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NextGen Flight Deck Data Comm: Auxiliary Synthetic Speech Phase I

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13. ABSTRACT (Maximum 200 words)
Data Comm—a text-based controller-pilot communication system—is critical to many NextGen improvements. With Data Comm, communication becomes a visual task. Interacting with a visual Data Comm display may yield an unsafe increase in head-down time, particularly for single-pilot operations. This study examined the feasibility of supplementing Data Comm with synthetic speech. To this end, thirty-two pilots flew two experimental scenarios in a Cessna 172 Flight Training Device. In one scenario, ATC communication was with a text-only Data Comm display, in the other, communication was with a text Data Comm display with synthetic speech that read aloud each message (i.e., text+speech). Pilots heard traffic with similar call signs on the party line and received a conditional clearance (in both scenarios); in either scenario, pilots received a clearance that was countermanded by a live controller. Results indicated that relative to the text-only display, the text+speech display aided single-pilot performance by reducing head-down time, and may have prevented participants from acting early on the conditional clearance. Supplementing text Data Comm with speech did not introduce additional complications: participants were neither more likely to erroneously respond to similar call signs, nor to ignore a live ATC voice countermand.

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Preface

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)	
1 inch (in)	= 2.5 centimeters (cm)
1 foot (ft)	= 30 centimeters (cm)
1 yard (yd)	= 0.9 meter (m)
1 mile (mi)	= 1.6 kilometers (km)
AREA (APPROXIMATE)	
1 square inch (sq in, in2)	= 6.5 square centimeters (cm2)
1 square foot (sq ft, ft2)	= 0.09 square meter (m2)
1 square yard (sq yd, yd2)	= 0.8 square meter (m2)
1 square mile (sq mi, mi2)	= 2.6 square kilometers (km2)
1 acre = 0.4 hectare (he)	= 4,000 square meters (m2)
MASS - WEIGHT (APPROXIMATE)	
1 ounce (oz)	= 28 grams (gm)
1 pound (lb)	= 0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	= 0.9 tonne (t)
VOLUME (APPROXIMATE)	
1 teaspoon (tsp)	= 5 milliliters (ml)
1 tablespoon (tbsp)	= 15 milliliters (ml)
1 fluid ounce (fl oz)	= 30 milliliters (ml)
1 cup (c)	= 0.24 liter (l)
1 pint (pt)	= 0.47 liter (l)
1 quart (qt)	= 0.96 liter (l)
1 gallon (gal)	= 3.8 liters (l)
1 cubic foot (cu ft, ft3)	= 0.03 cubic meter (m3)
1 cubic yard (cu yd, yd3)	= 0.76 cubic meter (m3)
TEMPERATURE (EXACT)	
((x-32)(5/9)) °F	= y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)	
1 millimeter (mm)	= 0.04 inch (in)
1 centimeter (cm)	= 0.4 inch (in)
1 meter (m)	= 3.3 feet (ft)
1 meter (m)	= 1.1 yards (yd)
1 kilometer (km)	= 0.6 mile (mi)
AREA (APPROXIMATE)	
1 square centimeter (cm2)	= 0.16 square inch (sq in, in2)
1 square meter (m2)	= 1.2 square yards (sq yd, yd2)
1 square kilometer (km2)	= 0.4 square mile (sq mi, mi2)
10,000 square meters (m2)	= 1 hectare (ha] = 2.5 acres
MASS - WEIGHT (APPROXIMATE)	
1 gram (gm)	= 0.036 ounce (oz)
1 kilogram (kg)	= 2.2 pounds (lb)
1 tonne (t)	= 1,000 kilograms (kg) = 1.1 short tons
VOLUME (APPROXIMATE)	
1 milliliter (ml)	= 0.03 fluid ounce (fl oz)
1 liter (l)	= 2.1 pints (pt)
1 liter (l)	= 1.06 quarts (qt)
1 liter (l)	= 0.26 gallon (gal)
1 cubic meter (m3)	= 36 cubic feet (cu ft, ft3)
1 cubic meter (m3)	= 1.3 cubic yards (cu yd, yd3)
TEMPERATURE (EXACT)	
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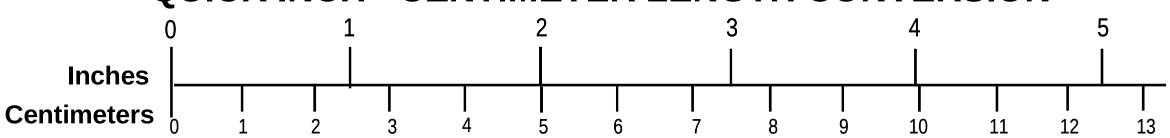

QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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Executive Summary

Data Comm—a digital, text-based communication system between pilots and controllers—enables many of the operational improvements envisioned in the Next Generation Air Transportation System (NextGen). Data Comm will allow written messages to be exchanged directly between a specific flight crew and Air Traffic Control (ATC), thereby alleviating congestion on the voice frequency. Written messages will be stored in a log on the flight deck, reducing flight crews' reliance on memory. Data Comm instructions may further be integrated with the Flight Management System (FMS), reducing crew workload. Communication difficulties associated with speech rate or accent are also alleviated. Relative to voice, it is anticipated that Data Comm will increase the accuracy and efficiency of pilot-controller communication—required to accommodate the increase in traffic associated with NextGen.

A potential challenge associated with the use of Data Comm on the flight deck is the increased visual task load. Data Comm transfers communication from an aural to a visual task. This could lead to an unsafe increase in head-down time as pilots interact with the visual display to read and respond to ATC communication—particularly for single-pilot operations. To avoid such unintended consequences, the National Research Council suggested that Data Comm should "[e]mploy redundant voice synthesis…operated in parallel with the visual (text and graphics) display of the message" (Wickens, Mavor, Parasuraman, & McGee, 1998, p. 251). The FAA has further been mandated to "address the problems and concerns raised by the National Research Council" (Title 49, United States Code Section 44516). The current proof-of-concept study supports this mandate by comparing pilot performance using Data Comm with and without an auxiliary-speech display. Of interest is whether a Data Comm display augmented with synthetic speech mitigates the challenges associated with text-only Data Comm, without introducing additional complications.

Thirty-two commercial certificated and instrument-rated pilots flew a Cessna 172 Flight Training Device (i.e., single pilot) in two experimental scenarios. In one scenario, communication with ATC was via a text-only Data Comm display, in the other, communication with ATC was via a Data Comm display and synthetic speech (i.e., text+speech). It was hypothesized that pilots in the text+speech condition would experience less head-down time, respond more accurately to ATC instructions, and perceive a lower communication workload. Each scenario also included a conditional clearance (e.g., AT [position] CLIMB TO [level])—participants may respond erroneously to this clearance (e.g., climb early), however the presence of synthetic speech was predicted to decrease the likelihood of such error. In either the text-only or text+speech condition, participants received a clearance that was countermanded by a live controller before it was displayed on the flight deck. It was hypothesized that pilots may be more likely to ignore the live countermand when the Data Comm message was displayed via both text and synthetic speech. Aircraft with similar call signs were also heard communicating with ATC on the party line. It was predicted that participants would be more likely to erroneously respond to a similar call sign when communicating via the text+speech display. Throughout the experiment, participants responded to Data Comm messages via a touch-screen tablet attached to their knee. When present, synthetic speech was played through the participants' headphones.

Results indicated that relative to the text-only Data Comm display, the text+speech Data Comm display aided single-pilot performance by reducing head-down time (especially the overall

duration of gaze dwell time on the touch-screen display), and may have prevented participants from acting early on the conditional clearances. No difference was observed in number of pilot queries to ATC or the need for live ATC intervention. Subjective responses indicated that pilots tended to perceive a lower communications workload using the text+speech display, relative to the text-only one, and felt the system was easy to use. Pilots found the auxiliary synthetic speech to be helpful and not distracting.

Importantly, the presence of synthetic speech did not appear to introduce additional complications. Relative to text-only Data Comm, participants in the text+speech Data Comm condition were not more likely to erroneously respond to similar call signs, nor did it cause pilots to ignore a live ATC voice countermand received prior to the appearance of the Data Comm message on the flight deck.

Taken together, the results indicate that the auxiliary synthetic speech display aided single pilot performance compared to a text-only display. Future research aims to examine the feasibility of implementing an auxiliary synthetic speech display in a multi-crew, realistic en-route environment, and whether such communication interferes with live oral ATC instructions.

Acronyms and Abbreviations

ATC	Air Traffic Control(ler/s)
C-172	Cessna 172
CDTI	Cockpit Display of Traffic Information
CDU	Control Display Unit
CPDLC	Controller Pilot Data Link Communications
DAB	Daytona Beach International Airport
Data Comm	(digital) Data Communications
dB	Decibels
DM	Downlink Message
EFC	Expected Further Clearance
ER	Embry Riddle
ERAU	Embry Riddle Aeronautical University
EUROCAE WG-78	European Organization for Civil Aviation Equipment Working Group 78
GA	General Aviation
FTD	Flight Training Device
FMS	Flight Management System
GUI	Graphical User Interface
HITL	Human In the Loop Simulation
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
MFD	Multi-function Display
ms	Milliseconds
NAS	National Airspace System
NextGen	Next Generation Air Transportation System
NTSB	National Transportation Safety Board
PTS	Practical Test Standards
RPM	Revolutions Per Minute
RTCA SC-214	Radio Technical Commission for Aeronautics Special Committee 214

S(s)	Subject(s)
s	Seconds
SD	Standard Deviation
SELCAL	Selective Calling
S/N	Signal-to-noise ratio
TRACON	Terminal Radar Approach Control
UM	Uplink Message
VFR	Visual Flight Rules
VOR	VHF Omnidirectional Range

I. Introduction

Traffic in the National Airspace System (NAS) is increasing, and as a consequence, the radio frequencies carrying the voice communications between air traffic controllers (ATC) and pilots are becoming increasingly congested. The transmissions may be noisy or broken up by pilots “stepping on” each other’s communications—resulting in requests to “say again”; or pilots are prevented from notifying ATC of an emergency because of frequencies blocked by stuck microphones, with potentially serious consequences. The fast pace of communications may inhibit proper readback or requests for clarification of ATC instructions or pilot queries. In addition, some properties of speech make voice communication particularly difficult. For example, pilots must listen for instructions to their call sign, sometimes amid instructions to aircraft with similar sounding call signs (e.g., 345 vs. 354). Such similarity can result in miscommunications (Grayson & Billings, 1981). Moreover, operators do not always adhere to standard phraseology (Bürki-Cohen, 1996; Cardosi, 1993; Morrow, Lee, & Rodvold, 1993) and can vary in both accent and speech rate. Communication errors are even more likely with long or complex voice instructions (Bürki-Cohen, 1995; Bürki-Cohen, 1996; Cardosi, 1993; Morrow et al., 1993). Even when an auditory instruction is correctly heard, a pilot may later forget the information, write it down incorrectly, or erroneously enter it into the Flight Management System (FMS; Kerns, 1999). Each of these factors can contribute to inefficient or inaccurate communication (Kerns, 1999).

Data Comm—a digital, text-based data communication system between pilots and controllers—may help to alleviate some of these problems inherent in voice communication. Data Comm is a key enabler for many of the operational improvements envisioned in the Next Generation Air Transportation System (NextGen). Data Comm is expected to help accommodate the increased capacity of the airspace, anticipated with NextGen, by increasing the efficiency and accuracy of controller-pilot communication. With Data Comm, written messages are exchanged directly between ATC and a specific flight crew. Consequently, the likelihood that a flight crew will misinterpret a clearance intended for another aircraft with a similar call sign on the shared communication frequency (the so-called party line) is reduced. Difficulties understanding messages due to speech rate or accent are nonexistent. Messages are preformatted: pilots and controllers select a given message from a menu without having to manually enter the entire text. This reduces workload and promotes the use of standard phraseology. Data Comm also alleviates the flight crew’s reliance on memory. In the voice environment, messages from ATC must be remembered and written down. With Data Comm, messages are stored in a log—pilots can read and retrieve the message when needed. Compared to voice communication, data communication is associated with fewer memory errors, and this benefit is most pronounced with long instructions (DeMik, 2009; Wickens, Goh, Helleberg, Horrey, & Talleur, 2003).

Replacing today’s aural radio communications, however, may entail some unintended consequences. For example, Data Comm shifts communication from an aural to a visual task. This may lead to an unsafe increase in head-down time, as pilots must interact with a visual display to read and respond to a message. Moreover, the increased visual task load may reduce flight precision and elongate the time between ATC communication and flight crew response. Verbal cues present in speech (e.g., use of intonation to specify an urgent instruction) are also lost.

In an attempt to preclude such potential unintended consequences, the National Research Council recommended that Data Comm should "[e]mploy redundant voice synthesis of uplink messages as a design option, operated in parallel with visual (text and graphics) display of the message" (Wickens, Mavor, Parasuraman, & McGee, 1998, p. 251). Moreover, the FAA has been mandated to "address the problems and concerns raised by the National Research Council…[and] respond to the recommendations" (Title 49 United States Code Section 44516). The current study complies with this law by comparing pilot performance when communicating with ATC using a visual Data Comm display with text only (text only) or a Data Comm display with text and synthetic speech (text+speech). Of interest is whether the Data Comm text+speech condition yields decreased head-down time and more accurate performance relative to the text-only condition, without introducing additional complications.

A. Review of Data Comm Experiments

Scientists have examined the potential effects of Data Comm for nearly a quarter century, long before today's concept of NextGen was fully developed. They used NAS simulations ranging from very basic part-task simulations to more sophisticated simulations including a broader range of ATC and pilot tasks.

1. Potential Benefits of Data Comm

Findings from these experiments confirm the Data Comm benefits named in the introduction. The use of text-based communication is associated with a decrease in congestion on the radio frequencies (cf. Kerns, 1999). Increased Data Comm availability yields a marked decrease in the number of voice communications, but not a corresponding increase in the number of data communications (Hinton & Lohr, 1988). Consequently, an overall reduction in controller-pilot communication is observed (Blassic & Kerns, 1990; Hinton & Lohr, 1988; for a review see Kerns, 1999). This suggests that controller-pilot communication is more efficient with Data Comm and results in fewer requests for clarification or repeated transmissions (Hinton & Lohr, 1988; Kerns, 1991; 1999; Talotta et al., 1990). Decreased voice communication increases the likelihood that the frequency will be available for urgent messages, in turn promoting needed requests for clarification and full read back of clearances (Kerns, 1991). (When communicating *primarily* with Data Comm, however, crews may be hesitant to contact ATC via voice or to request clarification; see Lozito, McGann, & Corker, 1993.)

In some implementations, Data Comm messages may be autoloaded into the Flight Management System (FMS), allowing pilots to review and integrate ATC instructions into the navigation system with minimal button presses. This increased automation is associated with an increase in efficiency—compared to manually-loaded messages, autoloaded messages are acknowledged and loaded faster (Logsdon, 1996; Logsdon, Lozito, Mackintosh, McGann, Infield, & Possolo, 1995), and crews spend less time communicating with ATC (Waller, 1992). Autoloaded instructions are thus associated with a decrease in flight-crew workload (Logsdon, 1996; Groce & Boucek, 1987). FMS integration may also improve accuracy, since pilots do not have to manually enter the clearance into the FMS.

2. Potential Challenges Associated with Data Comm

Some of the experiments point to potential challenges associated with the use of text-only Data Comm, however, as mentioned in the introduction. For example, with Data Comm, communication shifts from an aural to a visual task, and flying is already a heavily visual task, especially for the single pilot (Wickens et al., 2003). To retrieve and respond to ATC communications, pilots will need to interact with a display in the cockpit. Unlike voice communication, Data Comm may require manual tasks (e.g., button presses) to access and respond to a message (e.g., through the FMS). Pilots must look at a display to read the Data Comm message. In a single-pilot environment, this may result in an unsafe decrease in time spent looking out the window or at the flight instruments.

Data Comm may also lead to an increase in workload associated with communication. Research, albeit with two-pilot crews, does not typically report an overall increase in communication workload (Kerns, 1999; 1991)—visual tasking tends to increase, while aural tasking tends to decrease (Groce & Boucek, 1987). For single pilots, however, this additional visual workload may reduce flight precision. In particular, Wickens et al. (2003) observed a decrease in vertical tracking performance when pilots communicated via Data Comm compared to voice. Novice pilots (more typical in general aviation (GA) operations) may also experience a higher increase in visual workload than expert pilots (Waller & Lohr, 1989). The preponderance of texting especially among the younger population might attenuate this effect, however, if this study were replicated today.

Data Comm typically yields a longer total transaction time relative to voice communication (Waller & Lohr, 1989; Lozito et al., 1993)—Data Comm transactions were found to take about twice as long as voice (e.g., 10 vs. 20 seconds; Kerns 1999; 1991). The longer response time may, however, be related to crew multitasking (Lozito et al., 1993) and/or intra-crew communication procedures. In a mixed radio and Data Comm environment, voice communications are expected to be reserved for urgent communications, while most Data Comm messages will not require an immediate response (Navarro & Sikorski, 1999). Indeed, during experiments flight crews often initiated a change to the flight controls before sending a reply to ATC (Hinton & Lohr, 1988). Lastly, pilots may be more likely to accept an erroneous clearance when it is automatically loaded into the FMS. Logsdon (1996) observed that pilots accepted erroneous instructions (e.g., climb to a level below current altitude) more often with loadable, compared to manually-entered clearances.

B. How an Auxiliary Speech Display Might Help

An auxiliary synthetic-speech display may mitigate at least some of these challenges associated with Data Comm, particularly for single-pilot operations. Data Comm messages would be read aloud to the flight crew, by a synthetic voice, in conjunction with their visual presentation. Auxiliary synthetic speech may reduce time spent looking at the Data Comm display—pilots can access a message without having to look at the display, thus saving visual resources for their out-the-window and instrument scans. It may minimize the duration (dwell time) and frequency of looks at the display to respond to the message. Although it is anticipated that incoming messages will be preceded by an auditory indication (cf. working draft of RTCA SC-214/EUROCAE WG-78 Safety and Performance Requirements), annunciation may further serve as a cue for the receipt of a new message—reducing the time a pilot might spend monitoring the visual display. A redundant voice-visual display may help prevent communication errors—it is unlikely that a pilot will both misread and mishear a message. It may also safeguard pilots from acting on their expectations.

