En Route Air Traffic Control Input Devices for the Next Generation

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Abstract—The purpose of this study was to investigate the usefulness of different input device configurations when trial planning new routes for aircraft in an advanced simulation of the en route workstation. The task of trial planning is one of the futuristic tools that is performed by the graphical manipulation of an air**craft's trajectory to reroute the** aircraft without voice communication. In this study with two input device**s, the FAA's** current trackball and a basic optical computer mouse were **evaluated with the "pick" button in a click**-and-hold state and a click-and-release state while the participant dragged the trial plan line. The trial plan was used for three different conflict types: Aircraft Conflicts, Weather Conflicts, and Aircraft + Weather Conflicts. Speed and accuracy were the primary dependent variables. Results indicate that the mouse conditions were significantly faster than the trackball conditions overall with no significant loss of accuracy. Several performance ratings and preference ratings were analyzed from post-run and post-simulation questionnaires. The release conditions were significantly more useful and likable than the hold conditions. The results suggest that the mouse in the release button state was the fastest and most well liked device configuration for trial planning in the en route workstation.

Keywords-input devices, en route, controller, workstation, mouse, trackball, NextGen

I. INTRODUCTION

A. Background

The United States air traffic control system is expecting such a significant increase in traffic that the current system will not be able to handle it. Controllers have been using the radar scope to maintain separation and efficiency of air travel for more than half a century. Air traffic control has developed considerably over the years, but the fundamentals have remained the same. As traffic continues to increase in the future, the system that we have relied upon for many years may reach a breaking point in which traffic can no longer be safely managed with the current tools and/or operations.

In the en route airspace where aircraft fly at their cruising altitudes, capacity is limited by controller workload, which poses a significant barrier to the projected traffic growth in the future National Airspace System (NAS). For example, domestic figures show that between the years of 2004 and 2005 there was a 6.6 percent increase in the number of flights over the previous year [1], and overall, the FAA has predicted that by the year 2025, the "total mainline air carrier and regional enplanements are forecast to increase from 757.4 million in 2008 to 1.1 billion in 2025, an average annual rate of 2.2 percent" [1]. To prevent unnecessary accidents and delays, re-evaluating the radar controller workstation is one area that may help reduce the workload of the operator, therefore, aiding the main goal of reducing the strain on the entire system.

B. Input devices

One component of the controller workstation is the input device. Two of the most commonly used input devices when interfacing with a computer are the trackball and the mouse. Compared to the mouse, research has shown that task-based performance is worse when the trackball is used for several tasks including throughput (speed and accuracy), selection, dragging, and tracing [1][5]. Interestingly, one study's results show that participants who used a trackball regularly without ever using a mouse prior to the study performed better with the mouse [5].

C. Button states

Input devices can be operated with various combinations of movements and button presses performed at the same time. The current en route trackball, however, was designed to have the button pressed with no other event to be performed simultaneously. This means that tasks that may have involved selecting items while moving the cursor were not possible and the Display System Replacement (DSR) interface was built with no button press combination features. However, the modern mouse was designed with button state and movement interactions as a primary feature. This would enable several new interactions to exist such as drag-and-drop and selecting items in a group.

There are current day graphical user interfaces (GUIs) that incorporate the use of dragging the device cursor, even hand gestures, with one or more buttons held down to perform a variety of functions that increase the versatility of the device [6]. These combinations allow designers to add different interactions to their applications to effectively make the product easier to use and can decrease the time for completing various tasks. However, previous research shows that holding the button down while moving the cursor increased completion

times for a basic pointing task [3]. Would this effect carry over to the dynamic environment of the DSR with the use of a modern mouse? Are the current input devices capable of additional functionality (e.g. click-and-hold) in the software without degradation of performance?

D. Current study

The Airspace Operations Laboratory (AOL) at NASA Ames Research Center has developed the Multi-Aircraft Control System (MACS) which simulates a wide variety of ATC tools [4]. The specific section of MACS that includes the en route DSR has had many new graphical tools added in recent years that may benefit from a click-hold-and-drag input (e.g. trial planning). The trial plan is a futuristic tool that enables the controller to graphically manipulate the route of an aircraft as he sees fit.

In the present study, the aim is to discover the usefulness of a click-and-drag input device for NextGen via the DSR trial plan task. The trial plan tool is one of the most likely graphical tools to be implemented in future Air Route Traffic Control Center (ARTCC) workstations, and for this reason, it was included in the study. Three types of conflicts were presented to the controllers in which they used the trial plan tool to graphically alter the routes to maintain separation of the aircraft. The hypothesis was that a standard optical computer mouse would result in faster performance than the trackball for the graphical interaction task of trial planning in the DSR. It was also hypothesized that the hold condition would result in faster performance than the release condition when the mouse was used but slower performance when the trackball was used.

II. METHODS

A. Participants

Thirteen participants were selected from a pool of retired local controllers (ages 45-65) from the Oakland control center (ZOA). The number of participants was chosen based on availability. Criteria necessary for participation in the study were extensive experience in air traffic control and prior MACS (Multi-Aircraft Control System) software usage.

B. Design

A 2x2 factorial within-subjects design was used for the study. The independent variables were input device (mouse, trackball) and button state (hold, release). The four conditions in the 2x2 factorial included: Mouse + Hold (MH), Mouse + Release (MR), Trackball + Hold (TH), and Trackball + Release (TR).

