VISUAL CUE REQUIREMENTS FOR TERRAIN FLIGHT SIMULATION

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ABSTRACT

Three types of visual scene cues were varied in order to determine their effect on pilot performance during simulated low altitude flight. The three types of visual cues consisted of three sizes of ground texture patterns, the presence or absence of vertical object cues, and the presence or absence of an aircraft shadow. The pilots who flew the simulated missions reported that all three visual cues were useful, however the vertical object cues and texture patterns were more useful than the aircraft shadow. Both the texture patterns and the vertical object cues produced statistically significant differences in quantitative measures of pilot performance.

INTRODUCTION

The purpose of this study was to assess the effects of three types of visual scene cues upon simulated low altitude terrain flight missions in A-10 aircraft. The three types of visual scene cues studied were ground texture patterns, vertical object cues, and the aircraft shadow. The lack of adequate visual scene textural detail is often considered to be a limiting factor in the use of computer generated imagery for nap-of-the-earth (NOE) flight simulation. Low altitude terrain flight, including NOE maneuvering and contour flight, and aircraft flare and landing seem to require visual scene textural detail for optimum pilot judgment of distance above the ground. The actual level of textural detail required may vary as a function of aircraft speed. For example, it may be possible to use much grosser textural detail for A-10 NOE flight than for helicopter flight. Even with the limited edge capacity of the current Advanced Simulator for Pilot Training (ASPT) system, it may be possible to greatly enhance pilot performance during NOE flight maneuvers, using fairly large texture patterns. Also, by limiting the aircraft altitude and through the use of rolling terrain it should be possible to keep the visual scene edge requirements within the limits of the current ASPT Computer Generated Image (CGI) system. Thus, one goal of this study was to study the effects of maximum visual texturing, within the current ASPT visual system, upon pilot performance during NOE and low altitude contour flights.

Vertical object cues are also quite important for pilots to judge aircraft height above the ground. The relative trade-offs between ground textural cues and vertical object cues will be important in determining the optimum utilization of limited computer generated image edge resources. The relative importance of vertical object cues versus ground texture patterns will also be useful in assessing the utility of CGI hardware options which generate synthetic texture for visual scenes. Thus, simulated missions were also flown with and without vertical object cues in order to study their effect on pilot performance.

The aircraft shadow has also been proposed as an important visual cue for low level flight. Since this visual cue also imposes an additional burden on the CGI system it is important to assess its proven utility as a visual cue for terrain flight. As with the vertical object cues, half of the simulated missions were flown with and half were flown without the aircraft shadow in order to study its effect on pilot performance.

METHOD

The pilot's task consisted of flying missions in a simulated A-10 aircraft from an initialization point across approximately ten miles of rolling terrain, which consisted of eight valleys separated by low hills that were either 100 or 300 feet high. Twelve A-10 pilots, who were qualified as either instructor pilots or combat mission ready pilots, flew in the study. The flying task primarily consisted of maintaining a very low altitude flight profile consisting of both nap-of-the-earth flight around vertical objects and contour flight which followed the profile of the terrain. Low altitude flight was imposed by instructions to the pilots and by feedback concerning performance measurement scoring. Pilot performance was quantitatively measured in several ways. One primary measure consisted of scoring pilot ability to maintain aircraft altitude at 50 feet plus or minus 30 feet, while flying in the flat valleys. This score was computed as a percentage of the time within the altitude tolerance band from 20 to 80 feet above ground level (AGL). The pilots were also instructed to try to crest the hills at 50 feet. Actual aircraft altitude values were collected at the top of each hill as well as the minimum and maximum altitude while flying over each hill contour. The minimum altitude value attained while flying in each valley was also saved as a data point. Terrain crashes (strikes) were also detected and scored as the cumulative time spent in contact with the ground. Airspeed was also controlled by having each pilot fly the course at 300 knots. Time within tolerance scoring was also used for the aircraft airspeed with a tolerance band of plus or minus 15 knots.

Three types of visual cues, which served as the independent variables, were randomly varied in order to control for learning effects. The visual cues consisted of three different sizes of checkerboard texture patterns, the presence or absence of vertical objects, and the presence or absence of the A-10 aircraft shadow. There were thus twelve unique combinations of visual cues which were randomly presented to each pilot in a unique random order. The sizes of the checkerboard patterns were either 220, 440, or 880 feet on a side.

