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Shawn M. Doherty
Jonathan French
Embry-Riddle Aeronautical University
Daytona Beach, Florida

A common issue for aviation involves night flights into airports with no light or low light conditions. This study investigated the effectiveness of runway visual capture by pilots using an enhanced visual system that provided an integrated display of infra-red light and light intensification to the pilot or a low-cost lighting system on the ground during landings to an airport in Palatka, Florida. Six pilots each flew a series of five approaches into the airport in conditions utilizing these technologies as well as instances of full runway lighting or no runway lighting. Results indicated that both systems produced visual capture of the runway at a higher altitude and greater distance from the runway than the no lighting condition but were not as effective as full runway lighting. These results demonstrate the effectiveness of these new technologies for landings into airports with poor illumination or no illumination, making them available for night landings.

Introduction

Night flight landings into airports with poor illumination have long been a problem for aviation. Multiple cases have been reported of accidents in which the pilot had landed short of the runway or misjudged the landing due to an airport or surrounding area having insufficient lighting to provide adequate visual cues to the pilot. Multiple solutions to this issue have been offered, from technological advances in the cockpit for the pilot to enhanced lighting systems on the ground.

Black Hole Effects

Numerous studies have demonstrated the performance impairment that occurs for pilots when flying into conditions of poor lighting, typically leading to pilots producing steep approach angles (e.g. Mertens & Lewis, 1983). This “black hole” phenomenon in which pilots misperceive runway width, length, and slant is due to the absence of visual cues to calibrate accurate depth information.

One solution to this problem is to provide those absent visual cues to pilots through display technology. Recent advances in sensor technology and computerized databases have allowed for the visual presentation of runway and airport information to the pilot that mimic what would be seen outside the aircraft under good visual conditions even when actual conditions include bad weather or conditions such as those found to induce black hole effects (e.g. Sachs & Dobler, 1996)

Another solution is to find a mechanism to provide additional illumination to the area under poor visibility conditions so that pilots can more clearly see the cues necessary to accurately determine runway position and dimensions.

The current study investigated five different combinations of enhancement of nighttime landing operations that included both technological display solutions that combined infra-red and light intensification technologies as well as conditions that investigated providing alternate illumination sources for runway identification.

Method

Participants

Six pilots participated in the study. The participants ranged from 19 to 50 years of age. All pilots were required to have least 200 hours of flight time. Actual flight time ranged from 250 to 2200 hours with an average of 400 hours. Pilots were also required to have their instrument rating and all six pilots had their private, instrument, commercial and multi-engine ratings. Five of the six participants also had certified flight instructor and certified instrument flight instructor ratings as well.

Apparatus

An experimental Cessna 310 multi-engine aircraft was used for all flights. The aircraft was equipped with a glass display instrument panel consisting of a primary flight display representing the basic flight instrumentation in front of the pilot in command in the left seat and a multi-function display presented in front of the participant in the right seat of the aircraft. The multi-function display could present information regarding checklist information, system status, navigation information, or a redundant primary flight display.

An enhanced vision system (EVS) could also be presented in the MFD position. This enhanced night vision system combined information from a low light imaging sensor with an infrared imager that could be adjusted by the researchers in the amount each technology source contributed to the image presented to the participant. The balance of contribution between these two technologies to the display was able to be adjusted by the researchers so that at one extreme the display showed only infra-red information and at the other extreme only light amplification was presented. An example of the enhanced vision system display is shown in Figure 1.

Figure 1. A picture of the EVS display that combines both infra-red and light intensification technologies.

On the ground a low-cost lighting (LCL) array was spaced adjacent to every 2^{nd} standard runway lighting lamp from the runway threshold. Each of the 16 total LCL devices utilized incorporated multiple LED lights powered by a 9 volt portable battery that was angled upward toward the aircraft approach. A picture of the low-cost lighting device is depicted in Figure 2.

Figure 2. A depiction of the low-cost lighting system adjacent to the inactive standard runway lighting.

Design

The study was a within-subject design with five levels of illumination type: no illumination, low-cost lighting alone (LCL), enhanced vision system (EVS) alone, LCL and EVS together, and pilot controlled lighting that was the equivalent of full runway illumination. The dependent measures of the study were the altitude and distance from the runway when subjective reports occurred of runway visual capture for a safe landing.

Procedure

After a safety briefing and aircraft check by the pilot in command, pilot participants were flown at dusk to a local uncontrolled airport in Palatka, Florida. The pilot in command remained in control of the aircraft during the study. A ground crew arranged the LCL array upon the runway in preparation for the flights. Once the aircraft arrived in the area the sun had set and the pilot in command flew five approaches corresponding to one trial each of the five illumination conditions. The first four of the five approaches were counterbalanced across participants to guard against order effects. The final trial for all participants was always the pilot controlled lighting condition as the pilot controlled lighting required a period of time longer than a missed approach was executed before the lighting turned off, necessitating that the other conditions were tested first.