The MH condition was performed by pressing and releasing the mouse button on the portal icon (the arrow to the right of the callsign in the first row of the datablock) which opened the manipulatable blue trial plan line. The act of selecting with the left mouse or trackball button is also known as "picking." The controller would then pick on the trial plan line and simultaneously hold it in while dragging. The release of the button dropped the target and completed the mouse action for one trial plan. The controller would then type in the keyboard command "UC CID" (UC = Uplink Clearance, CID = Computer Identification) to uplink the clearance for the reroute of the selected aircraft. In this condition, picking on the route line and manipulating it was exactly like the Microsoft Windows "drag-and-drop" action. The MR condition was different in that the button was never held, but pressed and released twice instead. The first click grabbed the target while the second click dropped it, completing the mouse action. The TH condition was the same action as the MH condition but with the use of the trackball instead of the mouse. The TR condition was the same action as the MR condition but with the use of the trackball instead of the mouse. The TR condition is currently used as the exclusive device configuration for en route operations.

While manipulating the route of an aircraft, the participants either pressed the button and released it, or pressed the button and held it down. These two conditions are referred to as "release" and "hold," respectively. In the release condition, participants would simply press the button once to grab the trial plan line and press again to drop it. Movement of the device (and cursor) would occur between presses.

The software, MACS, was used in the experiment and was capable of simulating current day operations as well as many possible future concepts. An advanced display containing limited data tags, real-time convective weather, weather probe, and conflict probe was enabled because the hypothesis was constructed with tools that are not yet operational in the real-world (e.g. trial planning). Also, the results likely speak to issues of the future rather than the present.

C. Stimuli

Figure 1 shows the stimuli presented to the controllers. Full datablocks which contained information for a given aircraft including the callsign, altitude, speed, and time-to-conflict (in minutes) appeared in a scripted fashion when the aircraft entered sector ZKC 90 or when a conflict was going to occur within six minutes. All weather-based conflicts appeared when the aircraft crossed the sector boundary and all aircraft conflicts initially appeared at the six minute mark. Six minutes was chosen to provoke the controller to act immediately while still providing a large enough buffer if they needed more time to resolve the conflict or if they were behind due to working on other conflict resolutions.

The conflicts were determined by an algorithm that efficiently predicted if the aircraft would be in conflict with weather or another aircraft. When a conflict appeared, a salient full datablock popped up on the screen to call attention to it. The controller then picked on the portal (arrow to the right of the callsign) to open the trial plan line in which they were able to manipulate.

The controllers' sector of responsibility was ZKC 90, which is a real-world sector inside of Kansas City Center's airspace. Each participant was in a standalone configuration in which no networking was needed between machines. All workstations presented the same scenario simultaneously.

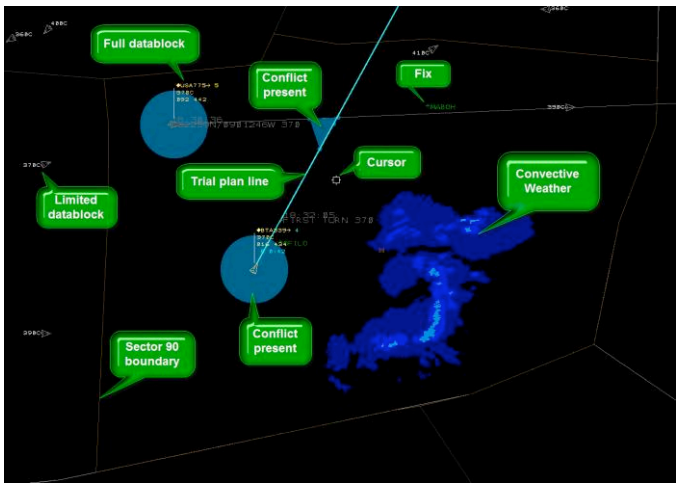

Figure 1. Stimuli presented to the participants on the Display System Replacement.

A convective weather cell was located in the southeast corner of the sector that closed off about 25% of the sector from use. The fixes "MABOH" and "OFILO" were chosen based on their location in reference to the weather cell. Convective weather was present for the entire duration of the trial and slowly moved east (~5-10kts).

Aircraft were all "owned" by the participant and required no check-ins or handoffs (assumed to be automated). Limited data tags were used because it was an advanced concept in which the controllers were monitoring for conflicts rather than actively solving them. It also served as the primary goal for the participants to maintain all limited datablocks as often as possible.

The participants were instructed not to use any alternatives to the lateral route maneuver such as radio communication, vertical maneuver, slowing the aircraft, or keyboard input. This forced the participant to query a trial plan for an aircraft in conflict. Trial planning is the graphical manipulation of an aircraft's 4D trajectory. When the portal was opened, a blue line appeared on top of the filed flight path that was extended from the nose of the aircraft to the destination airport, typically with several waypoints along the route. The blue line was then manually picked on and dragged to a new location and dropped to lock it in place. The controller was then able to uplink the clearance to confirm the new route for the aircraft. This reroute process can be done with no voice communication; therefore, voice communication was not necessary for rerouting aircraft in the study.

