated to the conversions from analog to glass cockpit displays.

Group A procedure

A brief familiarization with glass cockpits according the current procedures applied for the display conversions. A number of hours mentioned below exceed real number of hours utilized in the practice. Also there is an abstention of the flight simulator training. The pilots passed a short theoretical training (lasted 1 hour), the 5th measuring of pilots performance by a flight simulator with glass cockpit (lasted 1 flight hour) and the 6th measuring of pilots performance on an airplane with glass cockpit (lasted 1 flight hour). Above mentioned process giving an explanation how the display switch (analog to glass) can have an influence on pilots performance. The results were achieved by applying the precision of pilotage technique and a level of workload utilized all together with the current standards.

Group B procedure

There was a detailed familiarization with glass cockpit displays according the new training method applied for the display switch. Pilots passed a detailed theoretical training (lasted 3 hours), a basic pilotage training by a flight simulator with glass cockpit (lasted 4 flight hours), the 5th measuring of a performance on a flight simulator with glass cockpit display (lasted 1 flight hour) and the 6th measuring of a performance on an airplane with glass cockpit (lasted 1 flight hour).

Above mentioned process giving an explanation how the display switch (analog to glass) can influence pilots performance. The results were achieved by applying conditions of the precision pilotage technique and a level of workload utilized all together with the current standards. This technique for the Group B is the new proposed training method for pilots. The method is dedicated to processes of the conversion from analog to glass cockpits. The goal of the method is a practical application and retention of pilots performance on the level as before displays switch and minimize financial costs (the training preferably by flight simulators).

3. Research Findings

The chapter deals with a performance measured findings definite for the precision pilotage technique for a pilot/individual number 1 out of the Group A as well as overall findings out of the Group A and B and their comparison.

Below reported data came from a flight instructor and formed in an absolute deviation off defined flight parameters namely a magnetic course (*Km*), height (*H*), vertical speed (*Vv*) and slope (β). Instructor´s data recorded were compared with flight records and meets criteria for an evaluation of the pilotage precision. Each measurement had 3 manoeuvre series. And every serie included following manoeuvres: rectilinear horizontal flight (a derivation verification off defined a course *Km* and height *H*); horizontal 360o turn by β 30o slope (a derivation verification off defined slope β and height *H*); ascending 180° turn by 15° slope and vertical speed of 500ft/min (a deviation verification off defined slope β and vertical speed *Vv*); 180° descending turn by a slope of 15°and a vertical speed 500 ft/min (a deviation verification off defined slope β and vertical speed *Vv*).

The hypothesis number 1 affirmation or negation has been explained in the Fig. 1. The Fig. 1 shows a comparison of the pilot number 1 performance – a comparison of an adaptation period by the simulator training focused on the switch from analog to glass cockpit displays by application of the current training standards (a comparison of deviations measured during 2nd and 5th measurement of the performance).

The hypothesis number 1 affirmation or negation has been explained in the Fig. 2. This represents a comparison of pilot performance number 1 – a comparison of adaptation period during live flying from the analog display to glass cockpit display by applying the current training methods (a comparison of deviations measured during the 4th and 6th performance measuring).

Green background reflects a lower deviation – performance increase
Red background reflects a higher deviation – performance decrease
Blue background reflects a standard deviation – stable performance

Table 1

Pilot number 1 precision pilotage – simulator flights

1. Serie				
HPL	***Km***	2	***H***	40
360	***B***	3	***H***	40
s180	***B***	2	***Vv***	150
k180	***B***	2	***Vv***	100
2. Serie				
HPL	***Km***	3	***H***	60
360	***β***	3	***H***	20
s360	***β***	0	***Vv***	100
s180	***β***	3	***Vv***	100
k180				
HPL	***Km***	3	***H***	60
360	***β***	2	***H***	40
s180	***β***	2	***Vv***	100
k180	***β***	2	***Vv***	150

Table 2

Pilot number 1 precision pilotage – live flights

1. Serie				
HPL	***Km***	6	***H***	200
360	***β***	13	***H***	150
s180	***β***	4	***Vv***	700
k180	***β***	1	***Vv***	800
2. Serie				
HPL	***Km***	7	***H***	200
360	***β***	10	***H***	180
s180	***β***	0	***Vv***	600
k180	***β***	3	***Vv***	750
3.Serie				
HPL	***Km***	2	***H***	100
360	***β***	9	***H***	250
s180	***β***	4	***Vv***	600
k180	***β***	3	***Vv***	650

A conclusion on the pilotage precision technique for the pilot number 1:

A performance in the comparison in the Fig. 1 decreased 10x, balanced 5x and increased 9x.

