Impact of Aircraft Synoptic Page Designs on Pilot Flight Performance

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SUMMARY

This study evaluates the impact of a newly designed Hydraulic Synoptic page on pilot performance during emergency scenarios in simulated flights. By comparing it with the traditional Hydraulic page, the research assesses pilot workload, situational awareness, and system usability. Results suggest that the synoptic page significantly enhances performance, safety, and usability, offering valuable insights for cockpit interface design.

KEYWORDS

Aerospace, Situational Awareness, Usability

Introduction

This study examines the impact of a newly designed Hydraulic Synoptic page on pilot flight performance under emergency scenarios during simulated flight operations. The analysis focuses on pilot workload, situational awareness, and the usability of the synoptic page in comparison to the traditional Hydraulic page. These factors are crucial in ensuring operational efficiency and safety in aviation, particularly in critical scenarios.

Workload can be defined as the integrated mental and physical effort required to satisfy the perceived demands of a specified task. In the aviation concept, pilot workload can be defined as the demand placed on the pilot's mental and physical resources. During the flight operation, mental processes such as attention, perception, decision-making, and also physical cockpit controls are the factors that affect workload (Hicks, Durbin, Morris, & Davis, 2014).

Situational Awareness (SA) can be defined as the pilot's perception of the elements of the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future. Pilots must know the state of their aircraft, the environment through which they are flying, and relationships between them (Endsley & Robertson, 2000).

Usability is a quality attribute that assesses how easy user interfaces are to use. In addition, usability depends on how well design's features accommodate users' needs and contexts. Satisfaction, learnability, efficiency, few errors and memorability will be the main focus while measuring the usability of a system (Laubheimer, 2018).

Methodology

Five test pilots participated in two randomized simulated flight scenarios, each designed to simulate distinct hydraulic failure alerts:

- Scenario A: Utilised the traditional Hydraulic Page
- Scenario B: Employed the new Hydraulic Synoptic page.

