SAFETY ASPECT OF MISSION SUPPORT DISPLAY FOR HIGH-DEMAND AERIAL WORK

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Keywords: *Attention Capture, Tunnel-in-the-Sky Display*

Abstract

A series of flight simulations to investigate safety aspects of a Mission Support Display, such as course guidance. Relationships between performance indices such as attention capture and task performance, and parameters such as display position and display type are investigated.

1 Introduction

Displays for mission support have been proven to be very useful in some kinds of helicopter operations such as search and rescue, aerial survey and photography. Such displays can include a specially designed plan view “map” and forward-looking infrared (FLIR) and visible light images from external cameras. These displays are not flight-essential and so do not have to comply with flight instrumentation safety standards, either from reliability, integrity or human factors aspects. Although the efficiency of these displays is acknowledged, it is widely recognized that they should be used carefully so that pilots also direct their attention to other information such as certified flight instruments and outside visual cues, avoiding attention capture [1]-[7].

A series of flight simulation experiments was conducted to investigate possible over-reliance and attention capture regarding such non-essential displays and mission-related tasks. The outcome of this research is expected to be used to enhance pilot training for such tasks and also for determining display design requirements. This paper reports preliminary results from the study.

2 Identifying Problem

Mission support displays may present navigation and guidance information to support the mission and video images from external cameras. Although the installation of the display itself must be certified as airworthy, the content of the display is not considered as flight instrumentation and must not be used for primary flight cues. The location of the display is so selected so as not to obstruct flight instruments, switches and out-of-the-window visual cues

The following potential risks may result from improper use of such mission displays:

a) The pilot’s attention may be “captured” by the display so that he or she does not pay sufficient attention to flight instruments and out-of-the-window visual cues.
b) False cues presented on the display may lead the pilot to fly aircraft unsafely.
c) The pilot may be distracted or surprised by sudden failure of the display.
d) The intended mission may fail due to poor legibility of elements of the display, such as the aircraft’s location.

Causal factors of these risks can be hypothesized as follows:

a) Lack of integrity: The display may suddenly fail, or present false information, which can surprise the pilot.
b) Absence of integrity warning: The failure occurs without notice to the pilot and the pilot may continue to use the false information.

c) Poor viewability: Excessive pilot workload may result due to improper design or location of the display or its elements.
d) The display may be over-compelling: If all the necessary information for the task is presented on the display, such as attitude and guidance information, the pilot may fail to pay sufficient attention to flight instruments and out-of-the-window cues.

Many studies have been carried out concerning hypothesis d) in particular. One such study [7] dealing with HUDs (Head-Up Display) indicated the possibility of attention capture but also showed that it is difficult to repeatably reproduce attention capture in a flight simulation environment. On the other hand, another study showed that a compelling display could ease the pilot's control task such that he could direct more attention out of the window [8].

Considering these studies, a set of flight simulation was conducted particularly to validate hypothesis d).

3 Flight Simulation

3.1 Simulation Setup

A series of flight simulation experiments was conducted to investigate how the causal factors identified above affect safety. Two types of support display and two display mounting locations were compared.

The study used one of research simulators in the JAXA Flight Research Center. Figure 1 shows a view of the cockpit. The out-of-window display has six visual system channels of SXGA resolution presented on a half-dome screen with a FOV of 180 degrees horizontal and 80 deg vertical.

Mission support information was presented one of two small auxiliary flat-panel displays mounted on the top center and bottom right of the main instrument panel as shown in Figure 1. Figures 2 and 3 show the two types of guidance display: "PFD mode" and "MAP mode". In PFD mode, vertical and horizontal guidance integrated as a "Tunnel-in-the-Sky" which is displayed along with GPS altitude and air speed. In MAP mode, the display shows only the aircraft's horizontal situation without guidance cues, and the pilot has to obtain information such as airspeed, pressure altitude, and radio altitude from conventional analogue flight instruments.

"Markers" were presented in the out-of-the-window visual scene as small semi-transparent pink squares. Markers were presented one at a time and remained until either the pilot pressed a switch or until 8 seconds had elapsed. Figure 4 shows an example of a Marker in the center of the visual scene. The flight visibility conditions were set at "clear".

In a "Failure Scenario", the true altitude (height from the mean sea level measured by GPS) in the mission display increases in the pace of 300ft/min, and the vertical guidance leads the aircraft to descend as the result.