D. Types of conflicts

To maximize the number of conflicts presented while reducing redundancy and the learning effect, three types of conflicts were scripted within different areas of the sector. The most basic conflicts involved one aircraft and weather. When an aircraft in conflict with weather entered the sector, a full datablock appeared automatically with a blue number indicating how many minutes were left until the aircraft would enter the weather (Figure 2). The full datablock's appearance was their cue to resolve the conflict. When a full datablock appeared, the steps to complete the task were to pick on the portal, reroute the aircraft graphically around the weather cell over a specified fix, drop the route on the fix, and finally uplink the clearance via keyboard command. All aircraft that were headed west in conflict with weather were rerouted over the fix "OFILO," and aircraft headed east were rerouted over the fix "MABOH." The controllers were to be as precise as possible while still solving the conflicts quickly. They were told to "put the cross in the box," which represented the fix and cursor, respectively. A total of ten conflicts of this type were included in each trial.

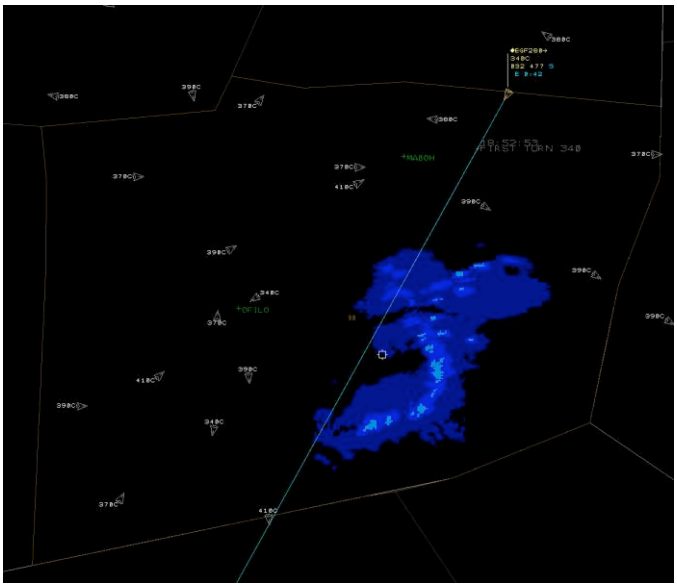

Figure 2. Aircraft flying into weather unless acted upon by a controller.

The second conflict type was between two aircraft. Unlike the weather conflicts, the controllers had some flexibility in the location of the reroute.

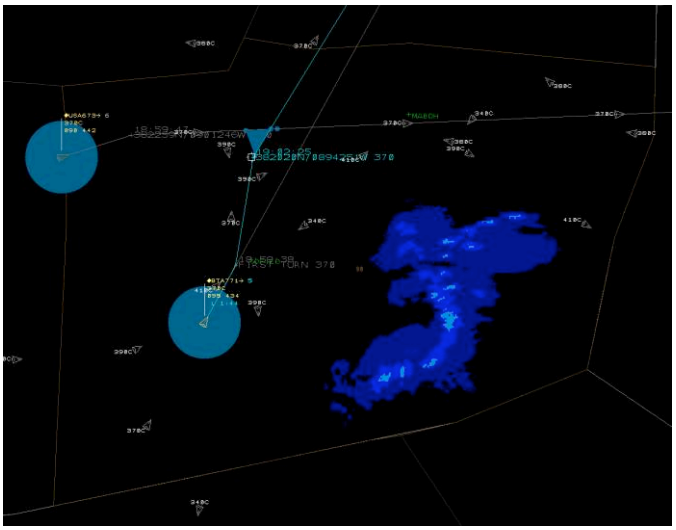

Figure 3. Two aircraft in conflict while the new route (blue line) was moved to the left.

For consistency the controllers were also instructed to maneuver the southernmost aircraft "behind" the other aircraft in conflict (Figure 3). Manipulation of the route so that the rerouted aircraft flew behind the other was typically a more reliable method of conflict avoidance and thus should have been the controllers' default response regardless of instruction. Real-time feedback for successful conflict avoidance was supported by the disappearance of the large blue circles that indicated a conflict was present as the controller manipulated the trial plan line. A total of ten conflicts of this type were included in each trial.

The third and final conflict type was a combination of a weather conflict followed by an aircraft conflict. This task first involved a reroute around weather over MABOH, exactly like the first conflict type for eastbound aircraft. When the controller rerouted the aircraft over MABOH to avoid the weather, a second conflict would appear with another aircraft along the new route (Figure 4). The controller then moved the line once more to manipulate the aircraft to safely fly behind the other one in conflict while leaving the initial reroute over MABOH alone. This made the conflict resolution more difficult and longer than the other types. The controllers would normally attempt to locate a single fix to resolve both weather and aircraft conflicts in the real-world if possible, however, the instructions were necessary so that each controller resolved the conflicts in the same manner. A total of five conflicts of this type were included in each trial.