On each approach the pilot participant was requested to indicate safe visual capture of the runway verbally. Three of the five conditions (pilot controlled lighting, low-cost lighting and no illumination) were head-up trials for the participant. The other two illumination conditions (containing the EVS) were head-down trials where the pilot viewed the approach through the display either alone or in combination with the LCL on the ground that appeared in the display. Upon visual capture of the runway by the participant the pilot in command identified the distance to runway and altitude provided by GPS equipment aboard the aircraft. Upon altitude and distance confirmation the pilot in command either issued a missed approach and continued with following trials or landed to refuel. Upon the last trial the aircraft returned to Daytona Beach, Florida, for aircraft tie-down and participant debriefing.

Results

A one-way ANOVA was performed on the two dependent measures of distance from threshold and altitude of visual capture at an alpha level of .05.

Results were analyzed on five participants as an incomplete set of data was obtained for the sixth participant.

Results indicated a significant difference between the illumination conditions for altitude, $F(4, 24)=48.94$, $p<0.0001$. A Newman-Keuls post-hoc comparison identified that the only comparison that wasn't significant was between the combined technology of EVS and LCL when compared against the EVS devices alone. All other comparisons were significant. This pattern of results can be seen in Figure 3.

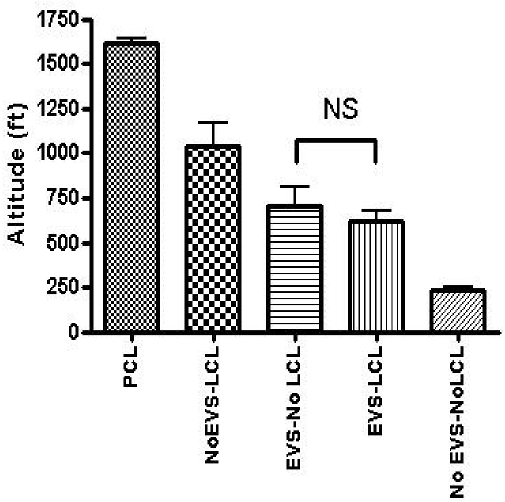

Figure 3. Altitude at which safe landing of the aircraft was assessed by pilots. The figure shows condition means for illumination condition and the bars specify standard error. NS shows the one non-significant comparison between the conditions.

A similar set of results was found for distance to runway upon visual capture. A significant difference was again found for illumination conditions for horizontal distance to runway, $F(4,24)=123.8$, $p<0.0001$. Newman-Keuls post-hoc comparisons were also performed on the distance measurements and all comparisons were significant except when the combined EVS and LCL technologies were contrasted against the EVS system alone. This pattern of results can be seen in Figure 4.

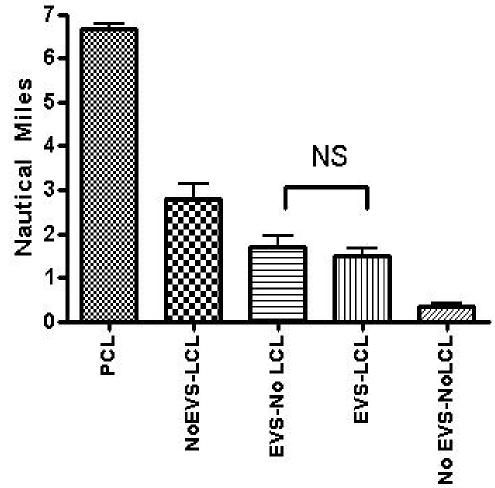

Figure 4. Distance from runway threshold at which safe landing of the aircraft was assessed by pilots. The figure shows means for illumination condition and the bars specify standard error. NS shows the one non-significant comparison between the conditions.

Discussion

This study investigated five different illumination conditions for nighttime operations at an uncontrolled airport. Not all airports have pilot controlled lighting so these new technologies present new opportunities for safe nighttime landings.

Results suggested that pilot controlled lighting (full illumination) produced the best visual runway capture while trials with no runway lighting lacking illumination technology produced the worst case.

One consistent result from both the altitude and distance data is that while the EVS system did produce better runway capture compared to no lighting, the conditions featuring the EVS did not differ with the absence or presence of the LCL system. It was expected that the combination of the two illumination systems would produce better runway capture than either one alone because of the light intensifier in the EVS but this result was not found. Two explanations may be offered for this result. First, this result may be a function of the difference in viewing runway information heads-down on a display versus heads-up through the windshield of the aircraft. Since the EVS display is heads-down and smaller than the view out the windscreen the size of the LCL information in the display may have been insufficient to produce earlier runway capture even when amplified by the light intensifier. Secondly, since the EVS system was a combination of infra-red and light amplification technology the researchers may not have had the balance between the two technologies set at the correct point to amplify the potential benefit of the low-cost lighting.

It is clear that the low cost lighting did have a benefit for runway capture on its own compared to the no illumination or the EVS system conditions. This finding is important for applications where full runway lighting might not be practical or during operations such as in emergency situations when electrical power is unavailable.

Therefore, while the EVS and LCL technologies were significantly worse in visually verifying the runway upon approach compared to when pilot-controlled lighting is available these two technologies present at least one solution that can address black hole landings. The LCL may provide a cost effective alternative to pilot controlled lighting (using the solar powered version) or backup to airports during power failures.

References

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