Fig. 1. Simulator cockpit

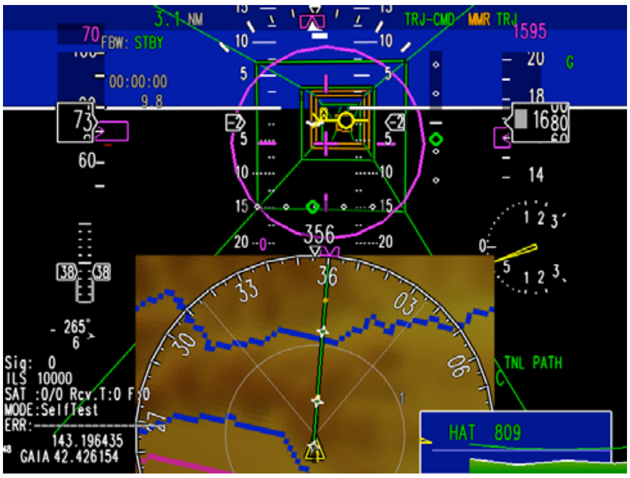

Fig. 2. "PFD mode"

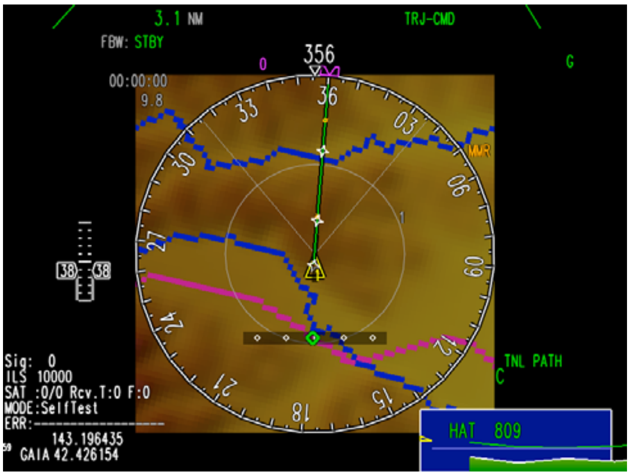

Fig. 3. “Map mode”

Fig. 4. “Marker” shown in the center

3.2 Task

Each trial (flight) started with the aircraft flying at 800 ft above ground level (AGL) and on the desired course. Each trial required pilots to fly a mission course consisting of a series of short straight (constant heading) legs with different altitude following a terrain with flat and rough portions, giving a vertical profile with climbs, level flight and descents. The length of the mission course was 3.0 NM. Subjects were instructed to fly along the displayed course paying sufficient attention to the out-of-the-window scene. The explicit excursion limit from the nominal path was set at 100 m as indicated by the horizontal deviation indicator on PFD or MAP. Vertical guidance cues presented in the PFD mode display followed the terrain profile at approximately 800 ft AGL. For MAP mode, subjects were told that the vertical profile was at their discretion but they should keep their height between 500 ft and 1,000 ft as indicated by the radio altimeter in the analogue instruments. Subjects were instructed that when they became aware of a Marker in the visual scene, they were to push the PTT (push-to-talk) switch on the cyclic stick. Each trial terminated when the aircraft reached the end of the course.

The instruction materials clearly stated “The mission-display is not airworthy, and is not be used as a primary navigation source” and “Pay sufficient attention to conventional instrument and out-of-the-window, assuming that the mission-display is not reliable”. Subjects were not told about the Failure-Scenario, and no explicit instruction was provided to the subjects in case they noticed a display failure.

3.3 Procedure

Each experiment session consisted of a briefing followed by training and then data acquisition flights. In the training phase, two flights were carried out for each of the display cases. The data acquisition phase consisted of 10 trials, two types of route for each display type, and two “Failure Scenarios” with PFD mode. Four subjects participated the experiment.

In addition to flight data, pilot eye movements were recorded and analyzed. The recorded eye point data is categorized into 4 areas of 1) out-of-the-window visual, 2) instrument panel, 3) upper-left and 4) lower-right displays.

4 Results

4.1 Display Type

Figures 5 to 8 compare the two display modes, MAP and PFD. Figures 5 and 6 show the proportions of time pilots spent looking at the mission display and at the out-of-the-window visual scene, respectively. Figure 7 shows average of the time required to detect a Marker in the visual scene. Figure 8 shows the average horizontal tracking error.

