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What is This?
Tower Controllers’ Response Behavior to Runway Safety Alerts

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As decision support tools to improve runway safety are introduced into Airport Traffic Control Towers, it is critical to understand their impact on controller performance. A Tower Human-In-The-Loop (HITL) simulation was conducted to evaluate the behavior of Local controllers in the presence of tower-based runway safety alerts. The results of this study suggest controllers like to gather as much information about the situation, within a reasonable amount of time (usually less than 5 seconds), before they initiate the action of issuing instructions to the aircraft involved in the emergency.

INTRODUCTION

One of the priorities of the Federal Aviation Administration (FAA) is the improvement of runway safety. To work toward this goal there are a number of ongoing initiatives, which include the examination of airport “hot zones” where runway incursions are likely to occur, the installation of surface lighting systems that notify pilots about the status of runways (McGarry & Long, 2008), equipping aircraft with surface moving maps that show own-ship location, and providing Tower controllers with decision support tools that provide information about the location of all surface vehicles and airborne operations within a defined proximity to the airport. These decision support tools are also designed to generate alerts in situations where collisions are likely. The primary tower-based systems used in the National Airspace System (NAS) are variants of the Airport Surface Detection Equipment (ASDE) surveillance systems. These systems generally fuse radar data with other sensing technologies to provide a picture of the surface traffic to the controller via a display in the tower. Furthermore, safety logic algorithms within the ASDE systems are designed to predict and alert controllers of possible collisions.

Therefore, as decision support alerting tools that provide additional information about the location of aircraft/vehicles are added into the tower environment, it is important to understand how controllers will integrate new visual and auditory information into their decision-making process, especially in critical situations. Tower controller behavioral research has been largely based on field observations. Since runway incursions are rare events and cannot be ‘controlled’, we lack an understanding of the impact of these events on controllers’ responses and behavior during these situations.

TOWER HITL SIMULATION

In preparation for the experiment, a visit to the Washington Dulles International Airport (IAD) Tower was made. This visit provided the research team with valuable insight into a real tower environment, which was instrumental in designing a tower experiment with ecological validity. For example, observing the impact of varying traffic levels (departures and arrivals) on controller behavior was critical to the development of realistic experimental scenarios. The visit also provided a valuable opportunity to observe how controllers utilize and interact with the various information displays in the tower environment. Tower Air Traffic Control (ATC) Subject Matter Experts were also consulted to help assess the ecological validity of the tower simulation.

Participants

Eight active and retired controllers participated in the study (age: $M = 41, SD = 6$; years of tower experience: $M = 9, SD = 5$; years removed from working as tower controller: $M = 3, SD = 2$). All of the controllers who participated worked the Local controller position in the experiment. The Local position is usually
tasked with the management of runways (arrivals and departures). The Ground controller directs traffic on taxiways while coordinating with the Local controller to ensure safe crossing of taxiing aircraft across active runways. The Ground position in this experiment was filled by a confederate controller who had over 14 years of experience in a civilian tower. Three of the participating controllers had experience in military towers, while the rest only had civilian tower experience. None of the controllers had previous experience with Louisville International Airport-Standiford Field (SDF), which was the airport environment used in the simulation.

Tower Simulator

Figure 1 is a photograph image of the Tower simulator used in this study. Controllers communicated via radio (voice communications) with pseudo-pilots, who were responsible for controlling all of the aircraft in the simulation. Pseudo-pilots were located in an isolated room adjacent to the tower simulator environment. The pseudo-pilots controlled aircraft via a customized Graphical User Interface (GUI), which sent commands to an application that managed all of the simulation displays. A head-mounted eye tracker (Applied Science Laboratories: Mobile Eye) was used to record the local controllers’ visual gaze patterns. The Ground and Local controllers stood side-by-side, facing the following tower components:

- A computer-generated graphical representation of the out-the-window environment. This view was composed of six diagonal wide-screen aspect ratio 24” monitors. Each Liquid Crystal Display (LCD) covered a ~30 degree field of view (total of approximately ~180 degrees field of view).
- A tower-based surface safety system. A 30” monitor was used to display an airport surface map with ground and nearby airborne traffic. The display showed the position of aircraft relative to the airport map, as well as data block information (aircraft identification, type, and ground speed). This display was intentionally designed with a ‘generic’ look to avoid associating controller performance to a single tower-based surface safety system display design. This display also was the source of runway safety alerts consisting of a visual and auditory component. When triggered, the visual component of the alert was presented on the top-right corner of the screen in red text. The text conveyed the runway where the predicted conflict was occurring, the identification of the aircraft involved, and a descriptive message indicating the problem, such as “runway occupied.”
- Also, during alerts, a red circle was drawn around the relevant aircraft targets on the airport map. The visual alert component was accompanied by an auditory alert message, delivered in a male voice. It is important to note that this surface safety system did not have any automated logic. Alerts were manually triggered by an experimenter and therefore, the system was 100% reliable (i.e., no false alerts or misses).
- Two Digital Bright Radar Indicator Tower Equipment (DBRITE) displays. The DBRITE is a tower display system that provides a raster scan presentation of radar/beacon videos and automation system alphanumeric data. The system is a Certified Tower Radar Display (CTRD). The DBRITE displays were located above the out-the-window monitors.
- Paper flight strips for all departing flights. Flight strip holders were also available.
- An Information Display System (IDS). An IDS presents real-time information to air traffic controllers on a single display platform. It consolidates data from many of the FAA’s key weather and safety monitoring systems and other external sources of information (e.g., pilot reports, aeronautical data, Notices to Airmen [NOTAM]).

Figure 1. Photograph of Tower simulator environment

Experimental Design

There were a total of 10 scenarios, each lasting between 10 – 15 minutes. Two of those scenarios were used for training/familiarization. The training scenarios were always presented first. Participating controllers were told the purpose of the study was a broad evaluation of procedures in the tower, including the measurement of eye-scan patterns of the Local control position, communication dynamics between the Ground and Local controllers, communication with aircraft, and
the use of displays that show ground traffic information. Four scenarios were alert scenarios and the other four were non-alert scenarios. All of the scenarios followed the same traffic patterns. The Local controller was in charge of arrivals on one runway (Runway 11) and departures on an intersecting runway (Runway 17L). There were also arrivals on Runway 17R, but those were not the responsibility of the study participants; they were told another Local controller was managing them. Taxiing patterns for arrivals and departures were the same throughout the scenarios. The weather in all scenarios was daytime Visual Meteorological Conditions (VMC), so controllers were able to see all aircraft in the out-the-window view. The level of traffic (arrivals and departures) was intended to provide a high level of workload demand. The scenarios were pilot-tested with experienced Tower controllers who helped set the level of traffic that would accomplish high workload demands.

All of the alert scenarios had a similar sequence of events. As soon as an aircraft was cleared for takeoff or landing by the Local controller, another aircraft holding short of an active runway, was sent across such runway by the pseudo-pilot (without a clearance from the confederate Ground controller). As soon as the ‘unauthorized’ aircraft began moving, the runway safety alert was manually triggered by an experimenter. In all alert scenarios, the confederate Ground controller was instructed to wait several seconds after the alert was initiated before talking to the crossing aircraft, which simulated the fact that in a real environment both controllers need time to react before responding. If the local controller asked the ground for help in identifying the source of the alert, the ground controller was allowed to contribute meaningful information such as “looks like flight 34 is crossing 11.” The alert scenarios consisted of the following situations:

- **Incursion on takeoff runway**: As an aircraft began its takeoff roll, another aircraft was sent across the active runway.

- **Incursion on takeoff runway (departure distraction)**: Similar to the incursion on takeoff runway scenario, but the Local controller was busy providing final heading information to an aircraft on queue for departure at the time of the alert.

- **Incursion on takeoff runway (unauthorized crossing)**: Similar to the incursion on takeoff runway scenario, but the Local controller was distracted by an unauthorized crossing on the arrival runway at the time of the alert. The confederate Ground controller was tasked with pointing out that an aircraft was making an unauthorized crossing.

- **Incursion on arrival runway**: An aircraft holding short of the arrival runway was sent across as another was approximately 1-mile from touchdown.

**RESULTS**

The key elements of the ATC Tower task appeared to have been designed effectively into the Tower simulator environment. Most participants commented on the realism of the scenarios and the experiment, and eye-tracking results showed that across all scenarios, participants spent ~55% of the time gazing out-the-window, ~17% gazing at the surface map display, ~16% gazing at their flight strips, ~7% gazing at the DBRITE, and ~2% gazing at the IDS screen. These scan patterns are consistent with previous Tower studies, which have shown that controllers’ visual attention tends to range from 30-50% of the time out-the-window, but can be as high as 70% (Pinska & Bourgois, 2005).