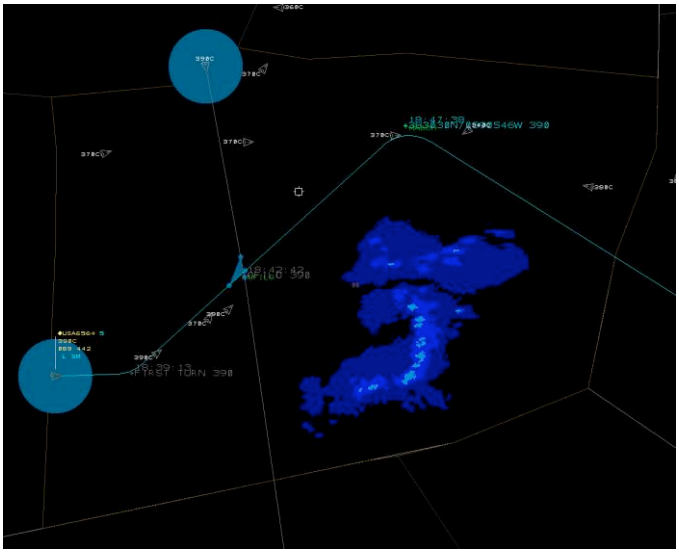

Figure 4. Two aircraft in conflict after one was rerouted around weather.

E. Dependent variables

Objective metrics included in the analysis were time and accuracy. The time to completion of the trial plan was measured as the initial pick on the portal to the final pick that dropped the trial plan line to lock the route in place. Between those picks was when the controller actually dragged the line to the new location, therefore, only the opening of the trial plan line to the release of the line was considered part of the trial plan time.

The accuracy of the pick on the waypoints was measured as the distance in nautical miles from the waypoint. The waypoints had a cross (+) to indicate the exact location of the fix. The cross was the aiming point for the participants to drop the trial plan line. MACS automatically recorded the point (x, y) that the participants actually dropped the line. The point was then compared to the known location of the waypoint.

Subjective metrics were analyzed from questionnaires taken by the participants after each trial and again at the end of the simulation.

III. RESULTS

A repeated measures ANOVA was conducted for all of the results that follow. Table 1 summarizes the F-values and p-values for each of the analyses with bold values to indicate significance ($\alpha = 0.05$). The factors (Device = D, Button State = BS) are listed in the top cells of the columns and the dependent variables are listed in the first column with their respective F-values and p-values to the right. Interactions that were found to be significant were followed up with a post hoc paired samples T-test with the Bonferroni correction.

Table 1. Summary of repeated measures ANOVA results.

Factor > Value >	D F	D p	BS F	BS p	DxBS F	DxBS p
Objective Metrics						
AC Conflict	5.13	**0.043**	0.29	0.603	5.22	**0.041**
WX Conflict	74.86	**0.000**	19.69	**0.001**	1.24	0.287
AC – WX Conflict	24.87	**0.000**	0.55	0.474	1.43	0.255
Accuracy	0.88	0.369	0.06	0.805	0.06	0.818
Subjective Ratings						
Workload	0.32	0.584	1.77	0.209	0.32	0.584
Usability	10.55	**0.007**	5.67	**0.035**	3.42	0.089
Usefulness	5.15	**0.043**	31.13	**0.000**	2.54	0.137
Accuracy of picking	2.25	0.168	1.16	0.309	4.97	0.053
Accuracy moving TP	7.36	**0.024**	9.53	**0.013**	6.00	**0.037**
Cursor speed	19.31	**0.001**	8.67	**0.012**	15.60	**0.002**
TP satisfaction	4.52	0.055	7.02	**0.021**	1.68	0.219
Comfort level	17.91	**0.001**	11.93	**0.005**	12.91	**0.004**
Likability	12.54	**0.004**	65.61	**0.000**	7.92	**0.016**

A. Trial plan completion time

The main goal and only task for the participants was to successfully trial plan aircraft to avoid conflicts with convective weather and/or other aircraft. The time to completion of the trial plan began with the opening of the portal and ended when the route line was dropped. These events were recorded with MACS internal data logging as well as video screen captures. The keyboard command to uplink the

clearance to finalize the process was not included in the analysis as keyboard inputs would have introduced unnecessary variables.

The metrics for the time to complete a single trial plan were measured in milliseconds but have been rounded for this paper. The three conflict types were calculated separately to show the results individually by conflict type, however, they cannot be directly compared as the trial plan manipulation was not the same for each conflict (i.e. the weather conflicts had specified waypoints to reroute to, while the aircraft conflicts had no specified points and minimizing delay was a priority).

1) *Aircraft Conflict*

Aircraft conflicts were resolved by rerouting the southernmost aircraft behind the other. The controllers were instructed to quickly resolve the conflicts while minimizing delay. The descriptive statistics for the conditions are MH (M = 7.87, SD = 1.98), MR (M = 8.66, SD = 3.53), TH (M = 10.49, SD = 3.33), TR (M = 9.15, SD = 2.52). The results of a repeated measures ANOVA show a significant main effect was found for device type ($F_{(1,12)} = 5.13$, $p < 0.05$) and interaction effect ($F_{(1,12)} = 5.22$, $p < 0.05$). The mouse was significantly faster than the trackball when trial planning for conflict avoidance between two aircraft, as shown in Figure 5.

A paired samples T-test with the Bonferroni correction was calculated to find which pair of means were significantly different. The interaction suggested that the MH took less time than the MR condition and the TH condition took longer than the TR condition. However, of the six possible combinations, only the MH condition's trial plan was significantly faster than the TH condition [MH-TH ($t(12)= 3.15$, $p < 0.0083$).