Each pilot flew the corridor three times for each unique combination of visual cues, for a total of 36 experimental sorties. Six initial sorties were also flown at the beginning of data collection in order to familiarize the pilots with the mission profile and the scoring feedback, and to reduce initial learning effects.

RESULTS AND CONCLUSIONS

In general the pilots who flew the simulated missions reported that all three types of visual cues were useful, however the vertical object cues and texture patterns were of greater help than the aircraft shadow. Some pilots reported that the aircraft shadow was particularly useful in signaling impeding contact with the ground. The vertical object cues, especially trees of a known height, were subjectively very useful in gauging height above the terrain. The texture patterns were also reported as desirable, but perhaps in a less conscious fashion than the vertical object cues. The pilots reported a definite preference for the smallest texture pattern, which used squares that were 220 feet on a side rather than the larger patterns. They also especially disliked flying over the largest texture pattern without vertical object cues. The pilots also would have preferred more irregular "natural" patterns rather than the highly regular checkerboard patterns.

The quantitative data from this study indicate that both the texture patterns and the vertical object cues produced statistically significant differences in pilot performance. These initial statistical analyses were performed using a multivariate analysis of variance (MANOVA) on several measures at once, with step down analyses of variance (ANOVA's) for the individual variables. The MANOVA probabilities for these two variables were both less than .001. However, only the texture pattern cues produced a significant effect ($p < .001$) on the time within tolerance scoring for altitude in the valleys. The presence or absence of the vertical objects did not significantly effect this measure. The average scores across pilots for the three texture patterns were 64.7% for the 880 foot, 72.6% for the 440 foot and 77.4% for the 220 foot texture patterns. The average score without vertical objects was 70.9%, and with vertical objects it was 72.2%. The texture patterns also produced the only significant effect ($p < .003$) on the average minimum altitude values in the valleys. These average values were 47.0 feet for the 880 foot pattern, 45.5 feet for the 440 foot pattern and 43.0 feet for the 220 foot pattern. The average value without vertical objects was 45.5 feet and with vertical objects it was 44.8 feet.

The vertical object cues had a significant effect ($p < .001$) on the average aircraft altitude (AGL) at the top of the hills. The average altitude without vertical objects was 72.7 feet and with vertical objects it was 63.6 feet. The 63.6 foot average value was closer to the requested 50 foot clearance at the hill tops. The texture patterns did not produce a significant effect on the average aircraft altitude at the top of the hills. The average values were 69.2 feet for the 880 foot pattern, 67.6 feet for the 440 foot pattern and 67.8 feet for the 220 foot pattern. Both the vertical object cues ($p < .001$) and the texture patterns ($p < .001$) produced significant effects on the average minimum altitude values that occurred over each hill. The average minimum altitude values were 47.9 feet for the 880 foot pattern, 45.9 feet for the 440 foot pattern and 40.6 feet for the 220 foot pattern. The average minimum altitude values were 48.2 feet without the vertical objects and 41.4 feet with the vertical objects. Apparently the pilots flew closer to the hill surface when both the vertical objects and the smallest texture patterns were present.

None of the visual cue variables significantly affected the amount of time crashed. In general, this measure was low with some pilots crashing into the simulated terrain more frequently than other pilots. There were also no statistically significant differences, due to the visual cues, in the aircraft airspeed time within tolerance scores.

Based upon the initial data analyses, the textural visual cue variable appears to have a stronger effect on pilot performance in general, than the presence or absence of the vertical object cues. At this point, the meaning of this effect is unclear, especially when it is contrasted with a nearly universal pilot preferance for vertical object cues.

ABOUT THE AUTHOR

George Buckland is a Behavioral Scientist at the Operations Training Division of the Air Force Human Resources Laboratory located at Williams AFB, Arizona. His current primary research efforts include the conduct and management of research in the area of visual display system requirements for USAF flight simulators. He received his PhD in Psychology from the University of Rochester in 1976, and he is currently serving as a Major in the US Air Force.