This report addresses the question of whether an auxiliary synthetic-speech display can reduce the challenges associated with Data Comm in single-pilot operations without introducing additional complications. Early investigations of Data Comm with an auxiliary synthetic-speech display have obtained mixed results. A study by Helleberg and Wickens (2003) varied whether GA pilots received data communication from ATC in a text-only display, a synthetic-speech-only display or both modalities (text+speech). Along several measures, pilots performed best in the text-only display. In particular, with text-only communication pilots flew more precisely and detected traffic faster than with synthetic-speech only or text and speech. Comparing the two remaining displays, performance was better with the redundant display than with the aural-only one. Both the text-only and redundant displays were associated with increased out-the-window scanning and fewer readback errors relative to the aural-only display (Helleberg & Wickens, 2003).

On the other hand, a recent simulation (Lancaster & Casali, 2008) found the use of a text-only display in a GA environment to be consistently associated with decreased performance compared to a synthetic-speech-only and a redundant (text+speech) display. Specifically, pilots were more likely to rate workload with the text-only display as "high" or "dangerous" whereas the workload ratings for the speech-only display and redundant display did not differ. Textual presentation also yielded the most head-down time, which did not differ for the remaining presentation modes. The discrepancy with the Helleberg and Wickens (2003) study may be explained by advances in the quality of the synthetic speech.

Additional results from McCarley, Talleur, and Steelman-Allen (2010), however, suggest that a speech-only Data Comm display is not sufficient. Here, instrument-rated commercial pilots communicated with ATC using a synthetic-speech-only display, a text-only display or a dual-mode (text+speech) display. The speech-only condition elicited the longest out-the-window dwell time. This benefit, however, may have come at a cost: Altitude tracking performance (a measure of flight precision) was lowest in the speech-only condition, compared to all other conditions, presumably because altitude awareness requires looking down from the window to the instruments. This benefit may not hold for transport pilots who are rarely, if ever, flying under Visual Flight Rules (VFR).

Nonetheless, compared to single-mode displays, redundant (i.e., text+speech) displays may have several disadvantages. In particular, redundant displays may elicit longer response times than text-only ones—both listening to and understanding an annunciated Data Comm message was found to take longer than simply reading it (Rehmann & Mogford, 1996). Moreover, pilots may check both modalities before responding (Hilborn, 1972). Speech intelligibility is also a factor; low-quality speech—especially for pilots who are unfamiliar with it—may elongate response time (Diehl, 1975). An aural display may also disrupt pilots' attention from other tasks; the temporal nature of aural information does not allow for efficient task management (Latorella, 1998).

Thus the findings from past research are contradictory: one display (speech only, text only, or text+speech) is not consistently associated with superior pilot performance. Yet, given the likelihood that a text-only Data Comm display will be implemented in the near future, of particular interest is whether the addition of speech to the text display 1) does not introduce harmful consequences to pilot performance, and 2) offers some benefits. Moreover, there are several open issues regarding the implementation of an auxiliary-speech display with Data Comm. In the voice environment, similar-sounding call signs are problematic: pilots may mistakenly interpret a clearance for another aircraft as their own. This problem will be alleviated with Data Comm since instructions will be uplinked to each individual aircraft (i.e., 345 ER will not hear instructions for 354 ER)—but not all aircraft will be communicating with ATC using Data Comm, and pilots must continue to monitor the party line for instructions to their aircraft. Therefore, pilots may be more likely to erroneously accept an instruction intended for an aircraft on the party line with a similar-sounding call sign when Data Comm messages are annunciated, compared to when they are displayed as text only.

It further remains unclear whether annunciated Data Comm instructions could be confused with instructions issued by a live controller, or whether the annunciation of Data Comm affects the processing of messages that must be retracted or revised by the controller. With Data Comm, there may be a delay between the time a controller sends an instruction and the time it is displayed or read on the flight deck. Therefore, it is conceivable that controllers may first send a Data Comm message and then retract that same message via voice without knowing that it has not yet arrived or not yet been read on the flight deck. Pilots will then receive the countermanded Data Comm message *after* it has been retracted via voice. Of interest is whether pilots obey the voice countermand, or whether the late arrival of the Data Comm message entices them to comply with the latter despite the earlier countermand. The rate of compliance may depend on the Data Comm display modality.

Another concern is the compliance with conditional clearances, and how this compliance interacts with Data Comm display modality. Conditional clearances instruct a pilot to act “at” or “by” a specific time or position. Operational experience indicates that pilots often act erroneously on such Data Comm clearances (Portugal, WP/22, 2010; United Kingdom, WP/18, 2010). Pilots may maneuver immediately before the condition is met or forget to maneuver later. Note that such clearances are less problematic in voice communications, likely because of the additional cues (e.g., intonation) that live voice affords. It is possible that pilots would be less likely to make an error when a visual Data Comm message is accompanied by synthetic-voice annunciation providing an extra cue.

C. The Current Study

The current study examined the feasibility of supplementing a visual Data Comm display with synthetic-speech annunciations in the single-pilot environment. Such annunciations read aloud each Data Comm message received from ATC, and may mitigate some of the risks associated with text-only Data Comm—but must do so without introducing new challenges. Each participant flew two experimental scenarios. In one scenario, ATC messages were communicated via a text-only Data Comm display; in the other scenario messages were communicated via a synthetic-speech display *in addition to* the text Data Comm display (text+speech display).

With regard to the positive effects of voice Data Comm, it was hypothesized that with an aural display supplementing the visual display, pilots would require less head-down time, perceive lower workload, and respond more accurately to ATC instructions. This would also improve the acceptability of Data Comm by pilots.

Each experimental scenario included a conditional clearance (“AT ORMOND VOR CLIMB TO 3,000”). It was hypothesized that participants may either forget to wait for the condition or forget to act once the condition is fulfilled; however, the presence of a synthetic voice may decrease the likelihood of error.

Finally, recall that with Data Comm, it is possible for a live controller to countermand a message by voice before it is displayed on the flight-deck. To investigate whether pilots comply with instructions issued by voice, each participant received one Data Comm message that was countermanded by a live controller, in *either* the text-only *or* text+speech Data Comm condition. The live countermand occurred thirty seconds before the Data Comm message was received on the flight deck (see Figure 5 for the timeline of the countermanded clearance). Here, it was hypothesized that pilots might be more likely to ignore the countermand when the Data Comm message was displayed both visually and via voice—an unintended negative consequence of implementing a synthetic-speech Data Comm display.

In both experimental scenarios, aircraft with similar-sounding call signs were also heard on the party line. It is generally hypothesized that pilots are less likely to respond to similar call signs with Data Comm; however, in the presence of the synthetic-speech Data Comm display, where pilots are more likely to listen to any voice instructions, this advantage of Data Comm may be less pronounced than with the visual Data Comm display alone.

II. Method

A. Participants

Thirty-two (28 men, 4 women) commercial certificated and instrument-rated pilots at Embry-Riddle Aeronautical University participated in exchange for $20/hour. Participants were recruited through a survey that assessed their flying experience (see Appendix A). Participants ranged between 19-28 years of age (M = 22.3), had at least 20/20 vision, and were native English speakers. A majority (N = 28) of participants reported being right-handed, with three being left-handed, and one “ambidextrous left-handed.” Participants had an average total flight time (excluding simulator time) of 554.1 hours (SD = 427.1, range = 138-1950) and an average total loggable Flight Training Device (FTD) time of 159.7 hours (SD = 177.7, range = 13-737). Participants reported an average of 158.6 hours in the Cessna 172 FTD (SD = 170.3, range = 5-700). All but one participant reported to meet the currency criteria of six instrument approaches in the last six months, and 28 reported flying an instrument approach in the last 30 days. In addition, participants reported an average of 7.2 months (SD = 4.4, range = 1-18) since passing their last flight review. Participants were highly motivated and familiar with the airspace used in the practice and experimental scenarios. Participants were run individually and the entire experiment took about two and half hours. Informed consent was obtained from all participants (see Appendix B).

B. Apparatus

1. Flight Training Device

Participants flew a single-engine Cessna 172S (Skyhawk) FTD developed by Frasca, as shown in Figure 1. The FTD comprised a 220-degree by 60-degree visual display. Aerodynamics and ground reactions were modeled via a computer solving a six degree-of-freedom set of dynamic equations. The FTD modeled asymmetric propeller loading, gyroscopic effects, destabilized propeller effects, and torque. The FTD had type-specific control loading, based on flight data from the Cessna 172. The FTD panel comprised an all-glass configuration based on the Garmin G1000 system. Realistic out-the-window scenery included geo-specific depiction of airports, key terrain, and cultural landmarks.

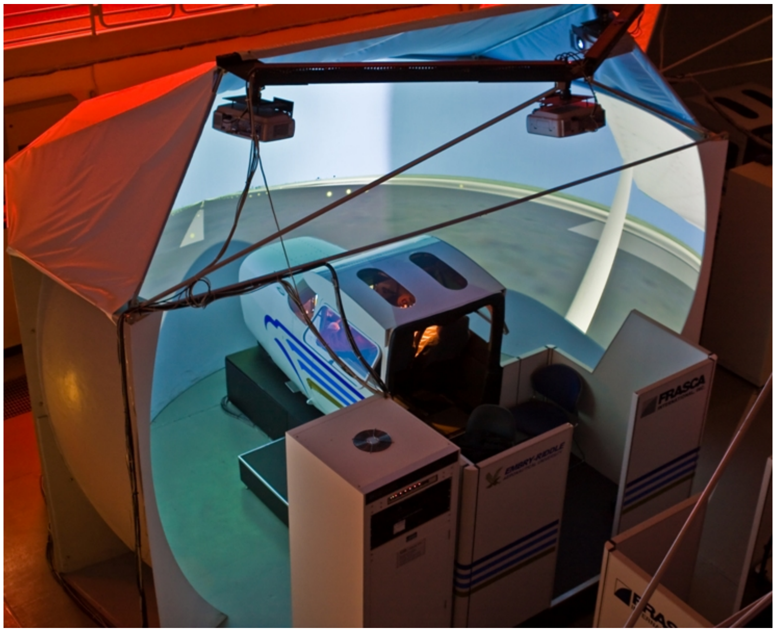

Figure 1. The Cessna 172S Flight Training Device.

2. Touch-Screen Tablet

A touch-screen tablet allowed participants to view and respond to Data Comm messages. As shown in Figure 2, ATC uplink messages were displayed in the upmost panel (labeled “ATC”), and accompanied by a timestamp noting when the message was received. The middle panel (“Log”) displayed a running history of the participant’s downlink messages to ATC. Each message showed the timestamp of when the message was sent. The bottom of the touch-screen tablet was fitted with a set of six virtual response buttons that allowed participants to select and review (on the “Pilot Response” panel next to the “SEND” button) their message before sending it to ATC. The three positive responses (“WILCO,” “ROGER,” “AFFIRMATIVE”) were displayed in green; the three negative responses (“UNABLE,” “NEGATIVE,” “STANDBY”) were displayed in magenta. An incoming Data Comm message was indicated with both a visual and aural alert. The message flashed in the “ATC” panel and was accompanied by a two-tone “ding-dong” chime similar to the SELective CALling (SELCAL) tone associated with ground communication in commercial aircraft. The touch-screen tablet was fitted on a kneeboard, which participants attached to their right or left leg (as shown in Figure 3)—this set-up was chosen because it could realistically be implemented in a general aviation cockpit (i.e., it did not require changes to existing displays).

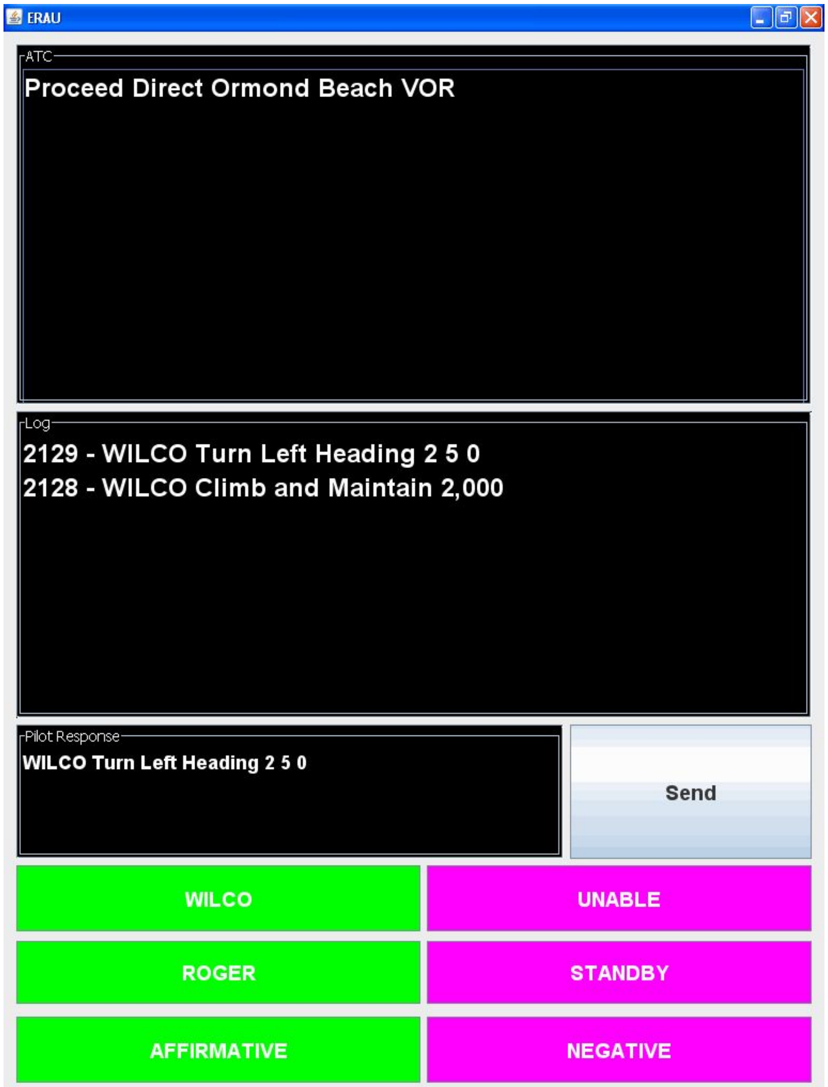

Figure 2. The touch-screen tablet.

Figure 3. A participant in the FTD with the touch-screen tablet.

3. Synthetic Voice

A highly-intelligible 16 kHz synthesized female voice, “Natural Voices Crystal,” developed by AT&T, was used for the aural Data Comm display.[1] All aural instructions were presented binaurally over David Clark H10-13.4 passive noise-reducing headphones.

4. Volume Setting for Data Comm Display

The volume setting for the “ding-dong” tone, which signaled the receipt of an incoming message, was calibrated such that the tone was perceptible above ambient noise in the FTD.

First, the ambient noise level of the 172 FTD was established relative to an actual Cessna 172 with an acoustic sound analyzer (Sencore SoundPro SP-495 in the A-weighting scale, dBA). The sound pressure level of an actual Cessna 172 was measured at different revolutions-per-minute (RPM) levels while the aircraft was stationary at the ramp (as shown in Table 1). The microphone was placed near the pilot’s right ear. Sound-pressure level was then measured in the FTD at 25% and 50% of the device’s maximum volume at varying RPM levels (volume did not exceed 50% to avoid damage to the speaker system in the FTD). As shown in Table 1, in the FTD, the average dBA at 25% and 50% volume settings were 75.3 and 77.3, respectively, and the average dBA for the Cessna was 87.2. Therefore, using the 50% volume setting in the FTD, pilots in the experiment experienced approximately 77 dBA of ambient noise in the flight deck. Although this level is roughly 10 dBA less than for an actual Cessna 172, increasing the level in

[1]For more information, see “AT&T Natural Voices^{TM} Text-To-Speech Engines: System Developer’s Guide – Server, Sever Lite, and Desktop Editions” [Computer software manual]: http://www.naturalvoices.att.com/support/ATTNaturalVoicesTTS14.pdf

the FTD any higher would have created distortion in the speakers and, as noted above, possibly damaged the speakers in the FTD.

Table 1. Ambient noise levels (dBA) in Cessna 172 and FTD.

Engine RPM	Cessna 172 (dBA)	Frasca FTD	
		25% volume	50% volume
700	74	72	73
1000	78	74	76
1700	88	76	78
2000	92	76	78
2200	95	77	79
2250	96	77	80
	M = 87.2	*M* = 75.3	*M* = 77.3

Second, using the 50% volume setting for the FTD, we calculated the signal-to-noise ratio (S/N) of the "ding-dong" tone to the ambient noise in the FTD. The microphone was placed inside the right and left side of the pilot's headset and sound levels were collected for the tone and ambient noise at different engine RPM levels. As shown in Table 2, the average ambient noise intensity was 71.3 dBA and the average tone intensity was 73.8 dBA, for an S/N of 73.8 - 71.3 = 2.5. Thus, the "ding-dong" tone was approximately 2.5 dBA above ambient noise in the flight deck. This was also assessed subjectively and perceived as very adequate.

Table 2. Signal-to-noise ratio at various engine RPM levels in the FTD.

Engine RPM	Ambient Noise	Ding
700	69	72
1000	73	75.5
1700	71.5	74
2000	70.5	73
2200	71.5	74.5
2250	72	74
	M = 71.3	*M* = 73.8

5. Audio Recordings

ATC communication on the party line was recorded in a soundproof booth using Adobe Audition (v3.0) software; several speakers played the role of pilots in other aircraft communicating with ATC. The wave files were then imported into the FTD scenario to create a realistic party line and the "live" ATC countermand. Participant pilots could self-adjust the volume on the headset in the same manner they used in flight.

C. Experimental Design

The experimental design included four independent variables: 1) Data Comm display modality (text only vs. text+speech), 2) call-sign similarity (similar vs. dissimilar), 3) type of Data Comm message (routine vs. conditional), and 4) modality of countermanded clearance (text only vs. text+speech). Data Comm display modality (text only vs. text+speech) and call sign similarity (similar vs. dissimilar) were examined together in a 2 by 2 completely within-subjects factorial design. The effect of Data Comm modality on conditional clearances was examined in a simple two-sample paired comparison (participants received a single conditional clearance amidst routine clearances in *both* the text-only and text+speech condition). The effect of Data Comm modality on the countermanded clearance was examined in a two-sample unpaired comparison (participants received one countermanded clearance in *either* the text-only or text+speech condition). A careful counterbalancing scheme was developed to avoid sequence effects (see below and Appendix D).