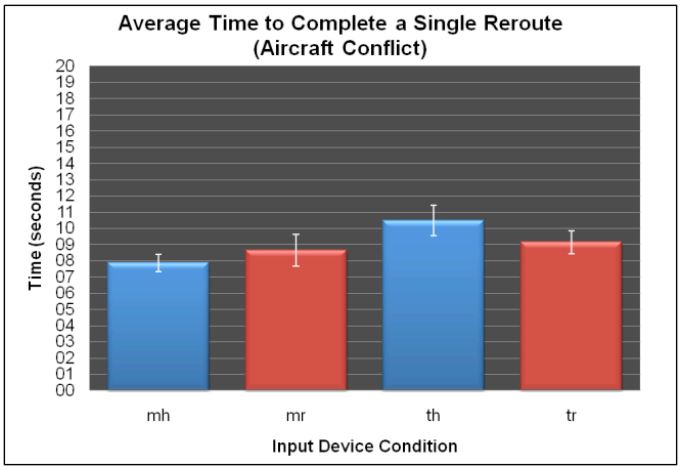

Figure 5. The average time to complete a single reroute for an aircraft conflict.

2) *Weather Conflict*

Weather conflicts were resolved by rerouting the aircraft around the weather over a specified waypoint (i.e. MABOH, OFILO) depending on the heading of the aircraft. The descriptive statistics for the conditions are MH (M = 7.65, SD = 2.38), MR (M = 6.89, SD = 1.66), TH (M = 10.54, SD = 2.32), TR (M = 8.83, SD = 2.59). The results of a repeated measures ANOVA show a significant main effect was found for device type ($F_{(1,12)} = 74.86$, $p < 0.001$) and button state ($F_{(1,12)} = 19.69$, $p < 0.01$). Unlike the Aircraft Conflict results, there was no significant interaction ($F_{(1,12)} = 1.24$, $p > 0.05$). Similar to the Aircraft Conflict results, the mouse was significantly faster than the trackball for trial planning around weather to a specified waypoint. In addition, the release conditions were significantly faster than the hold conditions (Figure 6).

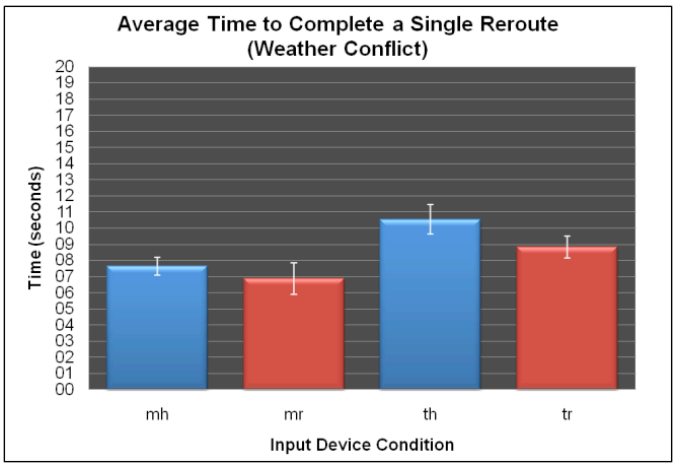

Figure 6. The average time to complete a single reroute for a weather conflict.

3) *Aircraft + Weather Conflict*

The aircraft + weather conflicts involved a combination of the two conflict types during a single trial plan. This added more complexity while lengthening the duration of the trial plan. The descriptive statistics for the conditions are MH (M = 12.42, SD = 4.34), MR (M = 12.77, SD = 2.93), TH (M = 17.50, SD = 4.21), TR (M = 16.18, SD = 4.06). The results of a repeated measures ANOVA show a significant main effect was found for device type ($F_{(1,12)} = 24.87$, $p < 0.001$). There was no main effect for button state ($F_{(1,12)} = 0.55$, $p > 0.05$). For this conflict type, the mouse was much faster than the trackball (Figure 7). Although Figure 7 suggests an interaction between device type and button state, the interaction was not significant ($F_{(1,12)} = 1.43$, $p > 0.05$).

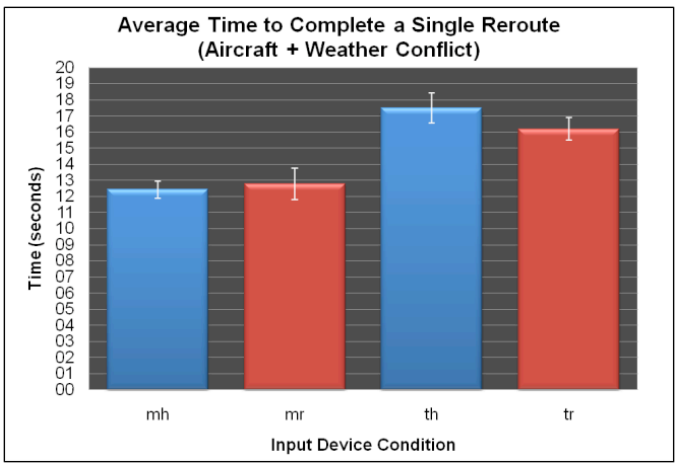

Figure 7. The average time to complete a single reroute for an aircraft + weather conflict.