The performance shows full decrease in this comparison.

A performance in a comparison in the Fig. 2 decreased 12x, balanced 4x and 8x increased.

The overall performance in this comparison was decreased.

The measurement applied on the subject number 1 affirms the first part of the hypothesis number 1 – the pilot performance teamed up to the Group A (after the switch from analog to glass cockpit display by applying the current procedures dedicated for such transmission) decreased in case of a simulator practice as well as live flying.

Tables 3 and 4 report final data for the Group A achieved during the simulator and live flying.

The performance of 7 pilots out of 10 teamed up in the Group A decreased, 1 pilot achieved balanced performance and 2 pilots achieved increased performance. Regarding evaluated the Group A manoeuvres during the simulator practice, the performance decreased in 103 manoeuvres (42,92%), balanced in 54 manoeuvres (22,50%) and increased in 83 maneuvers (34,58%) (Fig. 1).

The performance of 7 pilots out of 10 teamed up in the Group A decreased, 1 pilot achieved balanced performance and 2 pilots achieved increased performance. The current training procedures applied. Regarding evaluated the Group A manoeuvres during the live flights, the performance decreased in 126 manoeuvres (52,50%), balanced in 18 manoeuvres (7,50%) and increased in 96 manoeuvres (40,00%) (Fig. 2).

The overall Group A performance during the switch from analog to glass cockpit display by the simulator practice as well as live flights while applying the current training standards, decreased and affirms the first part of the hypothesis number 1 – the performance of the Group A pilots (during the switch from analog to glass cockpit display by the simulator practice as well as live flights while applying current training standards) decreased.

The Tables 5 and 6 reports summary data for the Group B during the simulator practice and live flights.

The performance of 3 pilots out of 10 teamed up in the Group B decreased, no pilot achieved balanced performance and 7 pilots achieved increased performance. Regarding evaluated Group B manoeuvres during the simulator practice, the performance decreased in 58 manoeuvres (24,17%), balanced in 73 manoeuvres (30,41%) and increased in 109 manoeuvres (45,42%) (Fig. 3).

Table 3

Group A performance – simulator flights

subject number	performance decrease	balanced performance	increased performance	summary of performance evaluation
1	10	5	9	Decrease
2	11	3	10	Decrease
3	11	8	5	Decrease
4	6	9	9	Increase
5	12	3	9	Decrease
6	12	5	7	Decrease
7	5	3	16	Increase
8	16	5	3	Decrease
9	13	3	8	Decrease
10	7	10	7	Balanced
Total	**103**	**54**	**83**	
%	**42,92**	**22,50**	**34,58**	

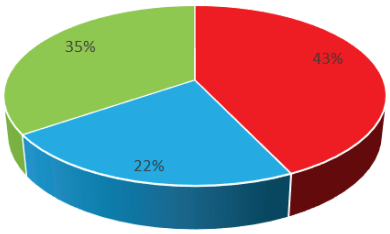

Fig. 1 The Group A, performance on simulator flights
Decreasing performance
Balanced performance
Increase performance

Table 4

Group A performance – lives flights

subject number	decreasing performance	balanced performance	increasing performance	overall performance evaluation
1	12	4	8	Decrease
2	17	2	5	Decrease
3	15	2	7	Decrease
4	12	2	10	Decrease
5	15	1	8	Decrease
6	11	2	11	Balanced
7	8	2	14	Increase
8	5	1	18	Increase
9	19	0	5	Decrease
10	12	2	10	Decrease
Total	**126**	**18**	**96**	
%	**52,50**	**7,50**	**40,00**	