1. Quantitative Data Collection

Gaze-dwell time (e.g., on the touch-screen tablet, out the window, etc.) was recorded via two small cameras, placed on the left and right sides of the instrument panel. Audio-tape recordings were used to measure the number of ATC interactions, including the number of live controller interventions (i.e., to correct gross piloting errors) and the number of pilot queries to ATC. Participant compliance with ATC instructions (e.g., countermanded clearance, conditional clearance) was recorded via experimenter observation and objective flight-precision measurement. Pilot response time to Data Comm messages was measured through: 1) inputs to the touch-screen tablet, 2) inputs to the flight controls (where applicable), and 3) time to complete ATC instructions (where applicable). Flight-precision data (e.g., airspeed, altitude, heading) were collected through the FTD at a sampling rate of 30 Hz.

2. Qualitative Data Collection

Pilot opinion data were collected through surveys administered after each experimental scenario and upon completion of the experiment (see Appendix A). Post-scenario surveys focused on workload, perception of head-down time, trust, and user acceptability. The post-experiment survey addressed user preference between the Data Comm displays (i.e., text only vs. text+speech). Any notes that participants took during each experimental scenario were also collected.

D. Procedure

Each participant flew two identical experimental scenarios, in counterbalanced order. They took off and landed at Daytona Beach International Airport (KDAB; see Figure 4) without leaving terminal radar approach control (TRACON). The scenarios took about 30 minutes to fly and imposed moderate workload (i.e., they began in VFR conditions and transitioned to Instrument Flight Rules [IFR] conditions). Traffic was representative of a high-activity day at KDAB. Data Comm was limited to Departure and Arrival ATC; communications with the Tower were via voice over radio. The amount of communication was designed to represent a relatively busy day at KDAB (approximately 80% of the voice traffic occurring on the busiest day). In both scenarios, two aircraft on the party line (354 Echo Romeo and 345 Delta Bravo) had a call sign similar to the participant's ownship (345 Echo Romeo).

While the actual flying was identical in both experimental scenarios, the presentation of Data Comm messages was varied. In one scenario, ATC instructions were issued only via a Data Comm text display. In the other scenario, instructions were issued via a Data Comm text display and annunciated by a synthetic voice. Each script contained mainly routine Data Comm messages, sampled from the proposed RTCA SC-214/EUROCAE WG-78 message set and one conditional clearance ("AT ORMOND VOR CLIMB TO 3,000"). As shown in Table 3, each scenario included 14 Data Comm messages: Six of the messages required the pilot to make a change to the flight controls (Key Events, e.g., "Turn Left Heading 310"); the remaining eight messages did not require the pilot to make a change (e.g., "At Dongs Expect Radar Vectors for ILS 7 Left"). These messages were dubbed "Stability Events," because pilots had to manually reply to the instructions on the touch-screen tablet without nudging the flight controls. In many, but not all cases, the Data Comm messages used in the experimental scenario corresponded to a message in the proposed RTCA SC-214/ EUROCAE WG-78 message set, as shown in Table 3.

Participants experienced one Data Comm instruction that was countermanded by a recording of a live controller. One half of the participants ($N = 16$) experienced the live controller countermand in the text-only Data Comm display condition. The other half ($N = 16$) experienced the countermand in the text-and-synthetic-voice Data Comm display condition. A 30-second delay was implemented between the live countermand of the Data Comm message and the receipt of the message on the flight deck (see Figure 5 for a timeline of events).

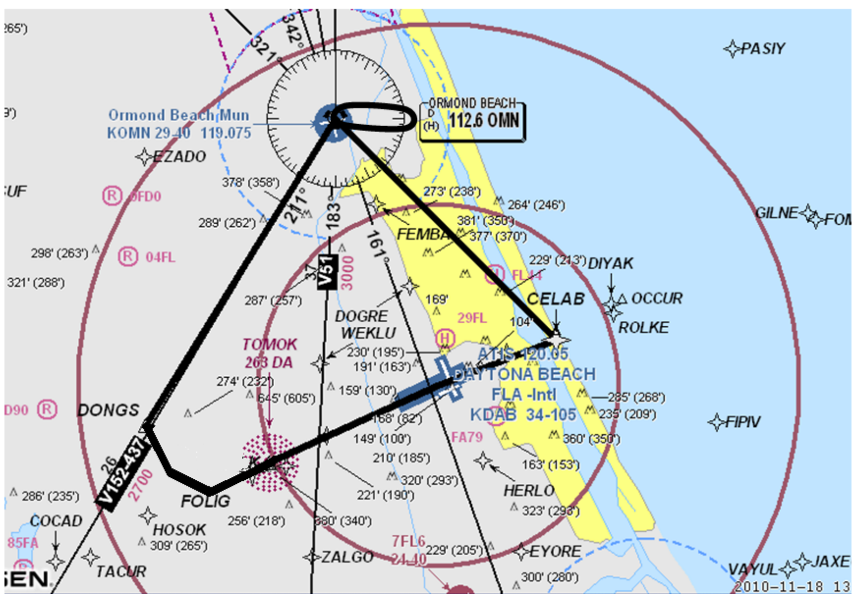

Figure 4. Flight path of experimental scenarios into and out of Daytona Beach airport.

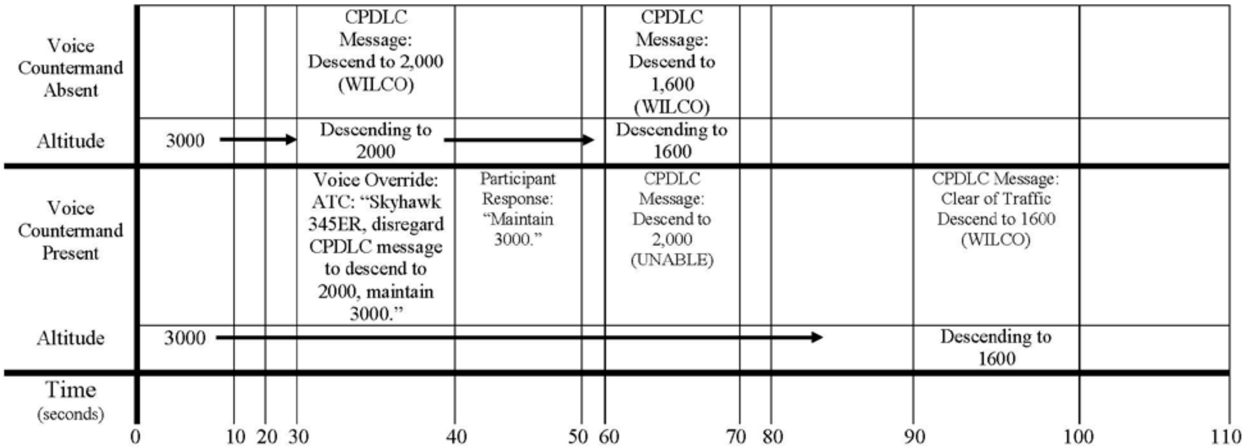

Figure 5. Timeline of countermanded clearance.

Before starting to fly, participants were familiarized with the touch-screen tablet through a short, hands-on tutorial led by the experimenter (the familiarization script is shown in Appendix G). Participants received an abbreviated flight briefing before each flying scenario (practice and experimental), which included hard copies of the necessary approach plates (e.g., for an ILS approach), and a written description of the flying conditions (e.g., weather; see Appendix C).

Prior to flying the experimental scenarios, participants flew a 15-minute practice scenario in the Daytona Beach airspace. In the practice scenario pilots used a different runway and flew different headings and a different approach path than in the experimental scenarios. To familiarize participants with the touch-screen tablet and the synthetic voice, during the practice scenario, participants received communication from ATC in both modalities: text only and text+speech. Given that participants were commercial certificated and instrument-rated pilots with previous training experience in the FTD, the practice scenario was intended to familiarize participants with the Data Comm procedures only; they were expected to know how to fly the FTD.

All scenarios were hand flown. A notepad was provided for the pilot to use as necessary. The scripts for the practice scenario and four experimental scenarios (1) text only, countermand absent; 2) text only, countermand present; 3) text+speech, countermand absent; and 4) text+speech, countermand present) are provided in Appendix D. The counterbalancing scheme to control any sequence effects from the order of presentation of the experimental scenarios is also given in Appendix D.

In all scenarios, a live controller (one of the voices heard on the party line) was available to respond to participants' questions while flying. No overlap occurred between the voice of the live controller and the synthetic speech. When the participant made an error, the live controller provided an appropriate, standardized reply to ensure that the participant was corrected back on course. For example, if the participant failed to ignore the countermanded Data Comm message, "Descend to 2,000," the live controller would instruct the participant, "Skyhawk 345ER, disregard CPDLC message to descend to 2,000, maintain 3,000 for now." Appendix E provides the set of standardized replies to anticipated participant errors (not all of which occurred).

Throughout the experiment, participants completed three surveys: one after each experimental scenario, and a final usability survey after flying both scenarios. Surveys (as shown in Appendix A) were completed online, and each took no longer than 15 minutes to complete. Participants were given ample breaks throughout the experiment. Experimenters used a script and a checklist to ensure the procedure and instructions were standardized between participants (see Appendix F and G respectively).

Table 3. A description of the Data Comm messages in the experimental scenarios.

Message type	Uplink message (UM)	Synthetic speech duration (seconds)	Expected downlink response	Corresponding messages in draft SC-214/WG-78 Set
A - Stability	CPDLC Now In Use, Acknowledge Now	2.99	ROGER	No standard message; free text
B - Stability	Climb and Maintain 2,000	2.07	WILCO	Similar to UM 20, UM 19
C - Key	Turn Left Heading 310	2.37	WILCO	UM 94
D - Stability	Proceed Direct Ormond Beach VOR Due to Traffic	3.58	WILCO	UM 74 + UM 166
E - Stability	Hold East of the Ormond VOR on the 090 Radial, Maintain 2,000, EFC, in 10 Minutes	8.33	WILCO	Similar to UM 91
F - Key Conditional Clearance	At Ormond VOR Climb to 3,000	2.57	WILCO	Similar to UM 22
G - Stability	Depart Hold at Ormond, Proceed Direct Dongs, Expect Radar Vectors for the ILS 7L	5.76	WILCO	No standard message; free text
H - Key Countermanded Clearance	Descend and Maintain 2,000	2.08	UNABLE	Similar to UM 23, UM 19
I - Key	[Clear of Traffic] Descend to 1,600[2]	2.03	WILCO	UM 23
J - Stability	At Dongs, Expect Radar Vectors ILS 7 Left	3.73	WILCO	No standard message; free text
K - Key	Turn Left Heading 160	2.30	WILCO	UM 94

[2] Note, the "Clear of Traffic" message only occurs in scenarios with a countermanded clearance. In scenarios where the countermanded clearance does not occur only "Descent to 1,600" is presented.

Message type	Uplink message (UM)	Synthetic speech duration (seconds)	Expected downlink response	Corresponding messages in draft SC-214/WG-78 Set
L - Key	Turn Left Heading 100	2.18	WILCO	UM 94
M - Stability	Maintain Heading 100, Maintain 1,600 Until Established on the Localizer, Cleared for the ILS Runway 7 Left	9.41	WILCO	No standard message; free text
N - Stability	Contact Tower Voice Now on 120.7	4.05	WILCO	UM 117

III. Results

A. First, do no harm…

The main purpose of supplementing text Data Comm with synthetic speech is to minimize the potential for Data Comm to increase head-down time. Any remedial measures, however, must be carefully examined for unintended consequences. A primary goal of the current study therefore was to assess whether the addition of synthetic speech to the Data Comm display harmed pilot performance. In support of this goal, performance was compared in the text-only and text+speech scenarios with regard to: 1) pilots' response times for Key and Stability events, 2) responses to similar call signs, 3) responses to the countermanded clearance, 4) number of pilot queries to ATC, and 5) the need for live ATC intervention.

1. Pilot Response Times

Pilot response times were examined for Key Events, in which the pilots were required to make a change to the flight controls to stay on course, as well as Stability Events, in which pilots were required to maintain flight precision within commercial Practical Test Standards (i.e., no flight control changes required; see Table 3 for a list of Key and Stability Events). Three response types were of interest for the Key Events: 1) time for pilots to acknowledge ATC's Data Comm message on the touch-screen tablet, 2) time for pilots to initiate input to the airplane controls following ATC instruction, and 3) time for pilots to complete ATC instruction (e.g., time to reach new heading after ATC instructs pilots via Data Comm to change heading). For Stability Events, we were only interested in pilots' time to acknowledge ATC's message via the touch-screen tablet (since pilots should not make any control inputs for Stability Events, the other response types are not applicable). All response times were calculated from message onset unless otherwise noted. Initiation of input to controls was defined as the moment at which the pilot made a 3-degree change in heading or a 50-foot change in altitude (depending on the relevant variable for each event) in the direction instructed by ATC. Completion of ATC instructions was defined as the moment at which the pilot was within 3 degrees or 50 feet of the desired heading or altitude, respectively, as instructed by ATC.

Of interest was whether response time differs for pilots communicating with the text+speech display compared to the text-only display. We expected pilots to be faster to respond to the message in the text-only condition because they would already be looking down at the touch-screen tablet in order to read the message. We did not expect this to affect time to initiate control inputs or to achieve compliance with ATC, however; we hypothesized that pilots would comply with ATC instructions in the text+speech condition no slower than those in the text-only condition.

a. Statistical Analysis Procedure

Response-time data, and all other non-normally distributed data, were analyzed using the Wilcoxon matched-pairs signed-ranks test. The Wilcoxon matched-pairs signed-ranks test is a nonparametric test which takes into account both the direction and the magnitude of differences between two matched samples. The Wilcoxon is basically the nonparametric equivalent to the paired *t*-test, and is often used when the data are not normally distributed (as is the case for most of the response-time data in this study).

To do the Wilcoxon test, each response-time difference score (text only vs. text+speech) was first ranked by the absolute magnitude of the difference (smallest magnitude = 1 and largest magnitude = 32). The ranks were then assigned a sign to indicate the direction of the difference (negative when text only < text+speech and positive when text+speech < text only). The ranks were then summed by sign, yielding a summed rank for pilots who were faster with text only and a summed rank for pilots who were faster with text+speech. The two groups of summed ranks were then compared to determine whether the sums of text-only and text+speech response times were significantly different. The Wilcoxon tests were run using the Statistical Analysis Software (SAS)® Enterprise Guide's Univariate procedure with pilots' response-time difference-scores (text only vs. text+speech) as the dependent variable (the same procedure was applied to additional dependent variables described below, but in some cases, using a different statistical software [SPSS]). For the Wilcoxon test statistic, SAS reports the signed rank (S), which is equal to the sum of the positive ranks minus the sum of the absolute value of the negative ranks.[3] (Thus, all negative S values in the response-time results indicate that the text-only response was faster, and positive S values indicate that text+speech response was faster.) For Key Events, separate Wilcoxon tests were run on three variables: 1) time to acknowledge ATC's message via the touch-screen tablet, 2) time to initiate input to the controls, and 3) time to complete ATC instruction (e.g., time to reach new heading after ATC instructs pilots via Data Comm to change heading). For Stability Events, Wilcoxon tests were run only on time to acknowledge ATC.

For each response type, we ran: a) one Wilcoxon signed-ranks test on the response-time differences with data from all Key or Stability Events pooled (using each pilot's average response time across all Key or Stability Events), to determine whether there was an overall difference in response time between text-only and text+speech conditions, regardless of the message content (i.e., Event); and b) separate Wilcoxon signed-ranks tests on each Event, to determine whether Events showed different patterns of response-time differences. Achievable effect sizes were calculated using the Hodges-Lehmann estimator and Hodges-Lehmann confidence intervals (95%).[4] The Hodges-Lehmann estimator is an estimate of the population

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[3] Later in the report, Wilcoxon tests run using SPSS are reported as Z-scores, although the analysis method is the same.
[4] For a more detailed description of the Hodges-Lehmann procedure, see http://www.iiap.res.in/astrostat/LecFiles/SushamBendre_notes.pdf.

median, calculated by taking the median of the averages between all possible combinations of response-time differences between text-only and text+speech conditions (called Walsh averages). The distribution of Walsh averages should approximate the distribution of the Wilcoxon statistic under the null hypothesis. The confidence intervals for the Hodges-Lehmann estimate of the population median are found using the probability table for the Wilcoxon signed-rank statistic. The confidence intervals tell us where, along the distribution of Walsh averages, we could expect to find the true median difference with 95% confidence.

b. Key Events

i. Overall Response-Time Results for Key Events

The results of the overall response-time analysis (with all Key Events combined) revealed no significant differences between text-only and text+speech conditions for 1) time to acknowledge ATC message, 2) time to initiate input to controls, and 3) time to complete ATC instruction (all $p > .14$; see Figure 6). The ranges of effect sizes that could have been achieved with 95% confidence confirmed that it was possible to find no difference between Data Comm conditions (effect size = 0, a confirmation of the null hypothesis). These achievable effect-size ranges, however, also indicated that it was possible to find response-time differences in either direction – that is, in favor of text-only or in favor of text+speech (see Figure 7). It should be noted that the median differences in Figure 7 may not match the mean differences depicted in Figure 6; this is because the data are skewed, which was the reason for using a nonparametric test (if the data were symmetrical, the median and the mean would align).