B. Accuracy of picking on the waypoints

Accuracy was measured by the proximity of the cursor to a waypoint that the participants were instructed to reroute the aircraft over (for conflicts that involved weather). They were also instructed to resolve the conflicts quickly while dropping the trial plan line as accurately as possible on the waypoint. Due to an inherent tradeoff between speed and accuracy, the precision of the pick on the waypoints MABOH and OFILO were analyzed with a repeated measures ANOVA [MH (M = 0.33, SD = 0.09), MR (M = 0.33, SD = 0.10), TH (M = 0.31, SD = 0.15), TR (M = 0.30, SD = 0.08)]. No statistical significance was found in the analysis. The overall precision of all four conditions was between 0.30 to 0.35 nautical miles with very little variance (0.01). Overall, there was no speed/accuracy tradeoff.

C. Workload

The workload level was immediately rated after completing a trial on a scale from 1 to 5 (Very low (1) - Very high (5)). Workload was defined as the overall cognitive demand on the participant while resolving conflicts. The hold conditions [MH (M = 1.31, SD = 0.48), TH (M = 1.38, SD = 0.65)] were rated as having slightly more of a workload than the release conditions [MR (M = 1.15, SD = 0.38), TR (M = 1.15, SD = 0.38)]. Workload ratings were very low for all conditions and the repeated measures ANOVA analysis showed no significance for main effects or interaction effect.

D. Participant ratings

Subsequent results were analyzed from participant ratings on post-run and post-simulation questionnaires. A Likert scale from 1 to 5 was used to capture the controllers' perception about specific aspects of the device configurations.

1) Usability ratings

Participants rated the usability (ease of use) of each device configuration on a 1 to 5 scale (Not easy (1) - Very easy (5)), [MH (M = 4.69, SD = 0.63), MR (M = 4.84, SD = 0.38), TH (M = 3.85, SD = 0.99), TR (M = 4.54, SD = 0.52)]. Results from the repeated measures ANOVA show a significant effect for device type ($F_{(1,12)} = 10.55$, $p < 0.01$) and button state ($F_{(1,12)} = 5.67$, $p < 0.05$). Regardless of the button state, the mouse was rated as significantly more usable than the trackball. Also, the release conditions were rated as significantly easier to use than the hold conditions (Figure 8).

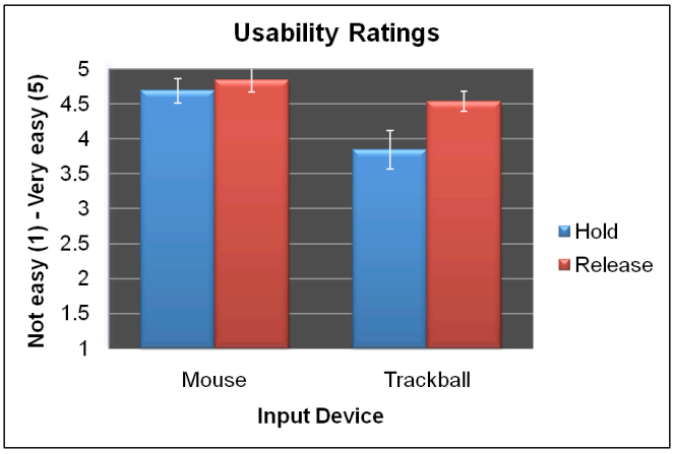

Figure 8. The usability of the device conditions as rated by the participants after each trial.

2) Usefulness ratings

The usefulness of the device configurations was rated on a 1 to 5 scale (Not useful (1) - Very useful (5)), [MH (M = 4.23, SD = 0.83), MR (M = 4.85, SD = 0.38), TH (M = 3.62, SD = 0.77), TR (M = 4.62, SD = 0.51)]. The participants' rating of the device type show that the mouse was significantly more useful than the trackball ($F_{(1,12)} = 5.15$, $p < .05$). The button state release condition was also significantly more useful than the hold condition ($F_{(1,12)} = 31.13$, $p < .01$). Graphically, the chart looks similar to the usability ratings (Figure 8) with the button state difference more pronounced (i.e. the hold condition values are lower).

3) Accuracy of pick action ratings

The accuracy of the pick action was rated on a 1 to 5 scale (Not accurate (1) - Very accurate (5)), [MH (M = 4.73, SD = 0.47), MR (M = 4.42, SD = 0.51), TH (M = 4.15, SD = 0.8), TR (M = 4.64, SD = 0.50)]. The repeated measures ANOVA analysis showed no significance for main effects or interaction effect.

4) Accuracy of moving trial plan line ratings

The accuracy of moving the trial plan was rated on a 1 to 5 scale (Not accurate (1) - Very accurate (5)), [MH (M = 4.73, SD = 0.47), MR (M = 4.75, SD = 0.45), TH (M = 3.54, SD = 1.13), TR (M = 4.73, SD = 0.47)]. The results show a significant effect for device type ($F_{(1,12)} = 7.36$, $p < .05$), button state ($F_{(1,12)} = 9.53$, $p < .05$), and interaction effect ($F_{(1,12)} = 6.00$, $p < .05$).

A paired samples T-test with the Bonferroni correction was calculated to find which pair of means were significantly different. Of the six possible combinations, the three that included the TH condition were significant [MH-TH ($t(10)= 3.46$, $p < 0.0083$), MR-TH ($t(11)= 4.10$, $p < 0.0083$), TH-TR ($t(10)= 3.36$, $p < 0.0083$)]. The TH condition was rated significantly lower than the other three conditions which were rated as very accurate (Figure 9).

