THE EFFECT OF DEVIATION ANGLE AND DEVIATION LOCATION ON AIR TRAFFIC CONTROLLERS' ABILITY TO DETECT AIRCRAFT BLUNDERS

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This paper presents the results of a human factors assessment sponsored by the Required Navigation Performance (RNP) Program Office (ATO-R). The National Airspace System Human Factors group (ATO-P, formerly ACB-220) conducted a reaction time task as part of the human factors evaluation at the Northern California Terminal Radar Approach Control (TRACON). Sixteen Air Traffic Controller Specialists (ATCSs) completed the 35-minute simulation task. The air traffic display presented one aircraft at a time. The display showed aircraft as they would typically appear on a radar display, i.e. identified by a radar symbol and updated every 4.8 seconds. Eight of the 20 aircraft "blundered" from the typical flight path by initiating a turn of 15º, 30º, 45º, or 60º. The participants identified when a blunder occurred by pressing a computer key. The results indicated that ATCSs identified deviations more quickly if the aircraft turned soon after becoming established on the flight path verses near the end of the flight path (6.0 vs 8.7 seconds). On average, participants responded most quickly to deviations of 30º (5.8 seconds) followed by 60º (6.7 seconds), 45º (7.1 seconds), and 15º (9.9 seconds). The researchers theorize that the controllers focused near the beginning of the flight path because, based on their ATC experience, this phase of flight represented a greater likelihood of a deviation. They also speculated that the superior performance at 30º may be due to everyday familiarity with this turn rate and distrust of rates more extreme than those typically experienced.

INTRODUCTION

The FAA forecasts that over the next ten years demand at the major hub airports will increase by 200 million passengers (FAA, 2002). In response, the FAA is pursuing the creation of area navigation and required navigation performance (RNP) arrival and departure routes. These routes leverage the capabilities of modern aviation systems to reduce reliance on ground-based navigation aids and promote more efficient flight paths.

The Required Navigation Performance Division (ATO-R) requested that the NAS Human Factors group (ATO-P) conduct a human factors assessment of a proposed Required Navigation Performance (RNP) converging approach procedure to San Francisco International Airport (SFO). Today, during adverse weather conditions, SFO must adopt a single stream operation. During these times, the airport acceptance rate falls from approximately 60 aircraft per hour to near 30 aircraft per hour.

In December 2004, the NAS Human Factors group conducted a simulation utilizing an RNP converging approach procedure that would maintain a dual stream operation during lower weather minimums. The study consisted of a reaction time task and four operational scenarios. The operational scenarios investigated two communications options, two options for locating the non-transgression zone, and two levels of traffic. One of the primary objectives of the study was to characterize controllers' ability to distinguish between standard track error and "blunders" using an ARTS Color Display showing ASR-9 radar data. The simulation environment provided the opportunity to measure ATCS response times to a number of aircraft deviations; an incident so rare that a controller may not experience a similar event during their entire ATC career. We implemented aircraft deviations of 30º in the operational scenarios in accordance with previous research (Magyarits & Ozmore, 1999; Magyarits & Ozmore, 2002). Unlike the operational scenarios, the reaction time task provided an opportunity to measure response times to varying deviation angles when controllers were not responsible for monitoring multiple aircraft, providing aircraft separation, or communicating with pilots. This paper presents results of the reaction time task.

Method

Participants. Sixteen ATCS Northern California Terminal Radar Approach Control (TRACON) participated in the study. All participants were males ranging in age from 35 to 60 years with a median age of 48.5 years. Their experience as a SFO terminal airspace controller ranged from 2 months to 31 years, with a median of 12.5 years.

Test Facility. The researchers conducted the simulation at the Enhanced Target Generator training facility at Northern California TRACON.

Apparatus. The apparatus consisted of four on site ARTS Color Displays (ACD), a portable high fidelity air traffic control simulator, and pre-recorded scripts. The simulation platform consisted of the target generation facility (i.e, a target generator) and the Distributed Environment for Simulation, Rapid Engineering, & Experimentation (DESIREE). The four reaction time scripts consisted of 20 pre-recorded flight paths. The researchers changed the aircraft callsigns and the order of presentation for each version, but the exact path of all aircraft remained identical.