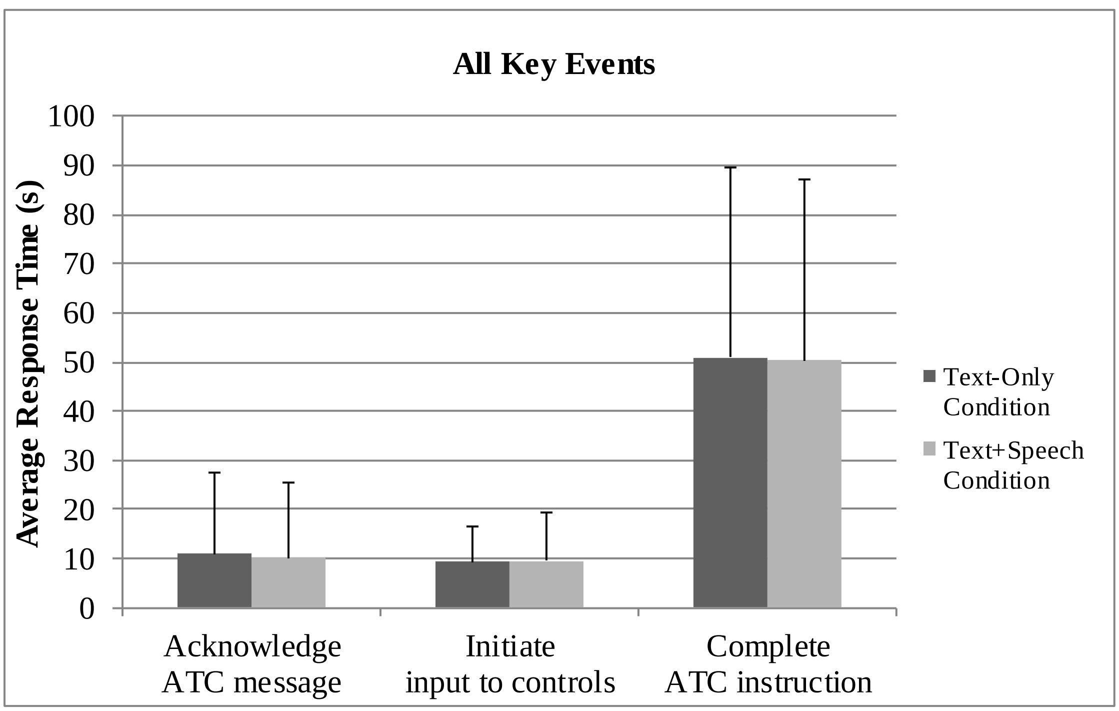

Figure 6. Average time to 1) acknowledge ATC message, 2) initiate input to controls, and 3) complete ATC instruction by Data Comm condition across all Key Events (whiskers=SD).

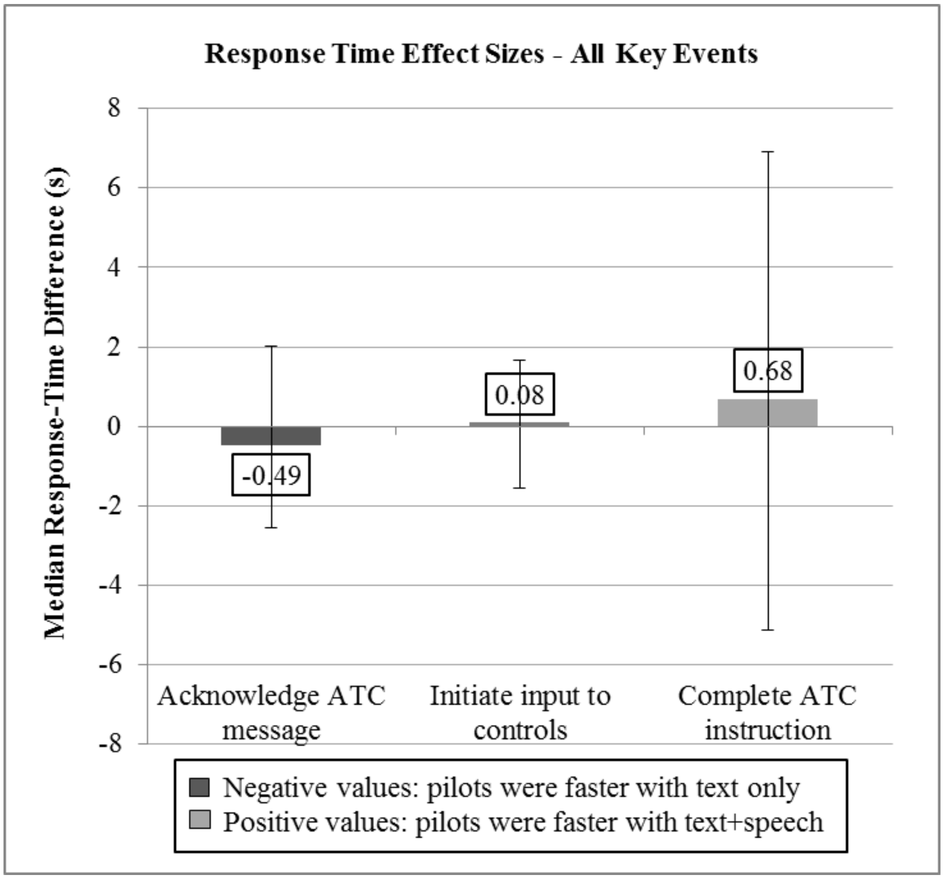

Figure 7. Effect sizes (population median difference) and 95% confidence intervals (whiskers) for response times for all Key Events combined.

ii. Response-Time Results by Individual Key Events

The differences in pilot response times by Data Comm condition for each Key Event are shown in Figures 7-14. Although there was no overall effect on response times (across Key Events), the examination of response times by Event yielded a few interesting findings.

For Key Event C ("Turn Left Heading 310," see Figure 7), there were no significant differences in pilots' time to acknowledge ATC message or to initiate input to controls (both $p > .45$), but there was a trend for time to complete ATC instruction. Pilots were a few seconds faster to reach heading 310 when the ATC instruction arrived via text+speech than when it arrived via text only, Wilcoxon Signed Rank (S) = 103.5, $p = .05$.

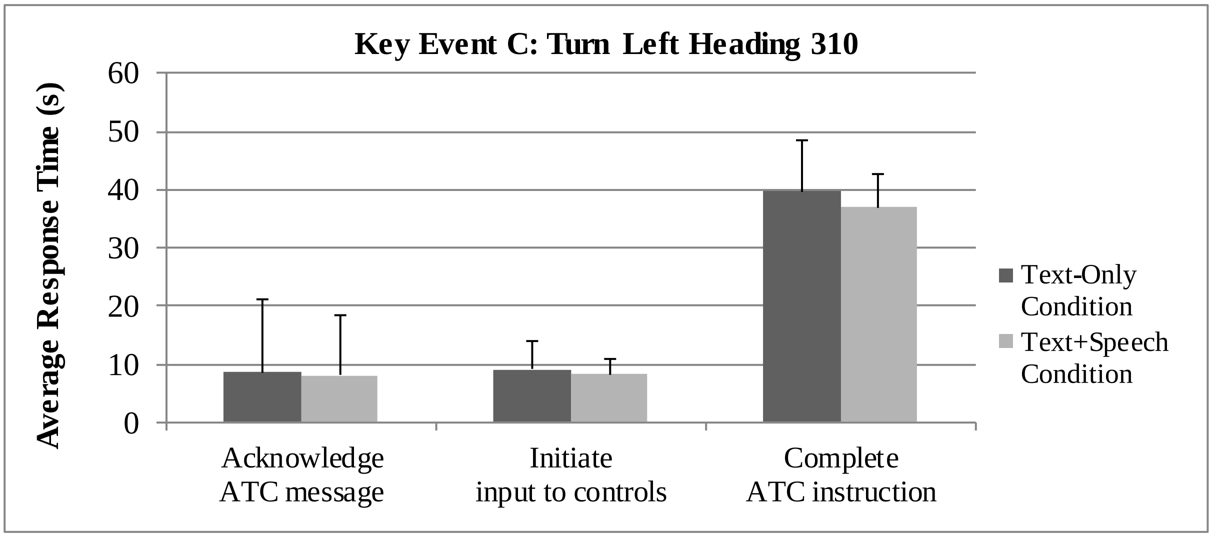

Figure 8. Average time to 1) acknowledge ATC message, 2) initiate input to controls, and 3) complete ATC instruction by Data Comm condition for Key Event C (whiskers=SD).

For Key Event F (see Figure 8), there were also no significant differences in response times between text-only and text+speech conditions. It should be noted that the time to initiate input to controls and the time to complete ATC instruction were calculated differently for Event F than for other Events. Event F contained the conditional clearance; pilots were instructed to climb to 3,000 feet upon reaching the Ormond VOR, rather than upon receipt of the ATC message. Thus, time to initiate input to controls was calculated from the time at which pilots had reached Ormond, rather than from message onset. Time to complete ATC instruction was calculated from the point at which pilots had initiated the climb to 3,000 feet. Some pilots erroneously acted on the conditional clearance by climbing immediately or by forgetting to climb at Ormond. Data for these cases were omitted from the response-time analysis. (Error data for the conditional clearance are reported in the section “Conditional Clearance.”) Two other data points were also omitted from the response-time analysis because the pilots’ altitudes were outside of performance standards when they reached Ormond (which might influence the time it takes to reach the desired altitude).

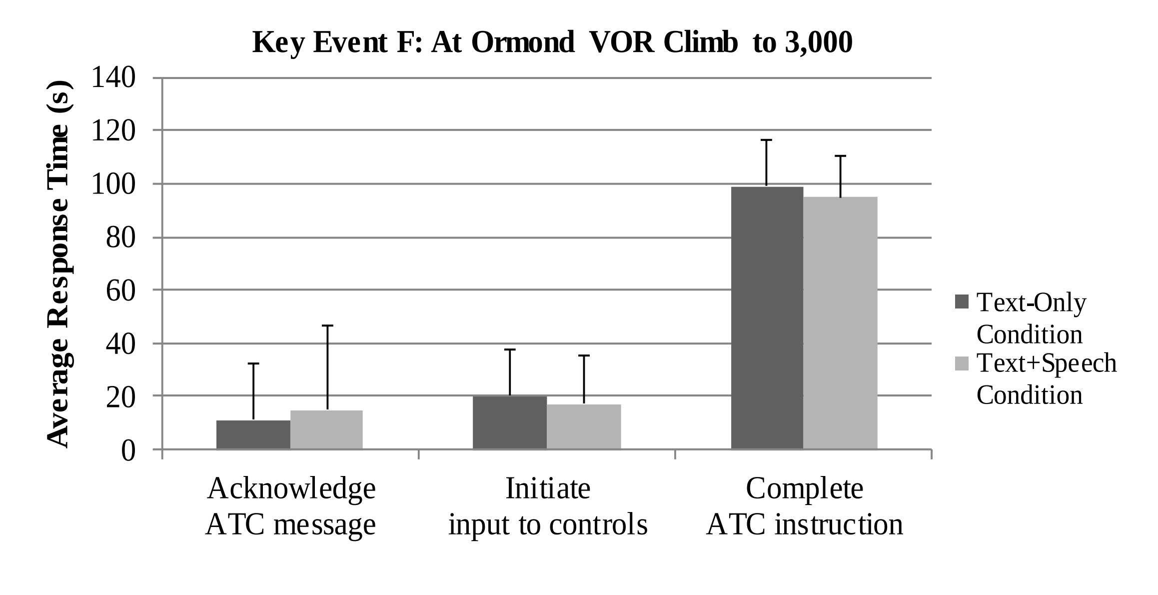

Figure 9. Average time to 1) acknowledge ATC message, 2) initiate input to controls, and 3) complete ATC instruction by Data Comm condition for Key Event F (whiskers=SD).

There was no significant effect of Data Comm condition on time to acknowledge ATC message for Key Event H (see Figure 9).

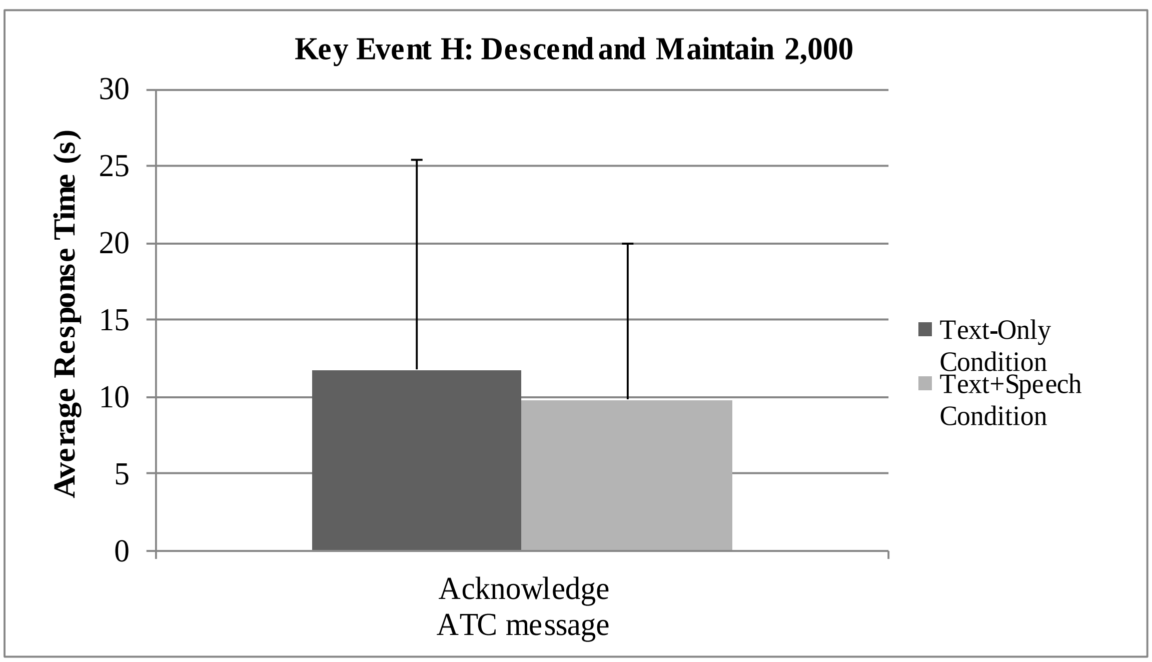

Figure 10. Average time to acknowledge ATC message by Data Comm condition for Key Event H (whiskers=SD).

There were also no effects on time to initiate input to controls or to complete ATC instruction. Time to initiate input to controls and time to complete ATC instruction are shown separately in

Figure 10. Event H contained an additional experimental condition: each pilot received a countermand of the clearance, and half of the pilots received the countermand when they flew with text-only Data Comm, and the other half received the countermand when they flew with text+speech Data Comm. When pilots received the countermand, they were expected to respond "UNABLE" to message H to "Descend and Maintain 2,000" and therefore should not have initiated or completed the descent. For this reason, there is no response-time data for initiating input to controls or completing ATC instruction when pilots received a countermanded clearance. Since half of the pilots received a countermand in the text-only condition and half received it in the text+speech condition, it was impossible to compare each pilot's text-only response time to his or her text+speech response time, and the Event H initiation and completion times had to be compared between-participants.

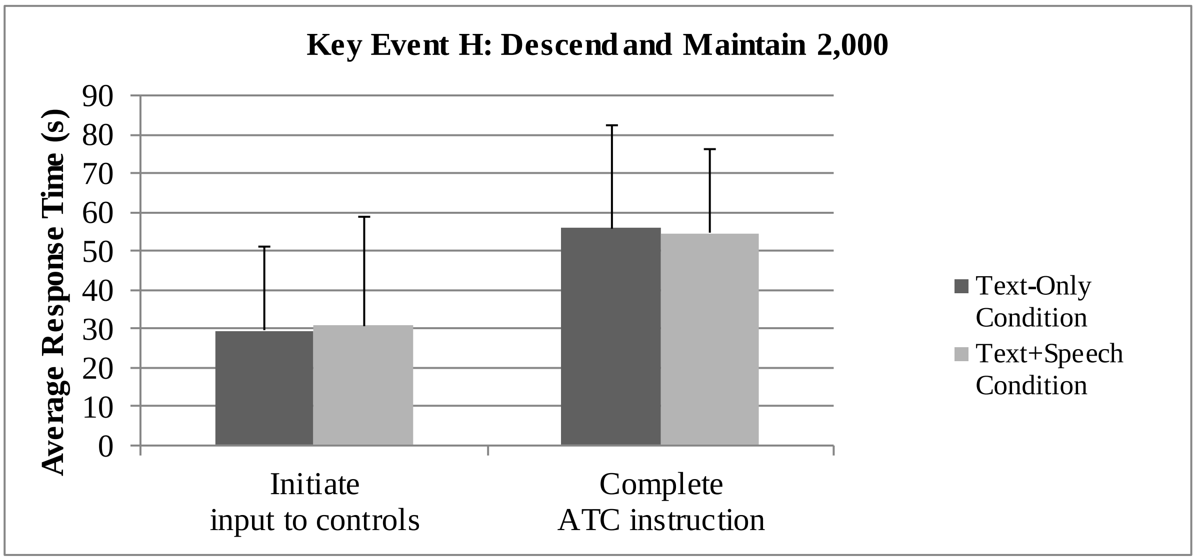

Figure 11. Average time to 1) initiate input to controls and 2) complete ATC instruction by Data Comm condition for Key Event H (whiskers=SD).

There were no significant effects of Data Comm condition on response times for Key Events I or K (shown in Figure 11 and Figure 12, respectively).