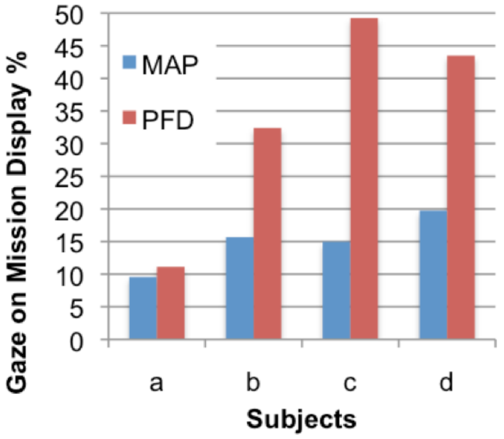

Fig. 5. Gaze on mission display, display mode

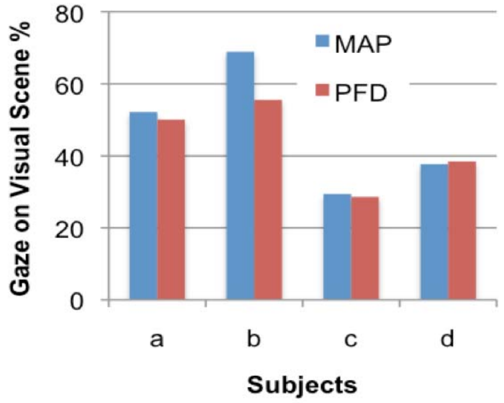

Fig.6. Gaze on visual scence, display mode

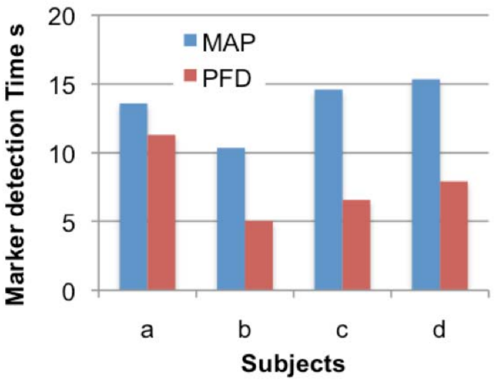

Fig. 7 Marker detection time, display mode

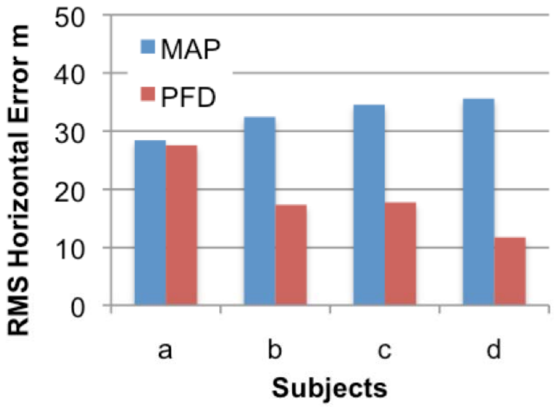

Fig. 8. RMS deviation, display mode

4.2 Display Position

Figures 9 to 12 compare the two display positions, upper-left and lower-right. Figures 9 and 10 shows the proportions of time pilots spent looking at the mission display and at the out-of-the-window visual scene, respectively. Figure 11 shows average of time required to detect a Marker in the visual scene. Figure 12 shows the average horizontal tracking error.

Subjects were asked which location they preferred. All preferred the upper-left location due to its lower scanning workload. One subject commented with the display in the upper-left location the visual scene could be observed by peripheral vision without moving the eye fixation point, while explicit scanning was required for lower-right display position.