Procedure. Each day, four ATCSs completed the 35-minute reaction time task. They concurrently observed the series of 20 individual aircraft turn onto the final approach course for SFO runway 28-Left. For this task, the ATCSs could only observe the aircraft and had no communications capability with the pilot. The researchers instructed the participants to indicate when an aircraft deviated from the final approach course by pressing any key on the ACD keyboard. Diverging aircraft turned 15º, 30º, 45º, or 60º. The researchers did not inform the participants that deviations occurred either soon after the aircraft was established on the approach, or near the end of the approach. All deviating aircraft continued on the divergent path until they entered a non-transgression zone (NTZ). The NTZ was a 2,000-foot wide area, located equidistant between the runway 28-Left and 28-Right final approach courses. We instructed the participants to indicate when they were certain that a deviating aircraft would enter the NTZ by pressing any key on the ACD. The simulator captured the system time for each display update and participant key press. Figure 1 depicts the areas where deviating aircraft on the 28-Left approach initiated the turn.

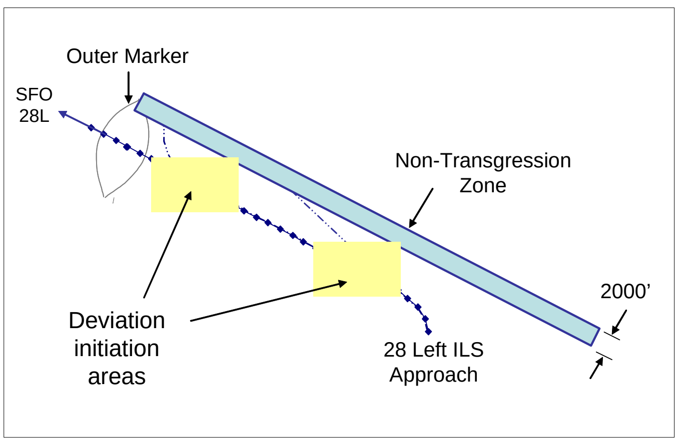

Figure 1. Approach used for reaction time task.

Variables. Independent variables included angle of deviation (i.e., 15º, 30º, 45º, and 60º) and deviation location (i.e., shortly after an aircraft was established on the approach, or near the end of the approach). The dependent measure presented here is the amount of time from the onset of the aircraft turn until the controller pressed a key to indicate that the aircraft deviated from the approach path.

RESULTS

The researchers averaged the reaction time to identify each blunder situation for all 16 participants. Figure 2 presents the average time to identify a deviation from the initiation of the turn. Deviation angle appears on the x-axis and average time for the controller to respond in seconds on the y-axis. The lower line (△) shows the average time controllers required to identify a deviation that occurred soon after an aircraft was established on the approach path. The upper line (□) presents the average time participants required to respond when the deviation was near the end of the approach path.

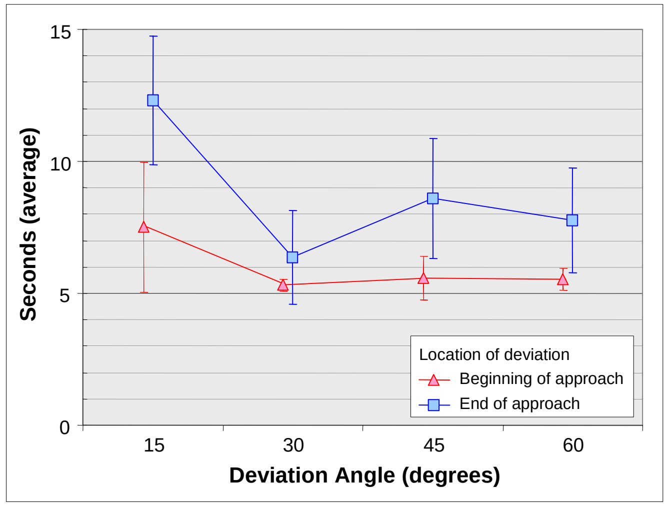

Figure 2. Average time to identify a deviation.