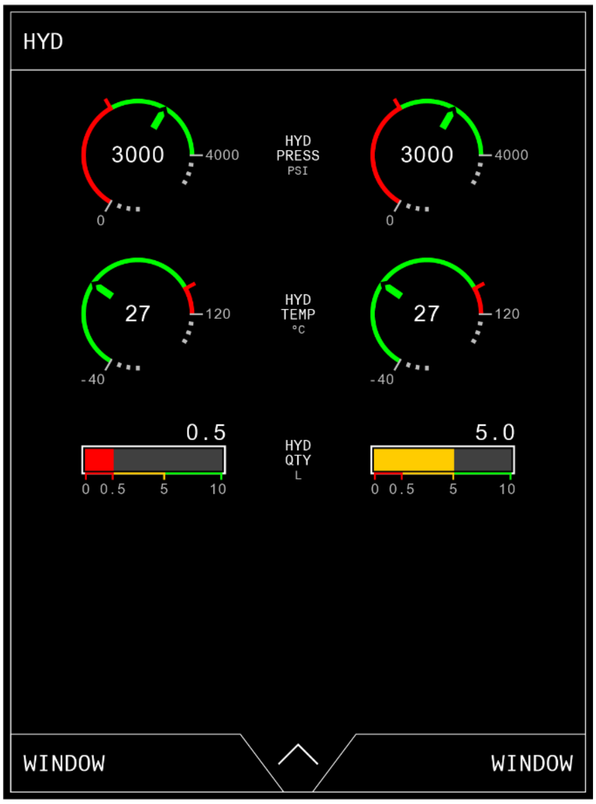

Figure 1: Traditional HYD Page

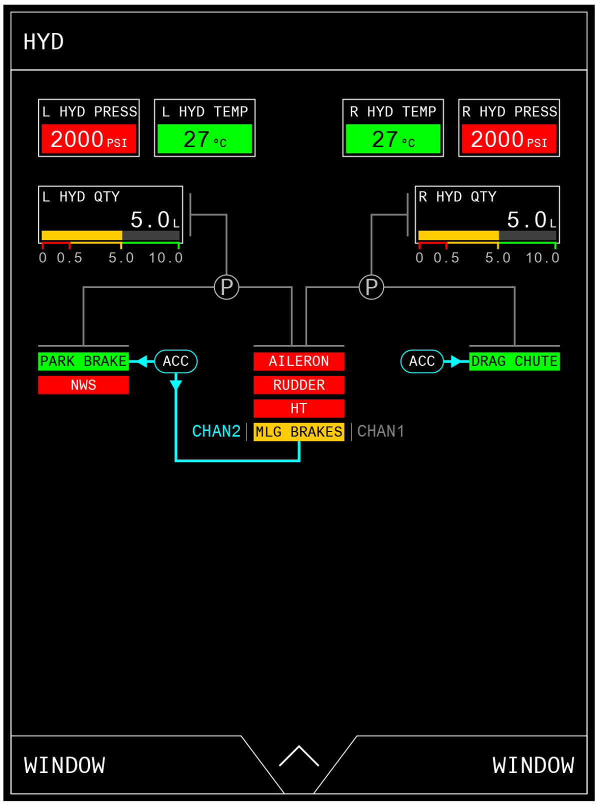

Figure 2: HYD Synoptic Page

During both scenarios, pilots conducted take-off, cruise, and landing phases, encountering hydraulic failure alerts during landing. The names of alerts were Left Hydraulic Quantity (L HYD QTY) and Left Hydraulic Pressure (L HYD PRESS). They performed predefined alert procedures while interacting with the respective Hydraulic page. Workload ratings (Bedford Scale), situational awareness scores (SART), and usability evaluations (SUS) were collected. Flight data such as response time and landing success were recorded.

Table 1: Alert Procedures

L HYD QTY	L HYD PRESS
1) LAND AS SOON AS PRACTICAL	1) LAND AS SOON AS PRACTICAL
WHEN TWO-POINT TOUCH DOWN; 2) DRAG CHUTE - DEPLOY 3) USE BRAKES TO DECELERATE A/C	WHEN TWO-POINT TOUCH DOWN; 2) DRAG CHUTE – DEPLOY 3) USE BRAKES TO DECELERATE A/C
4) DO NOT ENGAGE NWS	4) DO NOT ENGAGE NWS
5) USE DIFF BRAKING INSTEAD OF NWS	5) USE DIFF BRAKING INSTEAD OF NWS
6) USE BRAKE PEDALS TO HOLD A/C	6) USE BRAKE PEDALS TO HOLD A/C
7) PARK BRAKE SWITCH - PARK BRAKE	7) PARK BRAKE SWITCH - PARK BRAKE

Table 2: Details of Test Scenario

Scenario	Alert	Instrumentation	Independent Variables	Dependent Variables
Scenario A	L HYD QTY	Bedford Rating Scale Situational Awareness Rating Scale Qualitative Form Eye tracking data System Usability Scale	Hydraulic Page Design – Hydraulic failure situation without synoptic page	1. Situational awareness of the pilot 2. Pilot's workload 3. Simulator flight data (e.g., alert procedure completion & time spent, flight success, landing phase duration, pilot reactions to cockpit controls)
Scenario B	L HYD PRESS	Bedford Rating Scale Situational Awareness Rating Scale Qualitative Form Eye tracking data System Usability Scale	Hydraulic Synoptic Page Design – Hydraulic failure situation with synoptic page	

Instrumentation

1. Bedford Rating Scale (BRS)

After completing each task scenario, participants will be asked to complete the Bedford Rating Scale items (Figure 3).

Workload Success Criteria

The Bedford Rating Scale results will be evaluated according to the criteria as shown in Figure 4.