![Response Times to Alerts](image)

**Response Times to Alerts**

Figure 2 illustrates the average response time of controllers to runway safety alerts in the four alert conditions. Response time was measured as the difference between the onset of an alert and the onset of the controller’s action to instruct the pilot of the aircraft involved to “cancel takeoff clearance” or “go-around.” Response times were calculated from the eye-tracking videos in which sound was recorded. There was not a significant difference in response times as a function of scenario. In the two scenarios where the controllers
were distracted with another situation at the time of the alert (Takeoff [departure dis] and Takeoff [unauthorized], see Figure 2), it appears they were able to ‘disconnect’ from that distraction and switch their attention to the alert without a significant delay. The variance of response times was fairly large. Across all four conditions the minimum response time observed was 2.3 seconds (Arrival) and the maximum time was 8.1 seconds (Takeoff [departure dis]).

Eye-Gaze Patterns after Alerts

While all controllers gave priority to the runway alerts and relied on them, their response was not to immediately execute what the alert indicated. Instead, controllers used a trust but verify approach, which usually involved gathering additional information about the situation before instructing an aircraft to execute a specific action. To conduct this analysis, eye-tracking data were analyzed by logging every Area of Interest (AOI) that controllers gazed at between the onset of the alert and the onset of their response. The AOIs used for this analysis were the out-the-window view, the airport surface map with ground traffic display which included the visual alert component, the DBRITE display, and the flight strips.

![Figure 3. Average number of visual gazes between onset of the alert and onset of controller response.](image)

Figure 3 illustrates the average number of visual gazes between the onset of the alert and the onset of controller response. The data from Figures 4 and 5 help demonstrate the trust but verify behavior of controllers by showing that controllers spend a meaningful amount of effort gathering information from several disparate sources before making a decision or conveying a message to an aircraft.

![Figure 4. Distribution of the various AOIs where controllers allocated their visual attention during alerts.](image)

Figure 4 illustrates the distribution of the various AOIs where controllers allocated their visual attention during alerts. For example, in the takeoff alert scenario, 36% of the visual gazes of controllers, between the onset of the alerts and the onset of their responses, were directed out-the-window. Interestingly, in most alert scenarios, controllers gazed at the flight strips before issuing any instructions to an aircraft. Post-interview data revealed that controllers like to verify the aircraft identification before they call them to issue an instruction. Figure 5 illustrates the distribution of the first AOI where controllers allocated their visual attention after the alert. Overall, the first AOI controllers gazed at was the alert surface display. This display provides a text message with information about the situation (runway, aircraft IDs), as well as highlighting aircraft involved in the incursion. The data from Figures 4 and 5 help demonstrate the trust but verify behavior of controllers by showing that controllers spend a meaningful amount of effort gathering information from several disparate sources before making a decision or conveying a message to an aircraft.

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1 Eye-tracking videos were analyzed by recording gaze location for 7 frames per second.
DISCUSSION

The results of this study show that Tower controllers employ a trust but verify approach when responding to runway safety alerts. This finding should be considered in the design philosophy of runway safety tools for the Tower environment. First, the safety logic algorithms used to generate alerts should take into account controller response times, so that alerts are generated with sufficient lead time to give controllers an opportunity to formulate a decision and execute an action. Even though the average response time observed in this study is approximately 4.5 seconds, times as high as 8.1 seconds were observed in scenarios where the controller was busy attending to other important tasks/situations at the time of the alert. Furthermore, the content of runway safety alerts should be designed to help controllers execute their trust but verify behavior in a timely manner. For example, the auditory component of the alert could be designed to facilitate the controller’s information gathering process through the out-the-window view. This could be done by enhancing the content provided by the auditory alert component to contain spatial information about the location of the incursion in the real world.

As runway safety decision support systems are introduced into Tower environments it will be critical to understand how controllers will integrate that information into their decision-making process. To do this, it will be important to evaluate and document how various conditions in the Tower can impact the reliance behavior of controllers on these aids. For example, future studies on this topic should manipulate variables such as out-the-window visibility and complex airport surface configurations.

REFERENCES


EUROCONTROL, 2007, Warsaw tower observations. EUROCONTROL Experimental Centre.


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