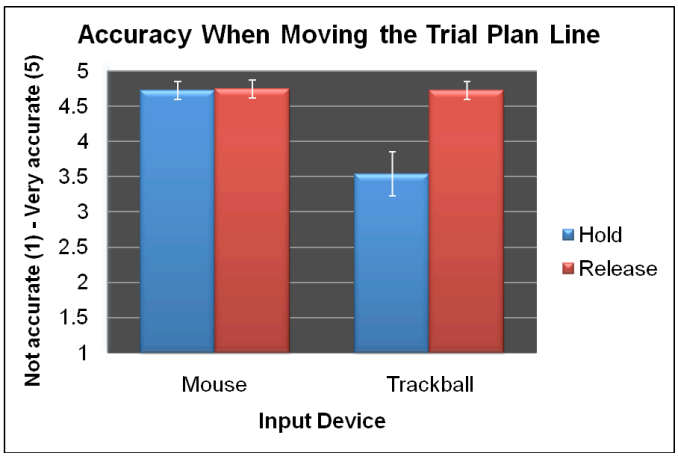

Figure 9. Accuracy of moving trial plan line ratings.

5) *Speed of cursor movement ratings*

The speed of the cursor was rated on a 1 to 5 scale (Not fast (1) - Very fast (5)), [MH (M = 4.77, SD = 0.44), MR (M = 4.77, SD = 0.44), TH (M = 3.46, SD = 0.88), TR (M = 4.46, SD = 0.52)]. Cursor movements occurred when the participant manipulated the device to move the cursor around on the screen whether or not the button was held down. A significant result was found for device type ($F_{(1,12)} = 19.31$, $p < .01$), button state ($F_{(1,12)} = 8.67$, $p < .05$), and interaction effect ($F_{(1,12)} = 15.60$, $p < .01$).

A paired samples T-test with the Bonferroni correction was calculated to find which pair of means were significantly different. Of the six possible combinations, the three that included the TH condition were significant [MH-TH ($t(12)= 4.98$, $p < 0.0083$), MR-TH ($t(12)= 4.57$, $p < 0.0083$), TH-TR ($t(12)= 3.61$, $p < 0.0083$)]. The TH condition's cursor movement speed ratings were significantly slower than the other three conditions. Graphically, the chart resembles that of the Accuracy When Moving the Trial Plan Line (Figure 9) with the TR value slightly lower.

6) *Trial planning satisfaction ratings*

Trial planning satisfaction was used to gauge which conditions the participants felt a sense of satisfaction when performing [MH (M = 4.54, SD = 0.66), MR (M = 4.85, SD = 0.38), TH (M = 4.08, SD = 0.86), TR (M = 4.69, SD = 0.48)]. Ratings were on a 1 to 5 scale (Not satisfying (1) - Very satisfying (5)). The trial planning satisfaction results (Figure 10) are similar to the usability and usefulness results. The button state release condition was significantly more satisfying to trial plan than the hold condition ($F_{(1,12)} = 7.02$, $p < .05$). The device type and interaction effect were not significant.

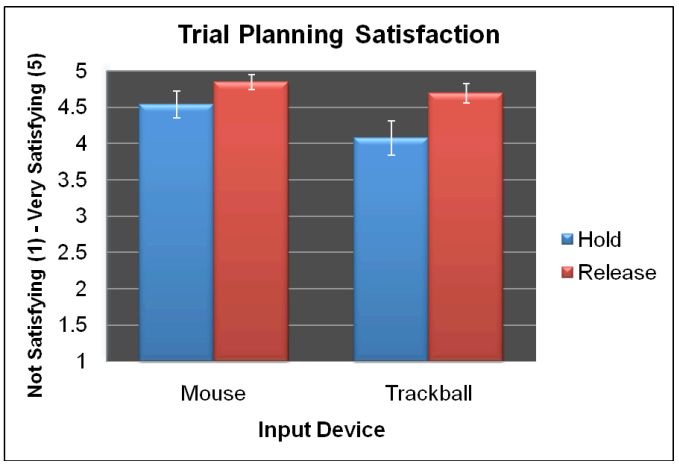

Figure 10. Satisfaction of trial planning ratings.

7) *Comfort level ratings*

The overall comfort of using the device configurations was rated on a 1 to 5 scale [MH (M = 4.85, SD = 0.38), MR (M = 4.92, SD = 0.28), TH (M = 3.31, SD = 1.32), TR (M = 4.62, SD = 0.51)]. A significant result was found for device type ($F_{(1,12)} = 17.91$, $p < .01$), button state ($F_{(1,12)} = 11.93$, $p < .01$), and interaction effect ($F_{(1,12)} = 12.91$, $p < .01$).

A paired samples T-test with the Bonferroni correction was calculated to find which pair of means were significantly different. Of the six possible combinations, the three that included the TH condition were significant [MH-TH ($t(12)= 4.38$, $p < 0.0083$), MR-TH ($t(12)= 4.40$, $p < 0.0083$), TH-TR ($t(12)= 3.58$, $p < 0.0083$)]. The overall comfort level of the TH was significantly less than the other conditions (Figure 11). Comfort level when picking and when moving the trial plan line were also gathered. The results mirror that of the overall comfort level.