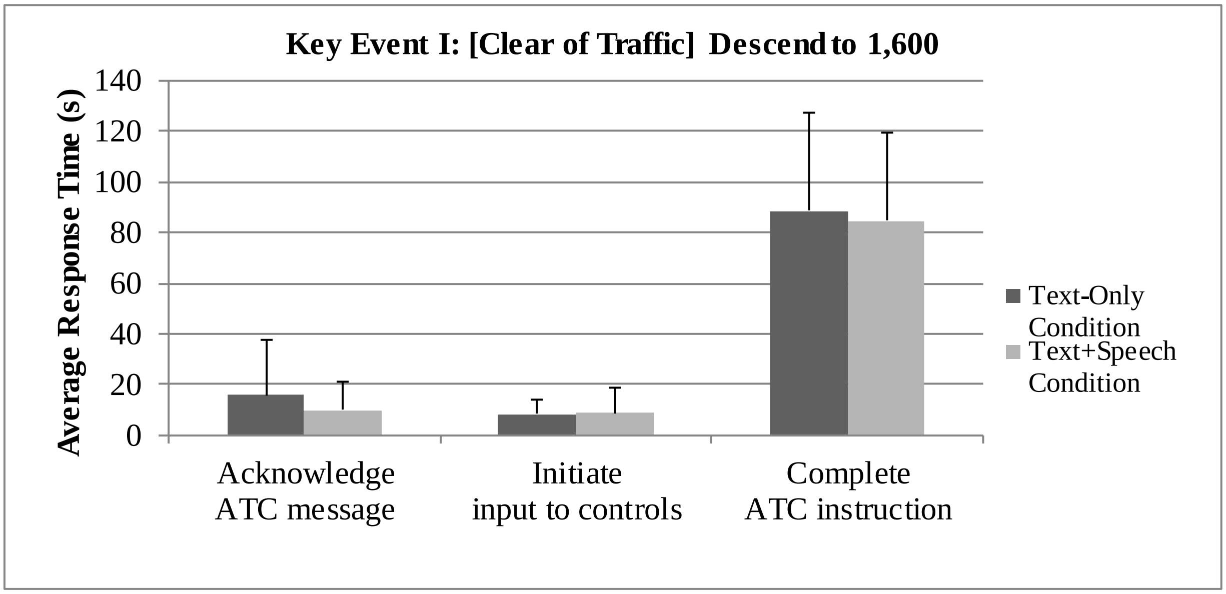

Figure 12. Average time to 1) acknowledge ATC message, 2) initiate input to controls, and 3) complete ATC instruction by Data Comm condition for Key Event I (whiskers=SD).

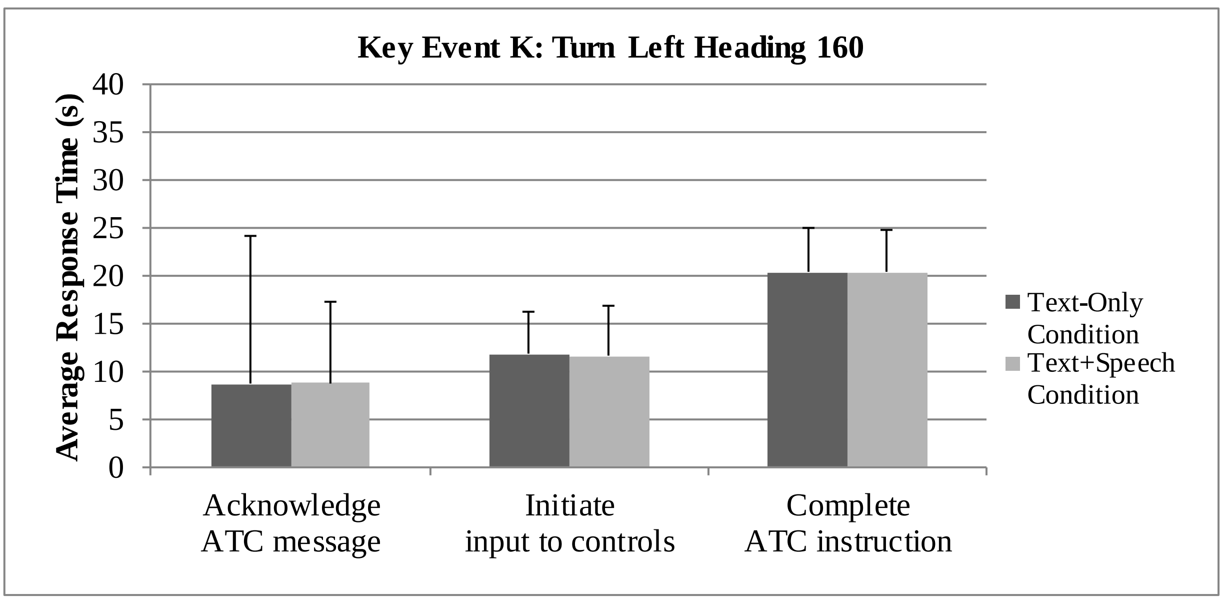

Figure 13. Average time to 1) acknowledge ATC message, 2) initiate input to controls, and 3) complete ATC instruction by Data Comm condition for Key Event K (whiskers=SD).

There was a significant effect on time to acknowledge ATC message for Key Event L ("Turn Left Heading 100," see Figure 13). Pilots were significantly faster to acknowledge the Data Comm message with text only than with text+speech, $S = -105$, $p < .05$. The average difference between text-only and text+speech response times, however, was only .4 seconds. In addition, the means alone imply a response-time advantage for text+speech ($M = 8.97$, $SD = 5.66$), not for text only as the Wilcoxon signed-ranks statistic suggests ($M = 9.38$, $SD = 11.23$).

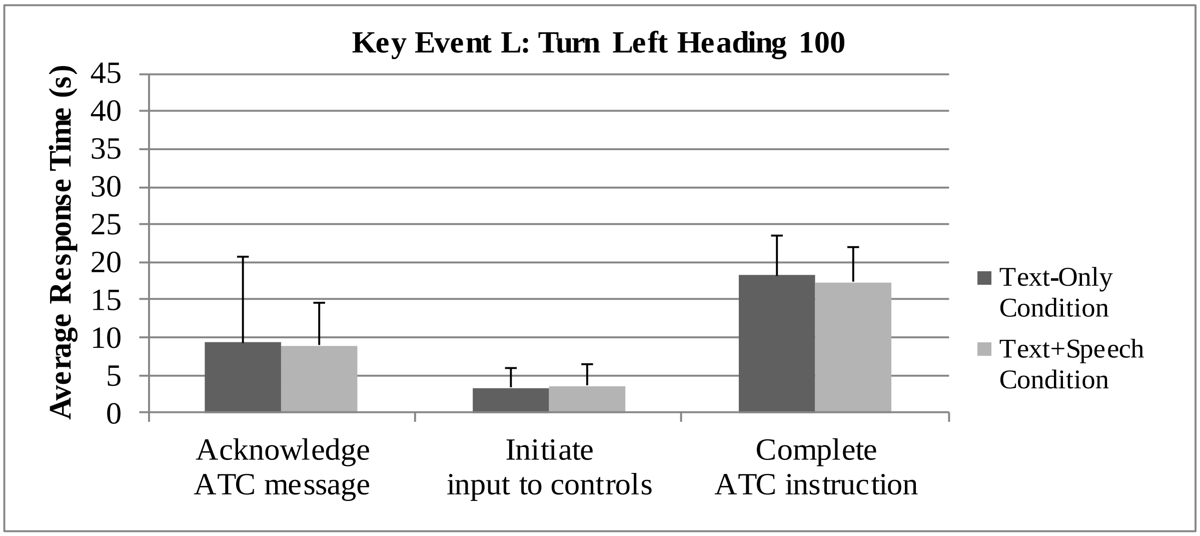

Figure 14. Average time to 1) acknowledge ATC message, 2) initiate input to controls, and 3) complete ATC instruction by Data Comm condition for Key Event L (whiskers=SD).

To illustrate why the Wilcoxon signed-ranks test was significant and in favor of text only despite the small average response-time advantage for text+speech, the data for each Data Comm condition were broken down to show the number and average response times of pilots who were faster with text only and pilots who were faster with text+speech. Figure 14 shows this breakdown. For those pilots who responded faster with text only, the average response-time advantage was only 3.57 seconds, compared to an advantage of 13.98 seconds for those pilots who were faster with text+speech. The significant Wilcoxon in favor of the text-only condition, however, is most likely driven by the number of pilots who responded faster with text only (24 pilots) vs. the number who responded faster with text+speech (only 7 pilots).

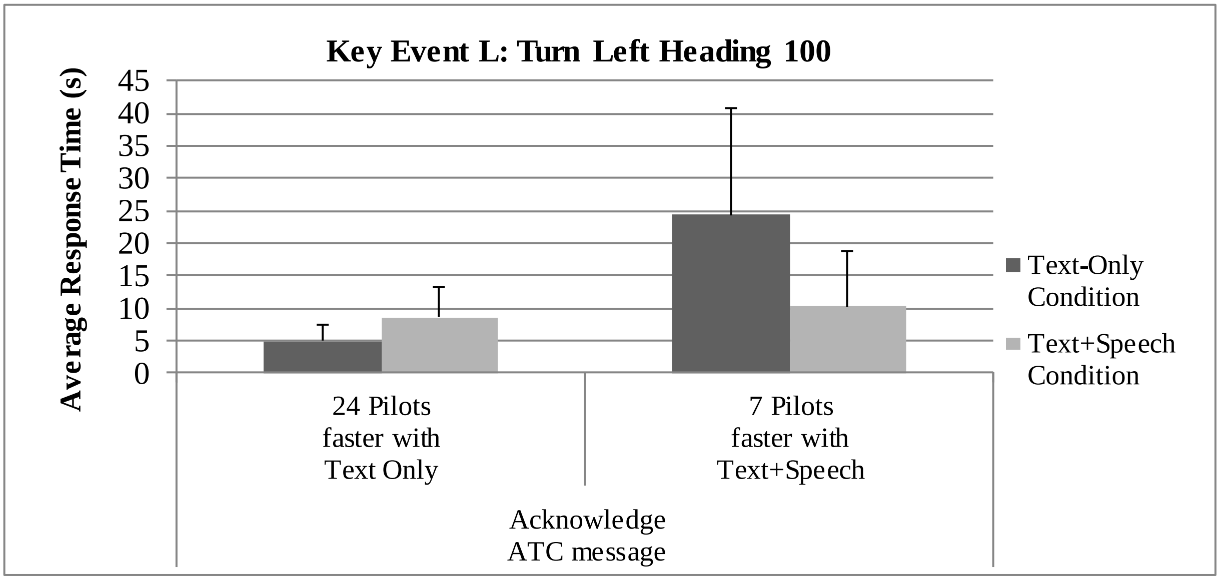

Figure 15. Average time to acknowledge ATC message by Data Comm condition and faster Data Comm mode for Key Event L (whiskers=SD).

c. Stability Events

i. Overall Response-Time Results for Stability Events

For the Stability Events, the overall response-time analysis (with all Stability Events combined) revealed a significant difference between text-only and text+speech conditions in time to acknowledge ATC message. Pilots were significantly faster to respond in the text-only condition than they were in the text+speech condition, $S = -4859$, $p < .001$ (see Figure 15). The range of achievable median effect sizes (with 95% confidence) supports this finding; although it was possible to find an effect as small as approximately .04 seconds (up to as large as 2.65 sec), the range of achievable effect sizes did not encompass zero, indicating that there was a true difference (with 95% confidence) between time to acknowledge the message with text-only vs. text+speech Data Comm (see Figure 17). Despite this difference, the *average* difference in response times (Figure 16) between the text-only and the text+speech condition was only .32 seconds. In addition, the means alone imply a response-time advantage for text+speech (M = 9.92, SD = 7.58), not for text only as the Wilcoxon signed-ranks statistic and Hodges-Lehmann estimator suggest (M = 10.25, SD = 21.17).

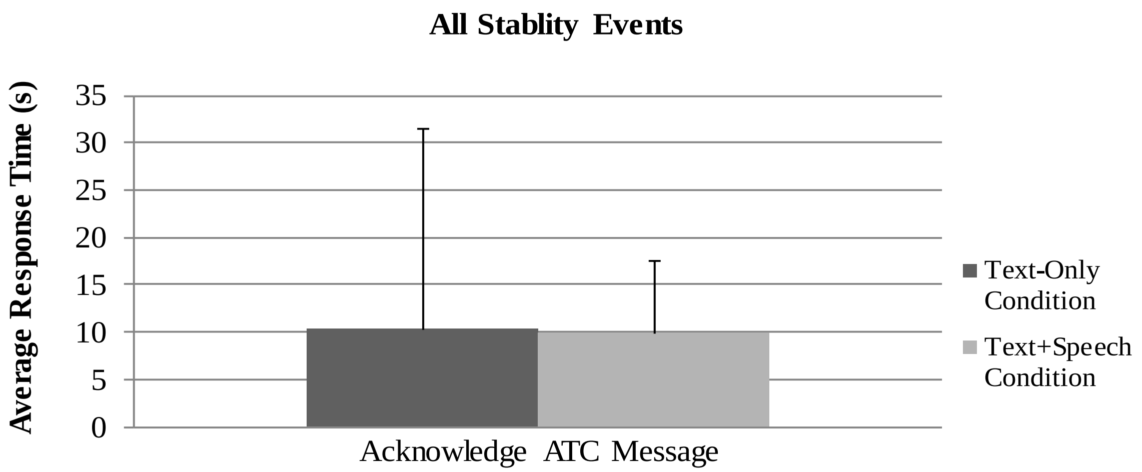

Figure 16. Average time to acknowledge ATC message across all Stability Events by Data Comm condition (whiskers=SD).

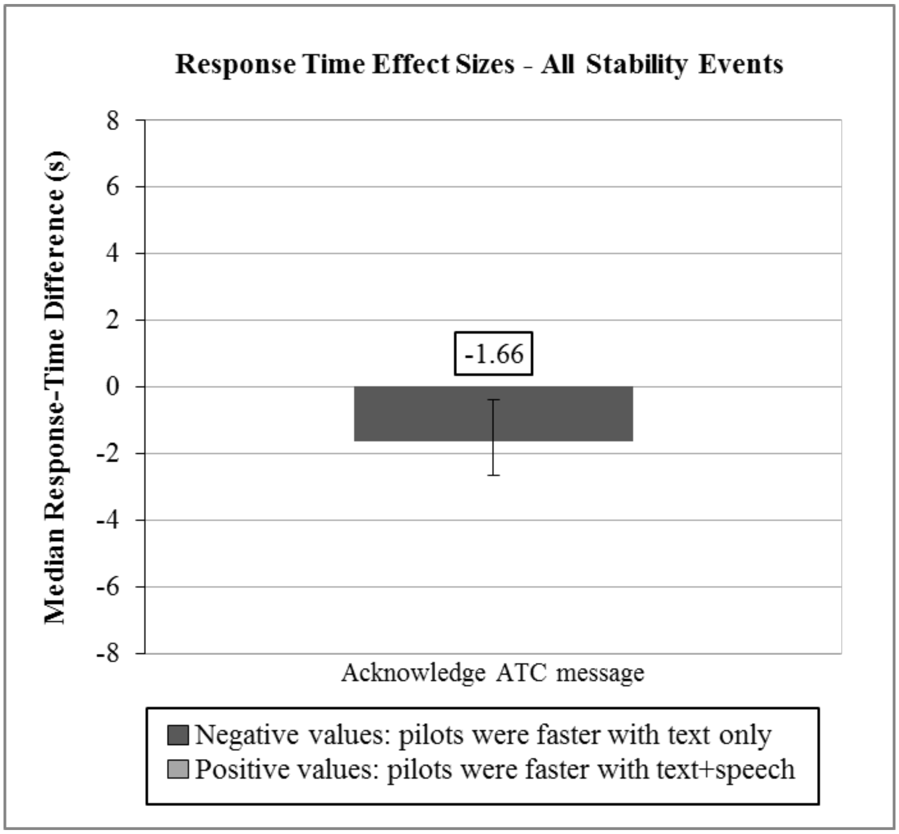

Figure 17. Effect sizes (population median difference) and 95% confidence intervals (whiskers) for response times for all Stability Events combined.

To illustrate why the Wilcoxon signed-ranks test was significant and in favor of text only despite the small average response-time advantage for text+speech, the data for each Data Comm condition were broken down to show the number and average response times of pilots who were faster with text only and pilots who were faster with text+speech. Figure 16 shows this breakdown. For those pilots who responded faster with text only, the average response-time advantage was only 3.13 seconds, compared to an advantage of 10.69 seconds for those pilots who were faster with text+speech. The significant Wilcoxon in favor of the text-only condition, however, is most likely driven by the number of pilots who responded faster with text only (24 pilots) vs. the number who responded faster with text+speech (only 8 pilots).

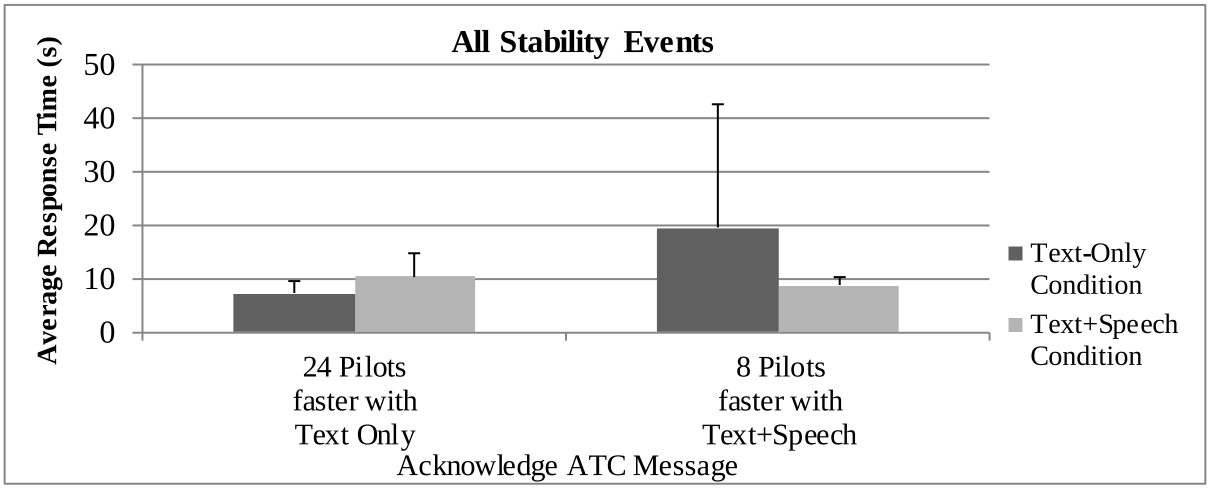

Figure 18. Average time to acknowledge ATC message by Data Comm condition and faster Data Comm mode across all Stability Events (whiskers=SD).

ii. Response-Time Results by Individual Stability Events

The differences in pilot response times by Data Comm condition for each Stability Event are shown in Figures 17-23. There were no significant differences in pilots' time to acknowledge ATC message for Stability Events A, B, D, or G (see Figure 17).