The researchers conducted a 2 X 4 repeated measures ANOVA to compare controller response times for deviation location and deviation angle. The first factor, deviation location, included two levels (i.e., soon after the aircraft was established on the approach or near the end of the approach). The second factor, deviation angle, had four levels (i.e., 15º, 30º, 45º, and 60º). There was a significant interaction for deviation location by angle, $F(3,45)=10.53$, $p<.001$. To investigate this interaction, we conducted an analysis of simple main effects for the deviation location. For turns at the beginning of the approach, there were significant differences in how quickly controllers identified blunders, $F(3,45)=12.48$, $p<.001$. Tukey Honestly Significant Difference (HSD) post-hoc comparisons indicated that controllers took longer to identify deviations of 15º compared to all other angles. For turns at the end of the approach, there were also significant differences among the deviation angles, $F(3,45)=47.15$, $p<.001$. Tukey HSD post-hoc comparisons indicated that controllers took the longest to identify deviations of 15º and that deviations of 30º were identified faster than 15º and 45º. We also conducted an analysis of simple main effects for the deviation angle. The results indicated that for each of the four deviation angles, controllers were faster at identifying blunders when the turn occurred at the beginning of the approach compared to the end of the approach.

DISCUSSION

The results demonstrated that on average, controllers' responded faster when a deviation occurred soon after an aircraft was established on the approach verses when it was near the end of the approach path (i.e., 6 secs vs. 8.7 secs). The researchers speculate that the reasons for the difference may be two-fold. First, as a vigilance task, the participants were required to keep their attention on the display. It was especially challenging since the controllers had to observe a single aircraft for nearly two minutes that exhibited little activity, particularly after initiating a turn and becoming established on the instrument landing system (ILS) approach path. During true operational conditions, controllers are responsible for monitoring several aircraft, maintaining aircraft separation, communicating with pilots, and performing several other tasks. Secondly, based on their ATC experience, controllers recognize that in the very rare circumstances that a deviation does occur, it is more likely to happen as an aircraft turns onto the ILS approach and not after it is established on the path. For example, when working at an approach sector, controllers report that on occasion aircraft cross the localizer approach path before turning to rejoin it. These situations typically occur as the result of a strong crosswind.

The researchers compared controller response times for each of the deviation angles. We hypothesized that response time would decrease in a roughly linear fashion as the angle increased from 15º to 30º, 45º, and 60º. The results confirmed that controllers exhibited different response times for each of the deviation angles. With the exception of 30º, response times did represent a linear trend to becoming shorter as the angle of deviation increased. However, on average, participants responded most quickly to deviations of 30º (5.8 seconds) followed by 60º (6.7 seconds), 45º (7.1 seconds), and 15º (9.9 seconds). The superior performance at 30º may be due to everyday familiarity with this turn rate and distrust of rates more extreme than those typically experienced. Controllers report that they frequently use 30º as a standard turn for merging aircraft onto an approach or when vectoring aircraft for traffic. The authors believe that when the separation between the target on the display and the projected location (i.e., the location at which the controller expected the target to be) approximated that seen for a standard turn, controllers readily recognized that a deviation had occurred. For rates greater than 30º, we speculate that controllers may be responding more slowly due to distrust of the unusual separation distance between the target and projected location, potentially resulting in them waiting for the next update to confirm the trend. Deviations of 30º represent a standard blunder turn for ATC simulations, however results from this study suggest that other deviation angle should be included.

The results indicate that controllers were extremely good at identifying blunders. They typically identified deviations within two updates. The only exception was for aircraft that initiated a 15º turn near the end of the approach path. In these situations, controllers required three updates before all controllers identified the event.

CONCLUSION

The participants demonstrated differences in their ability to discriminate blunders based on the location of the event and the angle of deviation. The ATCSs were extremely good at differentiating turns from standard track error, typically identifying a turn within two updates. Their superior performance at deviations of 30º suggest that when researchers conduct simulations in the future that they consider including other deviation angles in addition to the standard 30º blunder.

REFERENCES

Federal Aviation Administration. (2002). *Operational evolution plan* (Version 5.0). Washington, DC:Author.

Magyarits, S. & Ozmore, R. (1999). *Terminal air traffic control radar and display system recommendations for monitoring simultaneousiInstrument approaches* (DOT/FAA/CT-TN99/24). Atlantic City International Airport, NJ: Federal Aviation Administration, William J. Hughes Technical Center.

Magyarits, S. & Ozmore, R. (2002). *Evaluation of triple independent instrument landing system approaches to runways spaced 4,000 ft and 5,300 ft apart using a precision runway monitor system* (DOT/FAA/CT-TN02/16). Atlantic City, NJ: Federal Aviation Administration, William J. Hughes Technical Center.

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