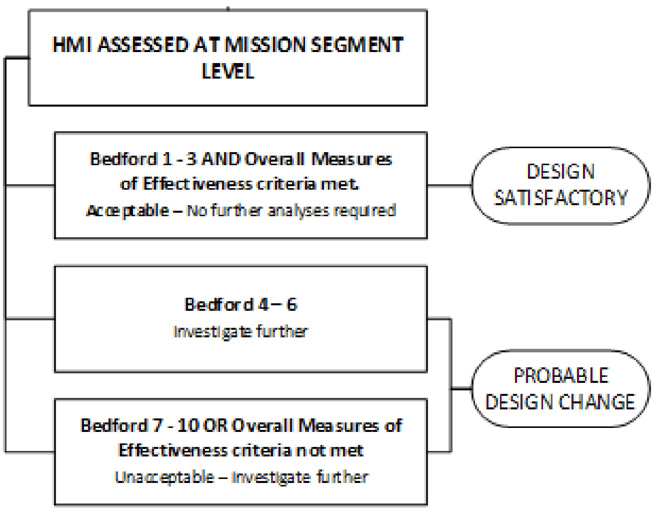

Figure 3: Bedford Rating Scale Interpretation

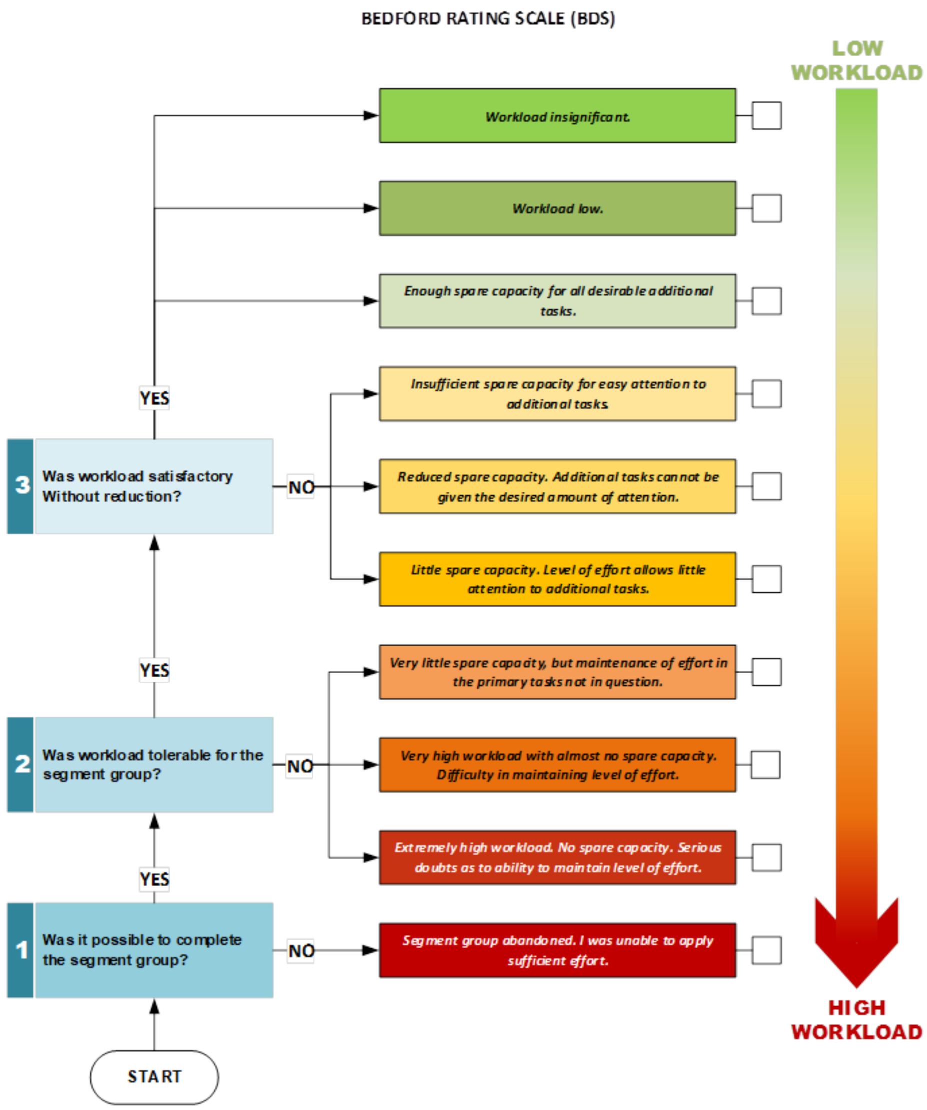

Figure 4: Bedford Rating Scale

2. Situational Awareness Assessment Method

Situational Awareness Rating (SART) will be used to measure SA (Tayor, 1990). SART technique allows subjective estimation of SA. It includes 10 dimensions which are used in conjunction with a likert scale. After completing each task scenario, participants will be asked to rate the SART rating scale items as given below.

Table 3: SART Rating Sheet

Plight Phase	Query No								
Demand	**1. How changeable is the situation?**								
	Stable and straightforward	1	2	3	4	5	6	7	Changing suddenly
	2. How many variables are changing within the situation?								

	Very few variables changing	1	2	3	4	5	6	7	A large number of factors varying
	3. How complicated is the situation?								
	Simple and straightforward	1	2	3	4	5	6	7	Complex with many interrelated components
Supply	**4. How alert are you in the situation?**								
	A low degree of alertness	1	2	3	4	5	6	7	Alert and ready for activity
	5. How much mental capacity do you have to spare in the situation?								
	Nothing to spare at all	1	2	3	4	5	6	7	Sufficient to attend to many variables
	6. How much are you concentrating on the situation?								
	Focusing on only one	1	2	3	4	5	6	7	Concentrating on many aspects of the situation
	7. How much is your attention divided in the situation?								
	Focusing on only one	1	2	3	4	5	6	7	Concentrating on many aspects of the situation
Understanding	**8. How much information have you gained about the situation?**								
	Very little	1	2	3	4	5	6	7	A great deal of knowledge
	9. How good is the information you have gained about the situation?								
	It is not usable at all	1	2	3	4	5	6	7	The knowledge communicated very useful
	10. How familiar are you with the situation?								
	It is a new situation	1	2	3	4	5	6	7	A great deal of relevant experience

Situational Awareness Success Criteria

The higher score indicates a better level of SA, while a lower score suggests a lower level of SA. Minimum SART rating score is -14, while maximum SART rating score is 46. Therefore, it can be said that if SART rating is greater than 16, situational awareness level will be considered as acceptable.