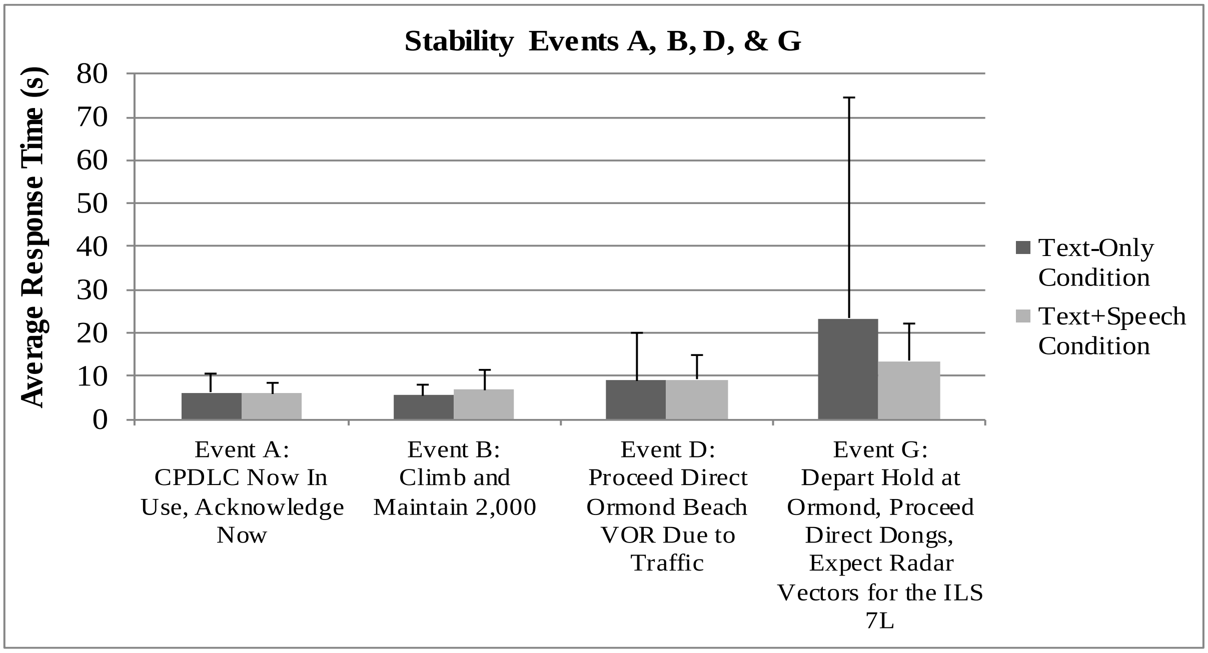

Figure 19. Average time to acknowledge ATC message by Data Comm condition for Stability Events A, B, D, and G (whiskers=SD).

There was a significant effect on time to acknowledge ATC message for Stability Event E (see Figure 18). Pilots were significantly faster to acknowledge the Data Comm message with text only than the one with text+speech, $S = -138$, $p < .01$. The average difference between text-only and text+speech response times, however, was only .23 seconds ($M = 12.54$, $SD = 13.86$ for text only; $M = 12.77$, $SD = 3.19$ for text+speech).

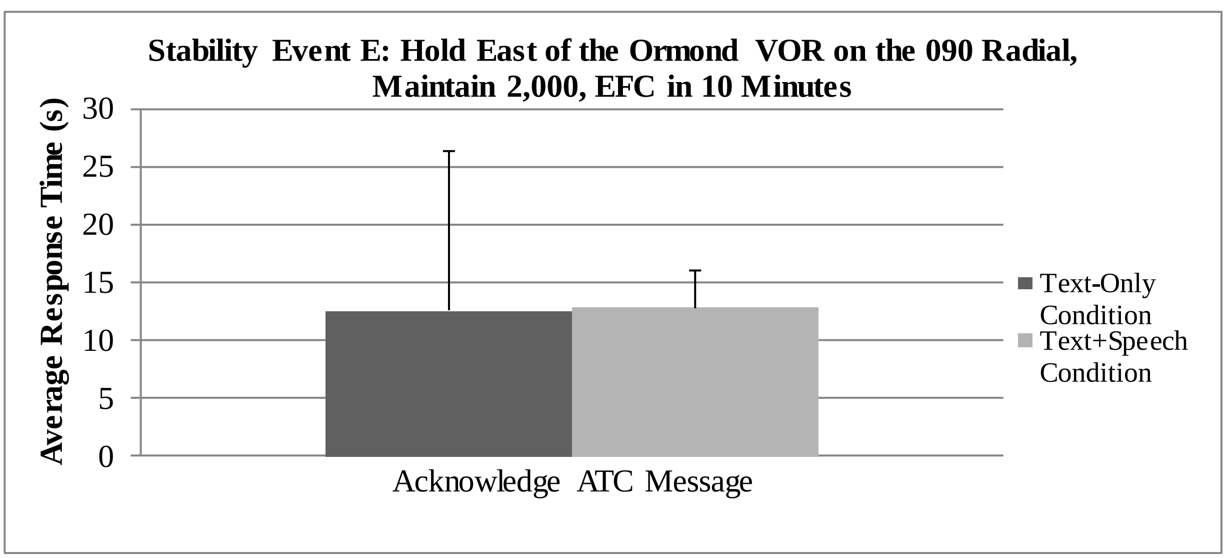

Figure 20. Average time to acknowledge ATC message by Data Comm condition for Stability Event E (whiskers=SD).

To illustrate why the Wilcoxon signed-ranks test for Stability Event E was significant despite the small average response-time difference, the data for each Data Comm condition were broken down to show the number and average response times of pilots who were faster with text only and pilots who were faster with text+speech. Figure 19 shows this breakdown. For those pilots who responded faster with text only, the average response-time advantage was only 5.15 seconds, compared to an advantage of 12.34 seconds for those pilots who were faster with text+speech. The significant Wilcoxon in favor of the text-only condition is most likely driven by the number of pilots who responded faster with text only (23 pilots) vs. the number who responded faster with text+speech (only 9 pilots).

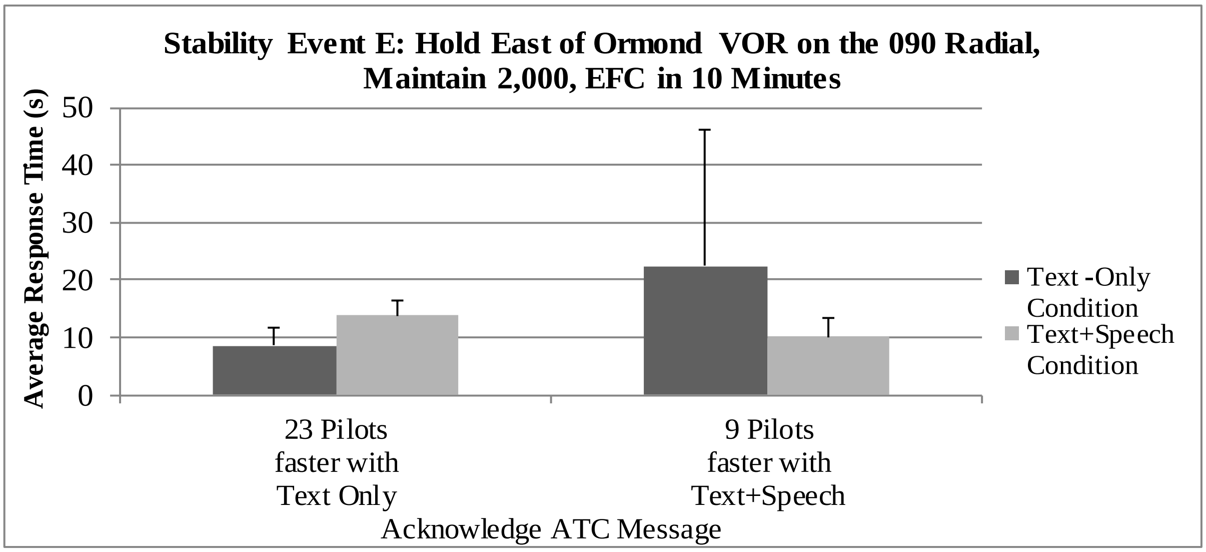

Figure 21. Average time to acknowledge ATC message by Data Comm condition and faster Data Comm mode for Stability Event E (whiskers=SD)..

There was a significant effect on time to acknowledge ATC message for Stability Event J (see Figure 20). Pilots were significantly faster to acknowledge the message with text+speech than the one with text only, S =117, $p < .05$. The average difference between text-only and text+speech response times, was 2.19 seconds (M = 11.01, SD = 20.33 for text only; M = 8.82, SD = 4.93 for text+speech).

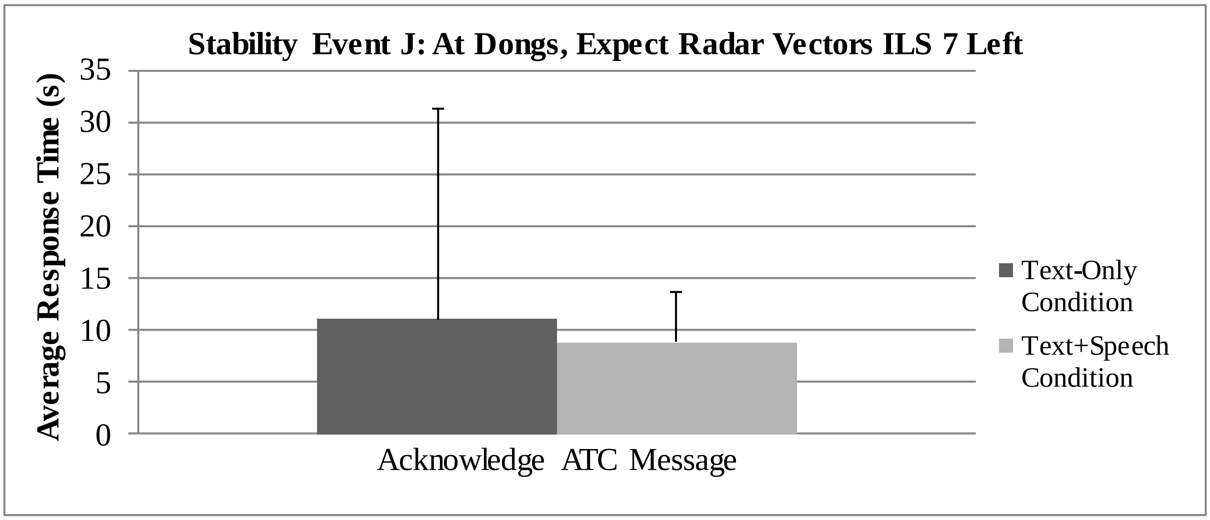

Figure 22. Average time to acknowledge ATC message by Data Comm condition for Stability Event J (whiskers=SD).

For Event J, there were actually more pilots who responded faster with text only (23 pilots) than with text+speech (9 pilots), but those 9 pilots that did respond faster with text+speech did so an average of 15.23 seconds faster than with text only, compared to an average difference of only 2.92 seconds for the 23 pilots who were faster with text only. This result is depicted in Figure 21.

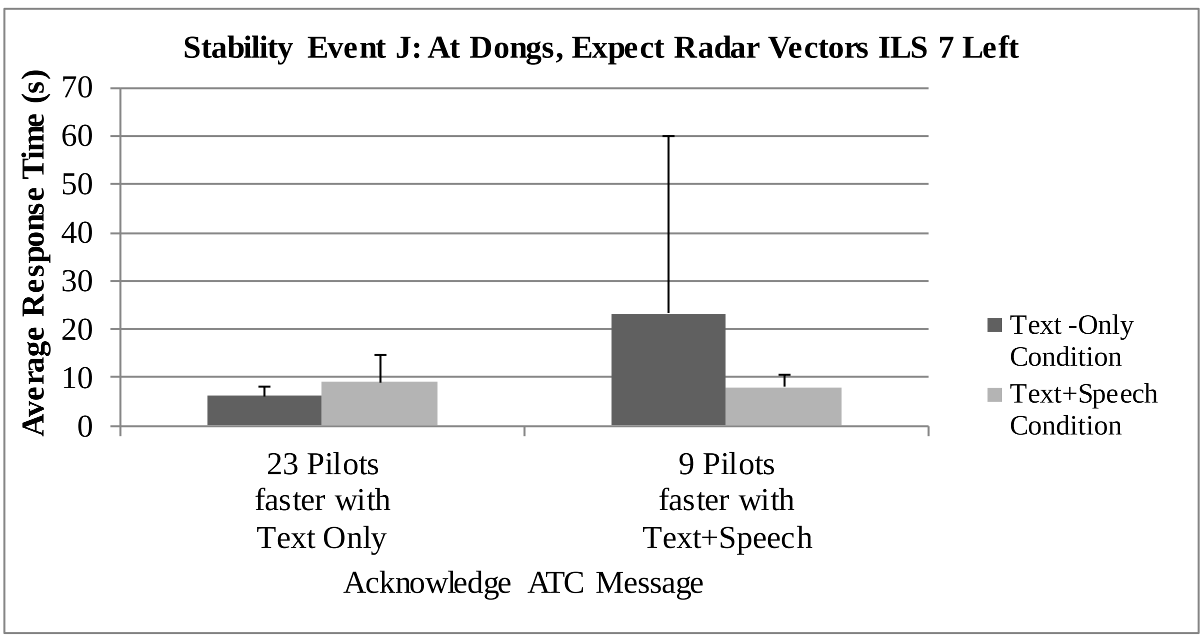

Figure 23. Average time to acknowledge ATC message by Data Comm condition and faster Data Comm mode for Stability Event J (whiskers=SD).

For Stability Events M and N, there were also significant effects of the Data Comm condition on the time to acknowledge ATC message. For both events, pilots were significantly faster with text only than they were with text+speech, $S = -182$, $p < .001$ for Event M, $S = -148$, $p < .01$ for Event N. Events M and N are depicted in Figure 22.

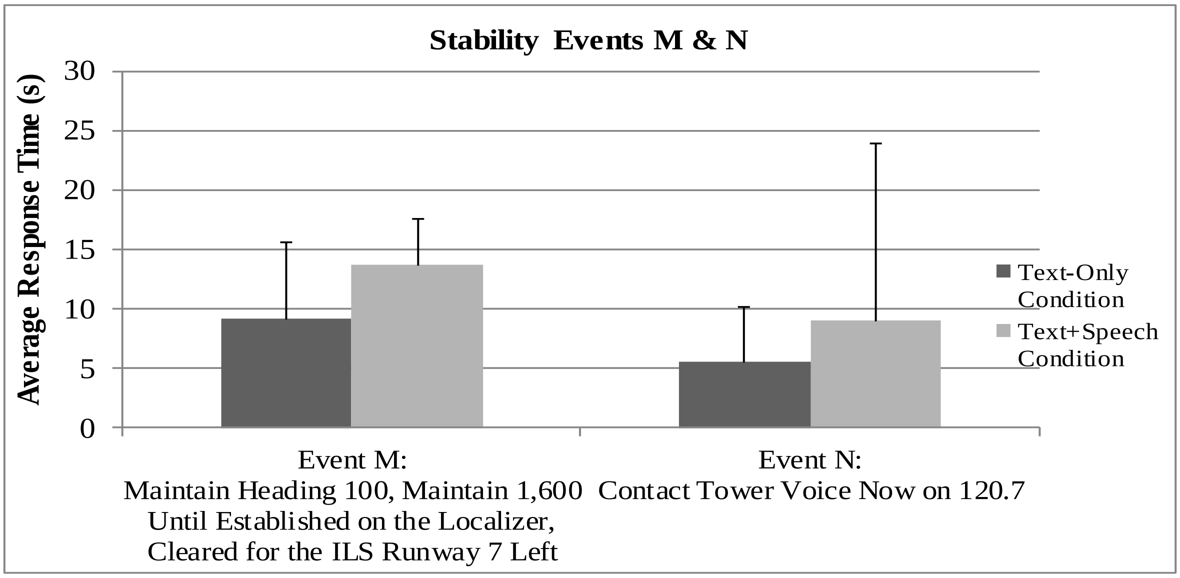

Figure 24. Average time to acknowledge ATC message by Data Comm condition for Stability Events M and N (whiskers=SD).

For both Events M and N, the significant effects were characterized by a larger number of pilots who responded faster with text only (26 and 22 pilots for M and N, respectively) than they did with text+speech (6 and 10 pilots for M and N, respectively). For Event M, the 26 pilots who were faster with text only were on average 7 seconds faster than they were with text+speech, compared to an average advantage of 5.99 seconds for the 6 pilots who responded faster with text+speech. For Event N, the 22 pilots who responded faster with text only were on average 6.66 seconds faster with text only, compared to the 3.68 second advantage for the 10 pilots who responded faster with text+speech. To see the breakdown of these two events by pilots who were faster with text only vs. text+speech, see Figure 23.