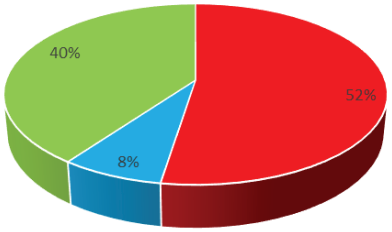

Fig. 2 The Group A, performance on live flights
Decreasing performance
Balanced performance
Increase performance

Table 5

Group B performance – simulator flights

subject number	decreasing performance	balanced performance	increasing performance	overall performance evaluation
11	4	4	16	Increase
12	7	5	12	Increase
13	2	8	14	Increase
14	4	5	15	Increase
15	6	7	11	Increase
16	3	12	9	Increase
17	3	6	15	Increase
18	8	11	5	Decrease
19	12	7	5	Decrease
20	9	8	7	Decrease
Total	**58**	**73**	**109**	
%	**24,17**	**30,41**	**45,42**	

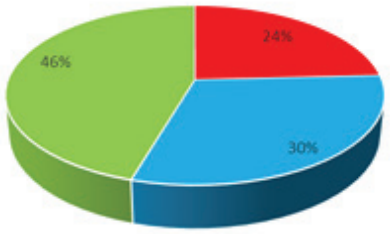

Fig. 3 The Group B, performance on simulator flights
Decreasing performance
Balanced performance
Increase performance

Table 6

Group B performance – live flights

subject number	decreasing performance	balanced performance	increasing performance	overall performance evaluation
11	2	1	21	Increase
12	1	3	20	Increase
13	6	3	15	Increase
14	4	1	19	Increase
15	4	4	16	Increase
16	4	7	13	Increase
17	7	6	11	Increase
18	6	2	16	Increase
19	1	4	19	Increase
20	3	1	20	Increase
total	**38**	**32**	**170**	
%	**15,83**	**13,33**	**70,83**	

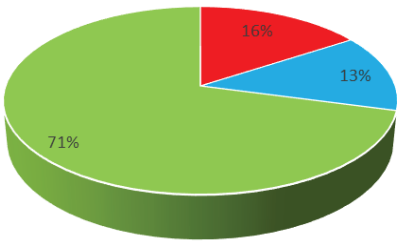

Fig. 4 The Group B, performance on live flights
Decreasing performance
Balanced performance
Increase performance

The performance of 10 pilots teamed up in the Group B during the switch from analog display to glass cockpit displays by the live flights and by application of the new training procedures, was reported as increased.

Regarding evaluated the Group B manoeuvres during the live flights, the performance decreased in 38 manoeuvres (15,83%), balanced in 32 manoeuvres (13,33%) and increased in 170 manoeuvres (70,83%) (Fig. 4).

The overall Group B performance during the switch from analog to glass cockpit displays by the simulator practice as well as the live flights while applying the new training standards, increased and affirms the hypothesis number 1 – the performance of the pilots teamed up in the Group B (during the switch from analog to glass cockpit display by the simulator practice as well as live flights while applying the new training procedures) increased.

4. Conclusion

The comparison results of pilots performance achieved by a tool of the precision of pilotage fully affirms the hypothesis number 1 – For pilots who experience in a practice the conversion from analog to glass cockpit displays by applying the new training methods, the change reports less negative performance.

After a comparison of the achieved results as reported in the figures above, we can proclaim following change of performance:

- simulator practice
  - decreasing performance group A 43% group B 24%
  - balanced performance group A 22% group B 30%
  - increasing performance group A 35 % group B 46%
- live flights
  - decreasing performance group A 52% group B 16%
  - balanced performance group A 8% group B 13%
  - increasing performance group A 40% group B 71%

The conversion from analog to glass cockpit display had the negative impact on the pilots performance. This fact concerns only those pilots who passed the conversion by applying the current training standards (their performance decreased). Before the display conversion they had passed only an elementary theoretical training in glass cockpit pilotage which lasted only 1 hour.

Those pilots who had passed the theoretical training by applying the new training methods reported less negative researched results (their performance even increased). It means that before the display conversion they had passed 3 hour detailed theoretical training in glass cockpit pilotage and 5 hour simulator training in glass cockpit pilotage.

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