3. Usability Assessment Scale

To measure usability, (SUS) technique will be used (Laubheimer, 2018). After completing each task scenario, participants will be asked to rate the usability scale items (Table 4).

Table 4: System Usability Scale (SUS)

Item #	Test Item	Strongly Disagree 1	2	3	4	Strongly Agree 5
1	I would like to use this system frequently.	◯	◯	◯	◯	◯
2	I found the system unnecessarily complex.	◯	◯	◯	◯	◯
3	The system was easy to use.	◯	◯	◯	◯	◯
4	I would need the support of a technical person to be able to use this system.	◯	◯	◯	◯	◯
5	I found the various functions of this system were well integrated.	◯	◯	◯	◯	◯
6	I thought there was too much inconsistency in this system.	◯	◯	◯	◯	◯
7	I would imagine that the most pilot would learn to use this system very quickly.	◯	◯	◯	◯	◯
8	I found the system very cumbersome to use.	◯	◯	◯	◯	◯
9	I felt very confident using the system.	◯	◯	◯	◯	◯
10	I need to learn a lot of things before I could get going with this system.	◯	◯	◯	◯	◯

Findings

The results reveal a significant impact of the Hydraulic Synoptic page on pilot workload, situational awareness, and usability:

1. **Workload Assessment (Bedford Scale):**

   Both Scenario A (Traditional Hydraulic Page) and Scenario B (Hydraulic Synoptic Page) received a workload rating of 1, indicating that pilots experienced minimal effort in managing the hydraulic failure alerts. This suggests that the redesigned page does not add cognitive burden, ensuring that pilots can efficiently handle emergency situations without increased stress or fatigue.

2. **Usability Evaluation (System Usability Scale - SUS):**

   The usability of both interfaces was rated highly, with Scenario A scoring 95 and Scenario B achieving a slightly higher 97.5. The improved score in Scenario B reflects better intuitiveness, ease of navigation, and pilot confidence in interacting with the synoptic display. Pilots reported that the synoptic design facilitated quicker identification of hydraulic system status and necessary actions.

3. **Situational Awareness (SART Scores):**

   Pilots using the Hydraulic Synoptic Page (Scenario B) achieved a SART score of 22, compared to 19 in Scenario A. The higher score indicates improved perception, comprehension, and projection of the system's operational state. The graphical representation and structured information layout of the synoptic page contributed to faster decision-making and a more accurate understanding of system behavior.

4. **Pilot Feedback and Observations:**

   Pilots noted that the synoptic page allowed them to access critical information with fewer visual transitions, reducing the need for extensive scanning across multiple displays. Some pilots mentioned that the traditional hydraulic page required more cognitive effort to interpret due to its text-heavy format, whereas the synoptic design provided a clearer, more intuitive visualization of the hydraulic system's condition. The improved efficiency in information retrieval and decision-making suggests that the synoptic page could enhance response times in real-world emergency scenarios.

Key Takeaways

1. **Enhanced Emergency Response and Performance:** The introduction of the Hydraulic Synoptic Page resulted in a more streamlined and efficient approach to handling hydraulic failures. The design supports pilots in diagnosing issues more effectively, contributing to faster and more accurate responses.

2. **Optimised Situational Awareness:** The synoptic display enhanced pilots' perception and comprehension of hydraulic system status, leading to better anticipation of system behavior and improved decision-making. The structured visualization minimized confusion and cognitive overload, helping pilots maintain high levels of awareness throughout the emergency procedure.

3. **Superior Usability and Interface Design:** The improved SUS scores indicate that the synoptic page offers a more intuitive and user-friendly experience compared to the traditional page. Reduced information clutter and enhanced graphical representation made it easier for pilots to process and react to critical alerts. These findings underscore the importance of human-centered design in cockpit interfaces, ensuring that pilots can operate efficiently under stressful conditions.

4. **Operational and Safety Implications:** Given the enhanced performance and usability, adopting the Hydraulic Synoptic Page in operational aircraft could contribute to reducing pilot workload and improving emergency management. The study's findings provide valuable insights for future cockpit interface development, reinforcing the necessity of intuitive visual displays in high-risk aviation environments.

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