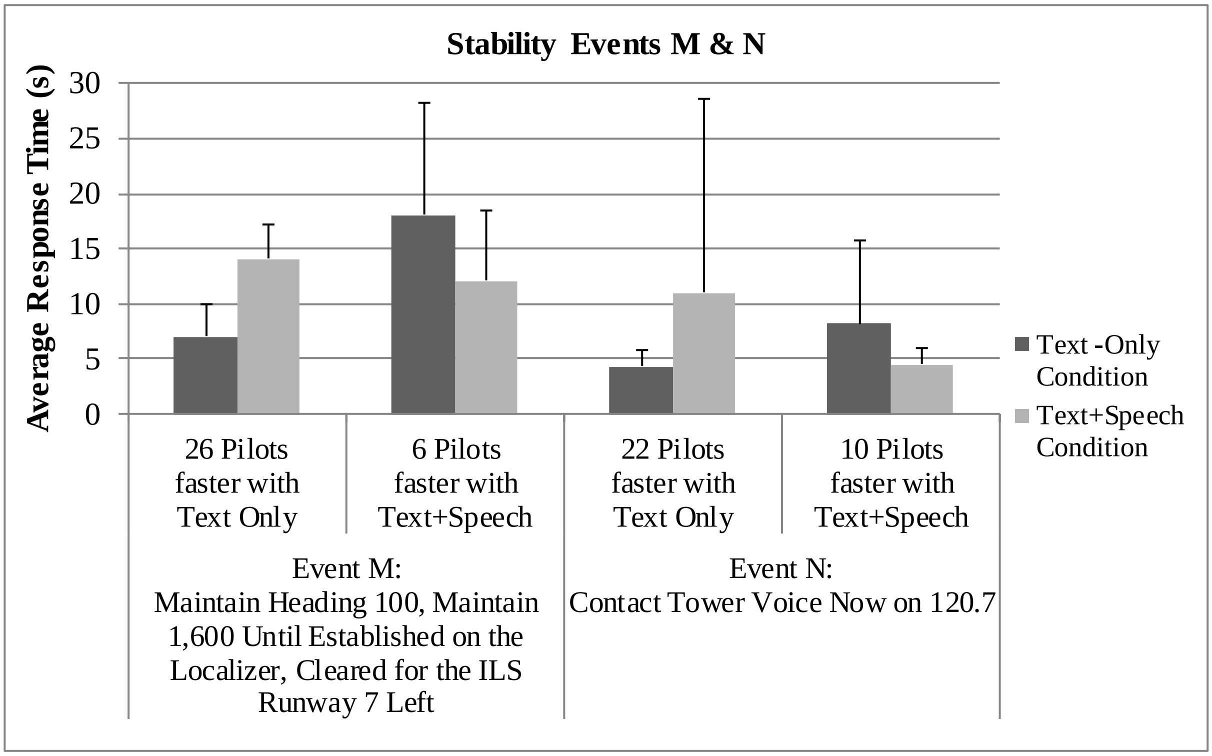

Figure 25. Average time to acknowledge ATC message by Data Comm condition and faster Data Comm mode for Stability Events M and N (whiskers=SD).

d. Response Times Summary

There was only one significant response-time effect for Key Events: Pilots were significantly faster to acknowledge the ATC message during Event L ("Turn Left Heading 100") when the message arrived via text only than via text+speech, and this effect was driven by the greater number of pilots who responded faster with text only than text+speech (rather than the magnitude of the difference). There were no differences in time to initiate input to controls or time to complete ATC instruction. A similar trend of faster time to acknowledge ATC for text only was found for Stability Events, both overall (with all events combined), and for three out of the eight individual events (Events E, M, and N). A significant effect was also found for Event J, but in this case there was a response-time advantage of text+speech, and the effect was driven by the magnitude of the difference rather than the number of pilots who were faster with text+speech. Overall, more pilots acknowledged the ATC message faster with text only than they did with text+speech, but in most cases the few pilots who were faster with text+speech had a larger response-time advantage (i.e., magnitude) than those who were faster with text only.

2. Similar Call Signs

Recall that similar-sounding call signs are problematic in the voice environment. Such call signs are heard on the party line, and consequently aircraft with similar-sounding call signs may misinterpret instructions for another aircraft as their own. This problem will be alleviated with text-only Data Comm since instructions are sent directly to one's ownship; however, the implementation of Data Comm with synthetic speech may make the misinterpretation of an instruction for an aircraft with a similar call sign again more likely.

Figure 26 shows the total number of responses to wrong call signs per condition—in both the text+speech and text-only condition participants erroneously responded to similar call signs (7 occurrences in each condition). But, a comparison between the numbers of pilots who erroneously responded to a similar call sign by experimental condition (as shown in Figure 25), demonstrated that the addition of synthetic speech did not affect call sign confusions. For most pilots (24/32), no difference in count of total errors was observed between conditions, and a nonparametric Wilcoxon matched-pairs signed ranks test did not yield a significant difference between conditions, $Z = .00$, $p = 1.0$.

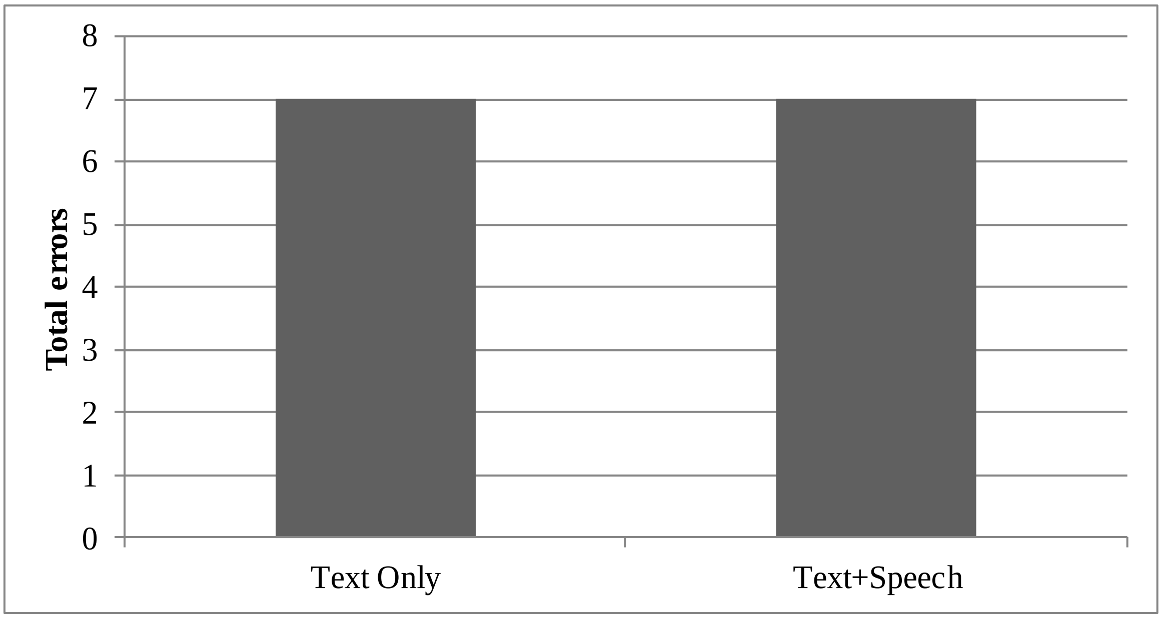

Figure 26. Total number of call sign errors by Data Comm condition to similar call signs.

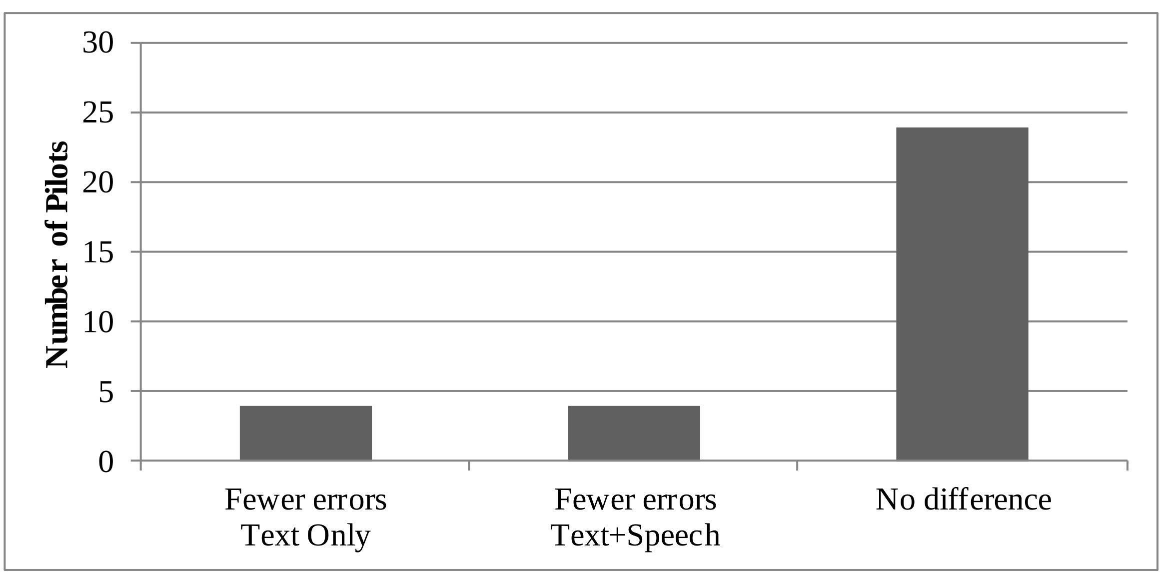

Figure 27. Comparison of pilot performance for similar call signs across Data Comm conditions.

3. Countermanded Clearance

Recall with Data Comm, it is possible that a controller may countermand a Data Comm message by voice before it is viewed on the flight-deck display. In the current experiment, the live controller countermanded a clearance to descend ("Disregard CPDLC message to descend to 2,000, maintain 3,000"), issued via Data Comm, before the Data Comm message had arrived on the flight deck (see Figure 5 for the timeline of events). To correctly respond, participants must 1) orally acknowledge the countermanded clearance ("Maintain 3,000"), and 2) respond "UNABLE" to the Data Comm clearance ("Descend to 2,000"). It was hypothesized that pilots may be more likely to ignore the countermanded clearance when the Data Comm message was displayed both visually and via voice. A comparison of the total number of errors by condition (see Figure 28) shows six errors in the text+speech condition vs. four in the text-only condition, but this difference was not significant, $Z = -.63$, $p = .53$. Of the six errors in the text+speech condition, three pilots failed to orally acknowledge the countermanded clearance, two pilots erroneously replied "WILCO" or "AFFIRMATIVE" to the Data Comm clearance, and one pilot both failed to reply via voice and erroneously replied via Data Comm. Such errors were less prevalent in the text-only condition (one failed to reply via voice, two failed to reply correctly via Data Comm, and one did both). However, as shown in Figure 27 in the majority of cases (22/32), pilot performance did not differ by condition.

While not an error, pilots may have contacted ATC following the countermanded clearance to seek clarification. Of the 32 participants, 4 called ATC following the countermanded clearance. For example, one participant inquired whether he/she should continue to listen to CPDLC. Only one out of the four queries occurred in the text+speech condition. One pilot in the text-only condition who contacted ATC also failed to orally acknowledge the countermanded clearance and failed to reply "UNABLE" to the Data Comm clearance. The remaining 28 participants did not initiate a call to ATC following the countermanded clearance.

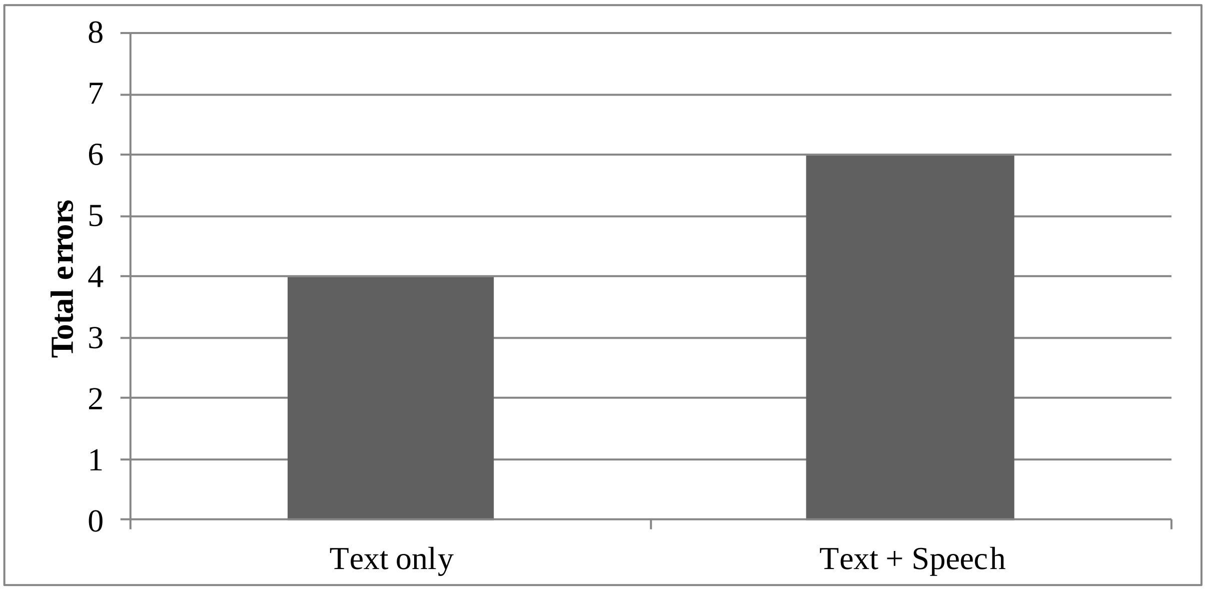

Figure 28. Total number of errors by Data Comm condition to the countermanded clearance.

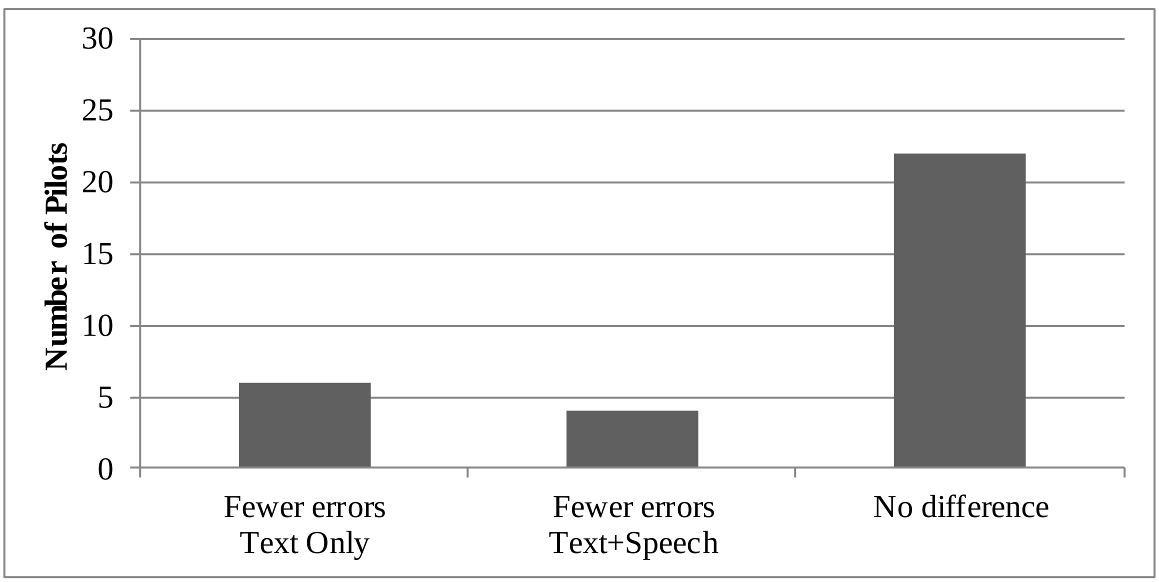

Figure 29. Comparison of pilot performance by Data Comm condition to the countermanded clearance.

4. Pilot Queries

The number of pilot queries to ATC may be indicative of communications difficulties. Of interest is whether the number of queries differs between the text-only and the text+speech conditions. As shown in Figure 28, some pilots did query ATC, however the addition of synthetic speech did not affect the number of pilot queries to ATC, $Z = -.30$, $p = .76$. As shown in Figure 29, the majority of pilots (24/32) queried ATC equally in both the text-only and the text+speech condition.

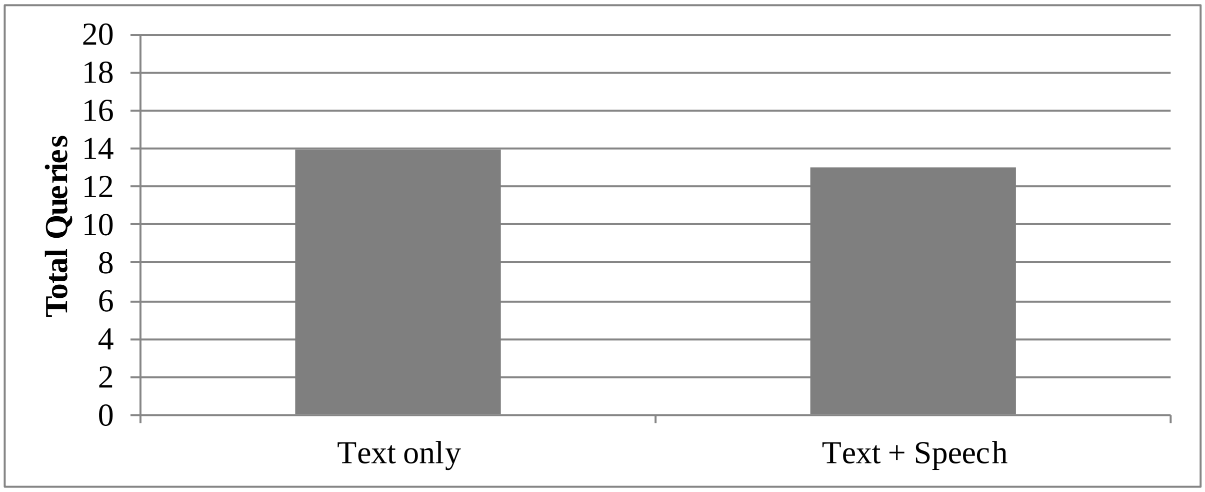

Figure 30. Total number of pilot queries by Data Comm condition.