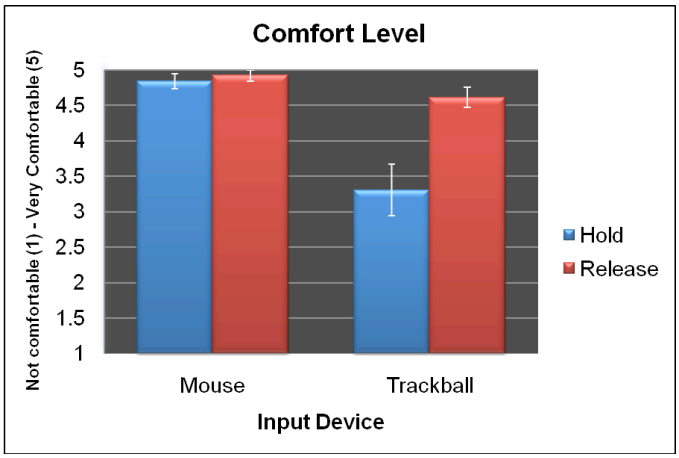

Figure 11. Comfort level of device configuration ratings.

8) *Likability ratings*

A post-simulation questionnaire was completed by the participants after they experienced each of the four conditions. The likability ratings greatly favored the release conditions

[MH (M = 3.73, SD = 0.44), MR (M = 4.77, SD = 0.44), TH (M = 2.46, SD = 1.05), TR (M = 4.54, SD = 0.66)]. The results were significant for device type ($F_{(1,12)} = 12.54$, $p < .01$), button state ($F_{(1,12)} = 65.61$, $p < .01$), and interaction effect ($F_{(1,12)} = 7.92$, $p < .05$). The mouse was significantly more likable than the trackball and the release button state was significantly more likable than the hold button state. A paired samples T-test with the Bonferroni correction was calculated to find which pair of means were significantly different. Of the six possible combinations, five were significant [MH-MR ($t(12)= 11.69$, $p < 0.0083$), MH-TH ($t(12)= 3.93$, $p < 0.0083$), MH-TR ($t(12)= 3.41$, $p < 0.0083$), MR-TH ($t(12)= 7.04$, $p < 0.0083$), TH-TR ($t(12)= 5.67$, $p < 0.0083$)]. The release conditions were very well liked and were not significantly different (Figure 12).

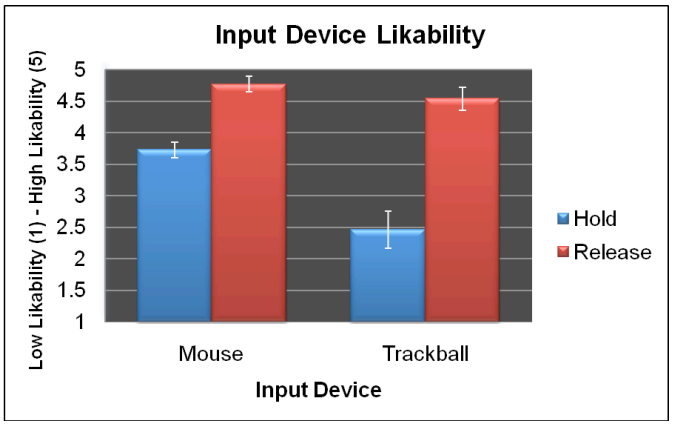

Figure 12. Device configuration likability ratings.

IV. Discussion

The purpose of this study was to investigate the usefulness of different input device configurations when trial planning new routes for aircraft in an advanced simulation. The four conditions were created to discover the advantages and/or disadvantages of each device configuration.

The results partially support the hypotheses because the mouse was significantly faster than the trackball for all conflict types. However, the MH and MR conditions were not significantly different for Aircraft Conflicts and Aircraft + Weather Conflicts. In fact, the MH condition was significantly slower than the MR condition for weather conflicts possibly due to the controllers' familiarity with the release condition.

There was no significant loss in accuracy even though the mouse conditions were performed significantly faster than the trackball conditions. This finding suggests that the mouse had the same accuracy strength but was much faster than the trackball. It appears that the mouse was a superior device for the trial plan task regardless of button state; however, the release condition was liked significantly more. If implemented in future workstations, controllers may enjoy the option to choose between the MR and MH conditions.

The mouse conditions were rated as significantly more usable overall, when picking, and when trial planning. The MR condition was considered the most usable device configuration, but the performance was not significantly different from the MH condition for the Aircraft Conflict and Aircraft + Weather Conflict types. However, the MH condition has the advantage of additional interactions that may benefit the future en route workstation depending on the toolset required.

Interestingly, The TR condition was rated as more likable than the MH condition even though performance was worse for the TR condition. The preference may be due to the extensive use with the TR over years of working traffic with that configuration. It was also present in the trial plan satisfaction ratings and the usefulness ratings, likely due to the general familiarity of the release condition. Issues such as reliability and trust may have been some of the underlying factors that influenced the ratings.

As expected, the TH condition was the slowest and least liked for trial planning in every case. The trackball was difficult to use when the participants were forced to hold the pick button and move the cursor with one hand.

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