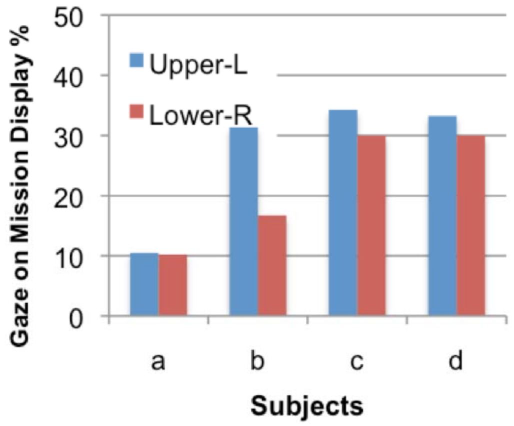

Fig. 9. Gaze on mission display, position

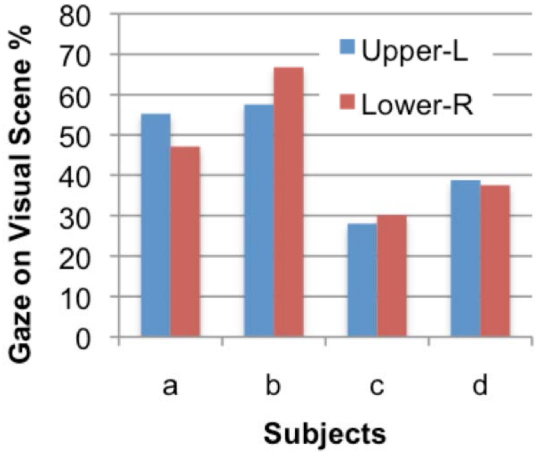

Fig. 10. Gaze on visual scene, position

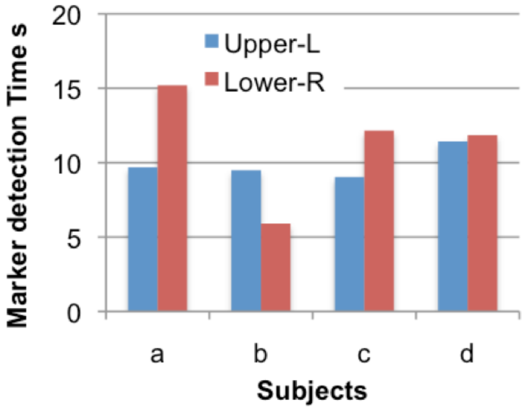

Fig. 11. Marker detection time, position

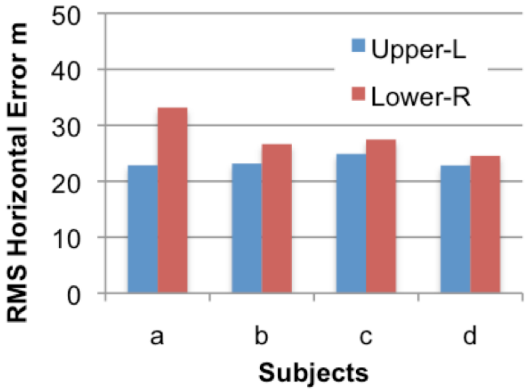

Fig. 12. RMS deviation, position

4.3 Display Failure

In all the cases with Failure Scenarios, subjects noticed the increasing proximity to the ground surface and recovered safely. All the subjects became aware the anomaly by observing the out-of-the-window visual scene. Although there was a significant difference between the absolute (GPS) altitude indication on the PFD and the pressure altitude shown on the instrument panel, none of the subjects noticed the discrepancy even after the awareness of the ground proximity.

5 Discussions

5.1 Display Type

Figure 5 shows that subjects looked at the mission display more often in the case of PFD mode than MAP mode. This is explained by the fact that the subjects using the MAP mode display had look at conventional instruments to obtain information such as speed and altitude, while these were presented on the PFD mode display. Figure 7 shows that the required time for marker detection is shorter for PFD mode, while Figure 6 shows that the proportion of time spent looking out-of-the-window is almost same level for the two modes. Although PFD mode gives better marker detection and horizontal tracking performance as shown in Figure 7, there is no obvious difference in gaze time at the out-if-the-window scene between the modes.

Although these results are consistent with our past experiments, the shorter marker detection time could not be related to a higher proportion of time spent looking at the out-of-the-window scene. From these results, it could be said that attention paid to out-of-the-window visual will not be degraded by the PFD mode display so long as the pilot remains aware of the importance of outside scanning.

5.2 Display Position

Except for a slight difference in tracking error shown in Figure 12, no difference in performance indicators was observed between the two display positions, although all the subjects agreed that the lower position display increased the scanning workload. As far as this experiment is concerned, the off-center display did not lead to significant degradation of scanning of the out-of-the-window scene.

5.3 Safety Risk

Safety issues for such mission display are discussed in terms of hypotheses b), c) and d) mentioned in section 3.

b) Absence of integrity warning:

The results from Failure Mode Scenario do not support this hypothesis. In all cases, pilots noticed the proximity to the ground from the out-of-the-window scene and recovered. However, the fact that none of the subjects noticed the discrepancy between the GPS altitude in the mission display and the pressure altitude in the conventional instruments indicates a risk of not noticing a hazardous situation when the visibility decreases.

c) Poor viewability of mission display:

As discussed in section 5.2, relocated display did not show significant degradation of scanning performance. This hypothesis is not supported in this experiment.

d) Over-compelling mission display:

As discussed in section 5.1, and as also supported by previous studies, this hypothesis was not supported by this experiment since pilots were able to keep scanning the out-of-the-window scene. On the other hand, the compellingness of the display is very much related to hypothesis b. This suggests that a similar experiment in more stressful and unsafe conditions, such as with low visibility or degraded flying qualities, might show different results.

6 Conclusions

The simulation experiment result showed that "Map" display attracted much attention than "PFD" with 2-axis guidance. There is no difference in path tracking performance nor in out-of-the-window looking-out task between different position of the displays. No significant relationship between looking-out task activity and eye motion were found. In failure scenario cases, although all display failures were successfully detected by the subjects, none of the subjects noticed the discrepancy of altitude indication between mission display and altimeter in instrument panel.

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