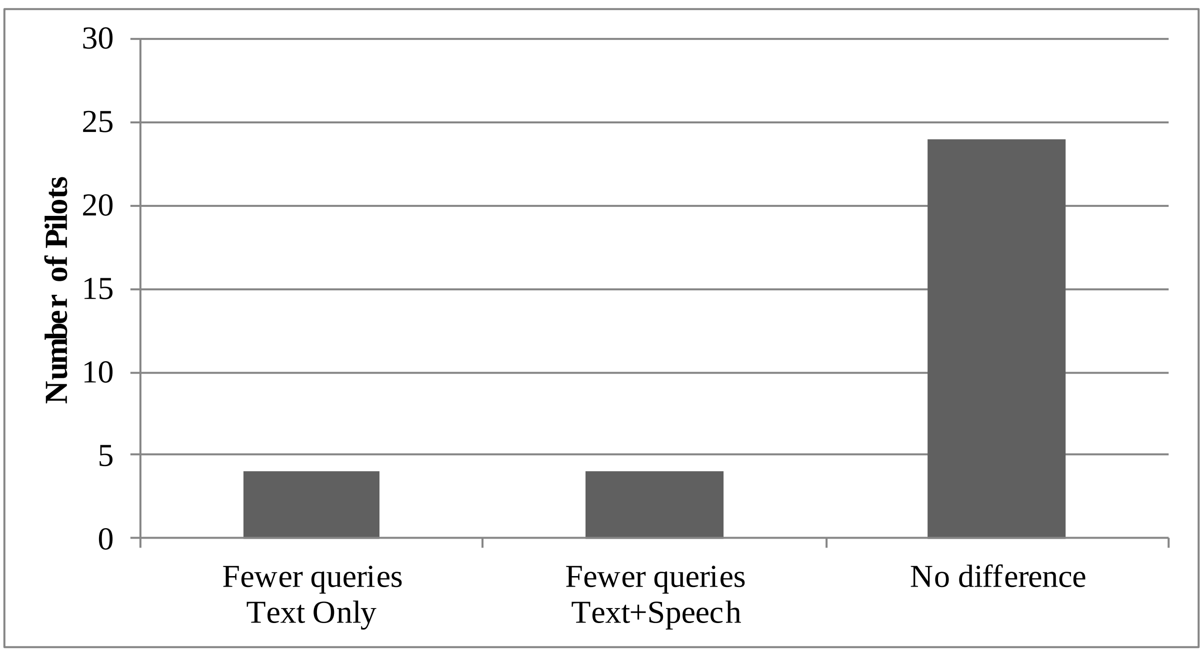

Figure 31. Comparison of pilot queries by Data Comm condition.

5. Live ATC Interventions

ATC interventions occurred when participants made an error and had to be corrected back on course (see Error Handling Script in Appendix E for a list of anticipated situations that, however, did not all occur), for example, due to errors in responding to the countermanded or conditional clearance. Like pilot queries, such errors may be indicative of communication difficulties. An inspection of the total number of interventions, shown in Figure 30, indicates that ATC did have to intervene on several occasions. While fewer interventions occurred in the text+speech condition, this difference was not statistically significant; in the majority of cases, pilot performance did not differ by condition, $Z = -1.89$, $p = .85$ (see Figure 31).

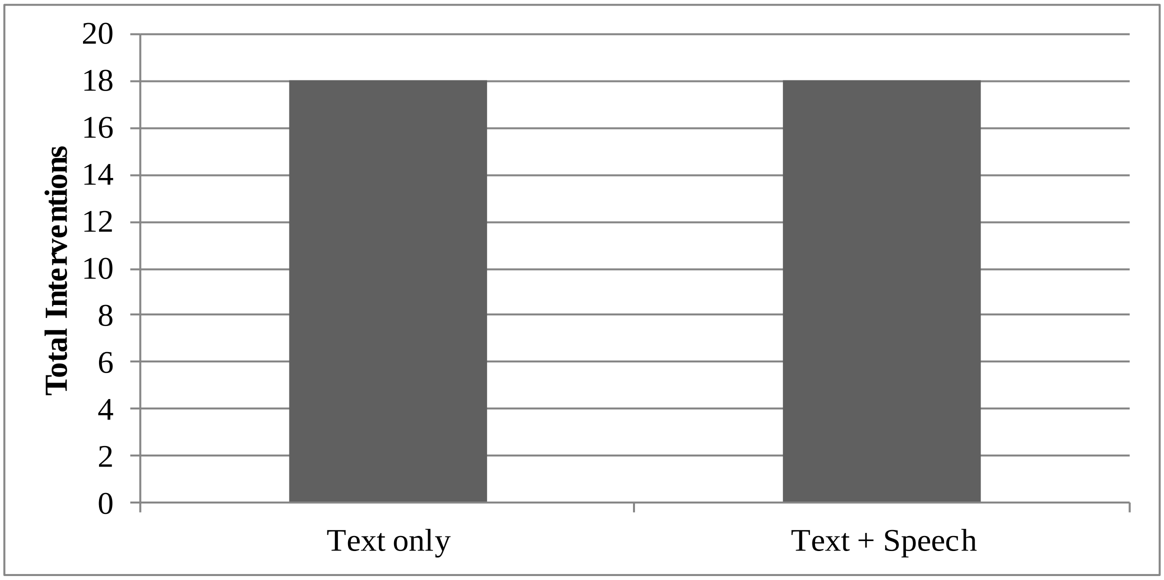

Figure 32. Total number of ATC interventions by Data Comm condition.

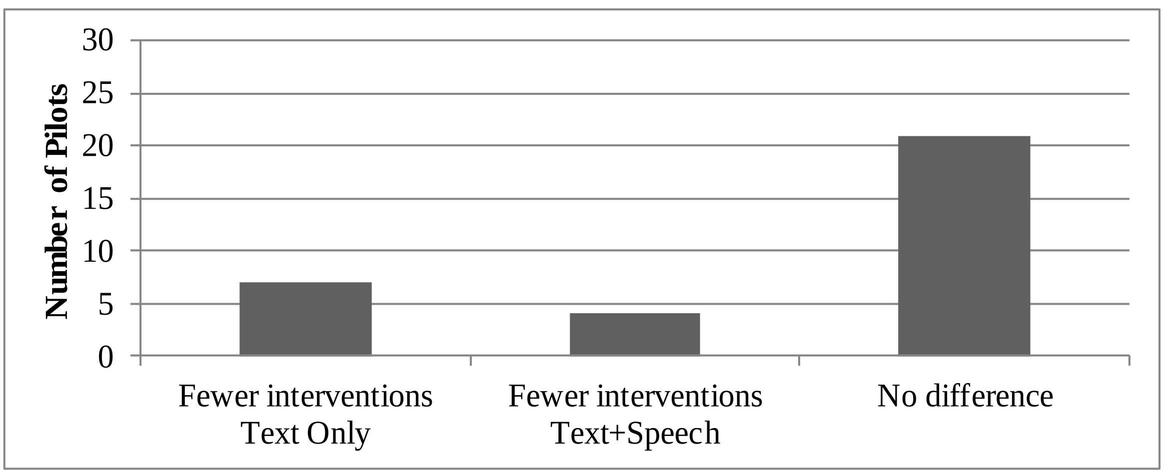

Figure 33. Comparison of ATC interventions by Data Comm condition.

In sum, the results suggest that the addition of synthetic speech to the display does not adversely affect pilot performance. Across all measurements, pilot performance did not significantly differ between the text-only and the text+speech conditions.

6. Additional Subjective Observations

Participants were provided with a pencil and paper to write down any notes throughout the experiment. An inspection of the participants' notes did not reveal any striking differences between the text-only and text+speech conditions. In both conditions, pilots typically wrote down the clearance, route, altitude, frequency, and transponder code during the preflight briefing. Many pilots also drew their entry to the hold after receiving holding instructions. In neither condition did pilots write down messages received from ATC in terminal airspace. This is likely because pilots were able to use the Message Log in both conditions to review a past message when needed.

Several participants were observed to talk to themselves during flight ("self-talk"), particularly during busy phases. For instance, prior to arriving to the final approach fix participants would brief the approach aloud. This technique is common among pilots, and Embry Riddle students are instructed to use self-talk to communicate intentions to the other pilot, or confirm that instructions were accurately received and understood. Experimenters, however, did not perceive a difference in the prevalence of self-talk between the text-only and text+speech conditions. Importantly, the prevalence of self-talk did not appear to interfere with the pilots' communication with ATC.

B. Second, help if you can…

A second goal of the current study was to assess whether the addition of synthetic speech to the Data Comm display aided pilot performance. Of interest is whether the presence of annunciations reduced the amount of time participants spent looking at the touch-screen tablet, aided flight precision, and whether it decreased the likelihood that participants would act early on a conditional clearance.

1. Gaze-Dwell Time

Two measures of dwell time were obtained: 1) qualitative data via post-scenario surveys, and 2) quantitative data, via video recordings of eye movement in the cockpit.

The post-scenario surveys asked pilots to assess the percent of time they spent looking at various locations in the cockpit (e.g., at the touch-screen tablet, out the window, at the instrument panel). As shown in Figure 32, results indicated that pilots in the text-only condition reported spending a significantly larger amount of time looking at the touch-screen tablet relative to pilots in the text+speech condition, $t(31) = 2.54$, $p < .05$; no other comparisons were significant, all $p > .15$. This suggests that the auxiliary synthetic-speech display may have decreased the amount of head-down time relative to the text-only condition. Of further interest was whether this trend was corroborated by the quantitative analysis of dwell-time data.

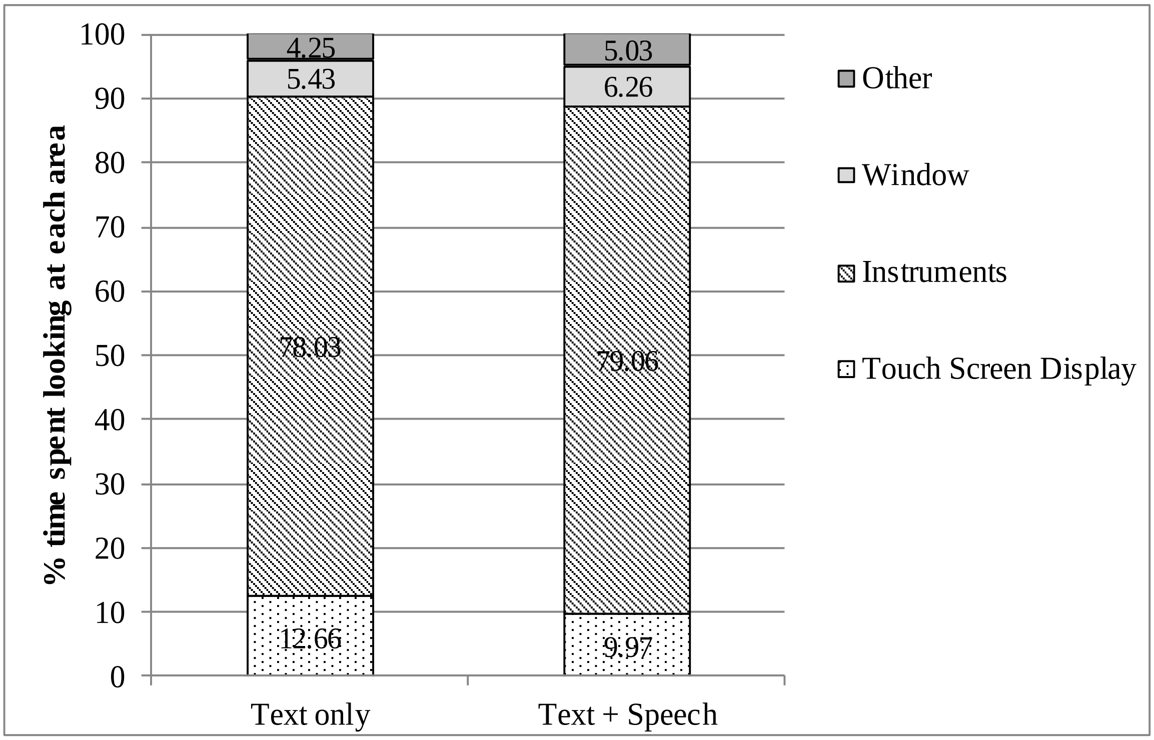

Figure 34. Percent of dwell time by area and Data Comm condition (self-assessed).

b. Quantitative Dwell-Time Data

Of the two cameras located on the flight deck, dwell-time data were collected from the camera mounted on the pilot's left side of the panel. A primary coder, blind to the experimental conditions, measured participants' gaze-dwell time on the touch-screen tablet by silently viewing video recordings of each pilot's two scenarios. A second coder analyzed a subset of data from each video (3 minutes). The Pearson product-moment correlation was used to determine inter-rater reliability. The Pearson correlation (*r*) tests for the degree of relationship between two continuous variables. The values of *r* can range from -1 (a perfect negative relationship) to +1 (a perfect positive relationship). The Pearson correlation indicated high inter-rater reliability between the two coders, $r(373) = .94$, $p < .001$. The positive relationship indicates that the coders' data varied in the same direction (i.e., coders' measurement increased or decreased in unison). Data from the primary coder were used for the quantitative dwell-time analysis. Movements of the eyelids, as opposed to the pupils, were used to define the duration of dwell time because: 1) pupils were not always visible in the ambient cockpit lighting, and 2) pupils were not always visible given that participants were of different heights and could adjust their distance from the camera.

The data were analyzed using a paired-samples *t*-test. This test is the parametric version of the Wilcoxon test described earlier, and is justified here due to the approximately normal distribution of the looking-time data. Analyses indicated that relative to text+speech, communicating with text only did not elicit a significant increase in the average number of looks for each participant to the touch-screen tablet, $t(31) = 1.71$, $p = .10$ (see Figure 35). This is likely because the ding-dong chime to announce an incoming message was effective. The average duration of dwell time per look for each participant also did not significantly differ between the text-only and text+speech conditions, $t(31) = 1.81$, $p = .08$ (see Figure 36).

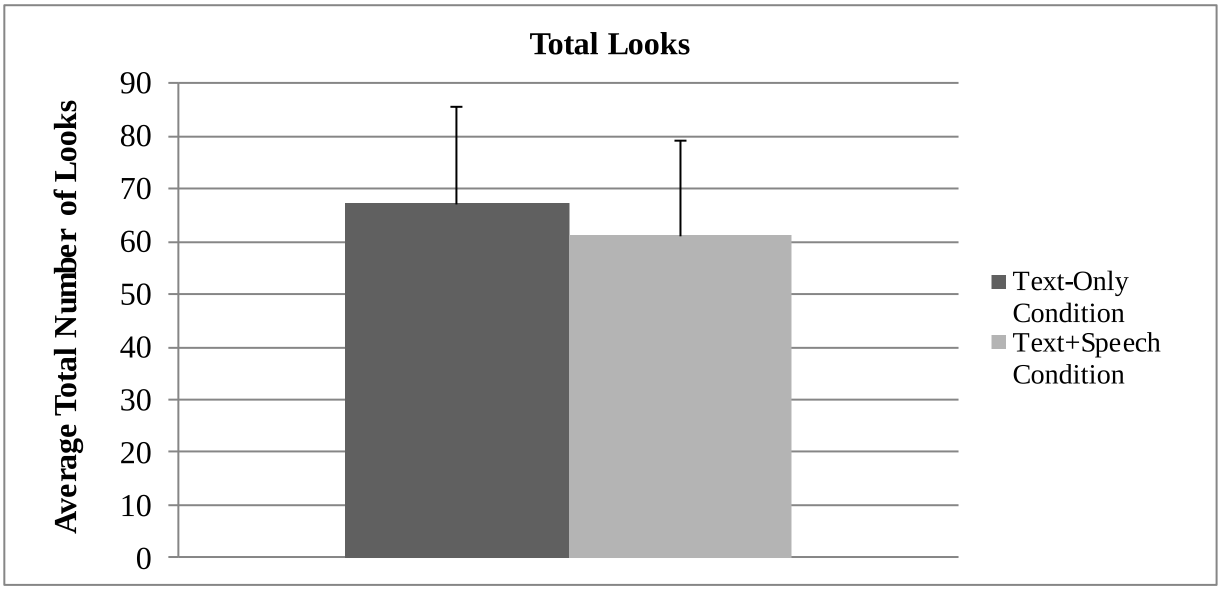

Figure 35. Mean frequency of looks to the touch-screen tablet by Data Comm condition (whiskers=SD).

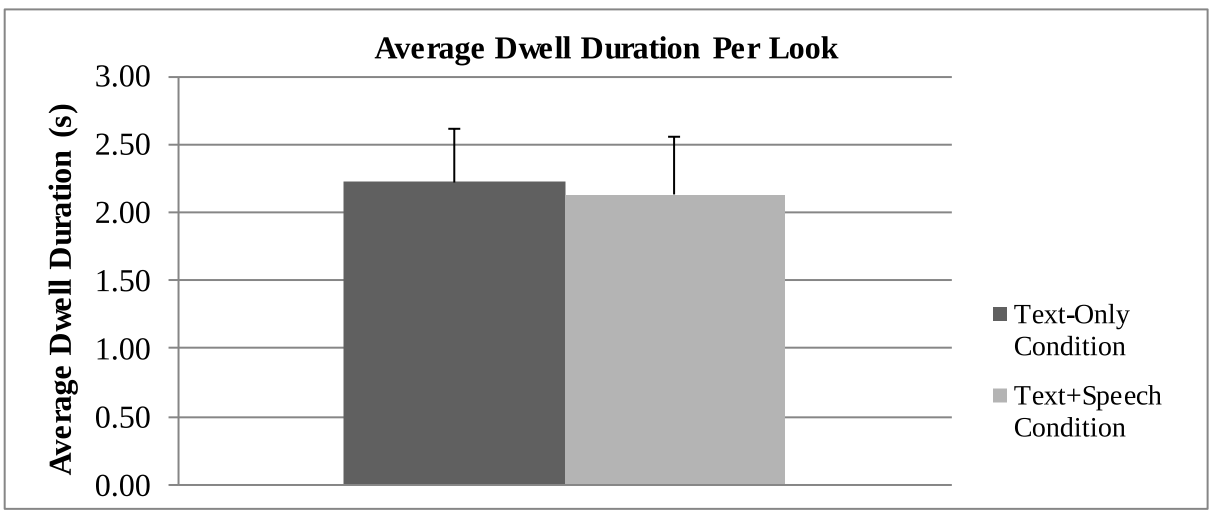

Figure 36. Mean dwell time per look on the touch-screen tablet by Data Comm condition (whiskers=SD).

Figure 37 displays the average of participants' total dwell time at the touch-screen tablet. Participants in the text-only condition spent an average of 147 seconds dwelling on the display, approximately 2 minutes and 27 seconds, while participants in the text+speech condition spent an average of 127 seconds, or 2 minutes and 7 seconds, dwelling on the display. That is, participants spent an average total of 20 seconds longer dwelling on the text-only display compared to the text+speech display. A paired-samples *t*-test indicated that this result was statistically significant, $t(31) = 2.50$, $p < .05$. Indeed, the range of achievable effect sizes did not encompass zero – an indication that a true effect is present. The smallest difference that could have been found with 95% confidence was a dwell-time advantage of 3.75 seconds for text+speech, but it was also possible to find a text+speech advantage as large as 36.92 seconds (see Figure 38).

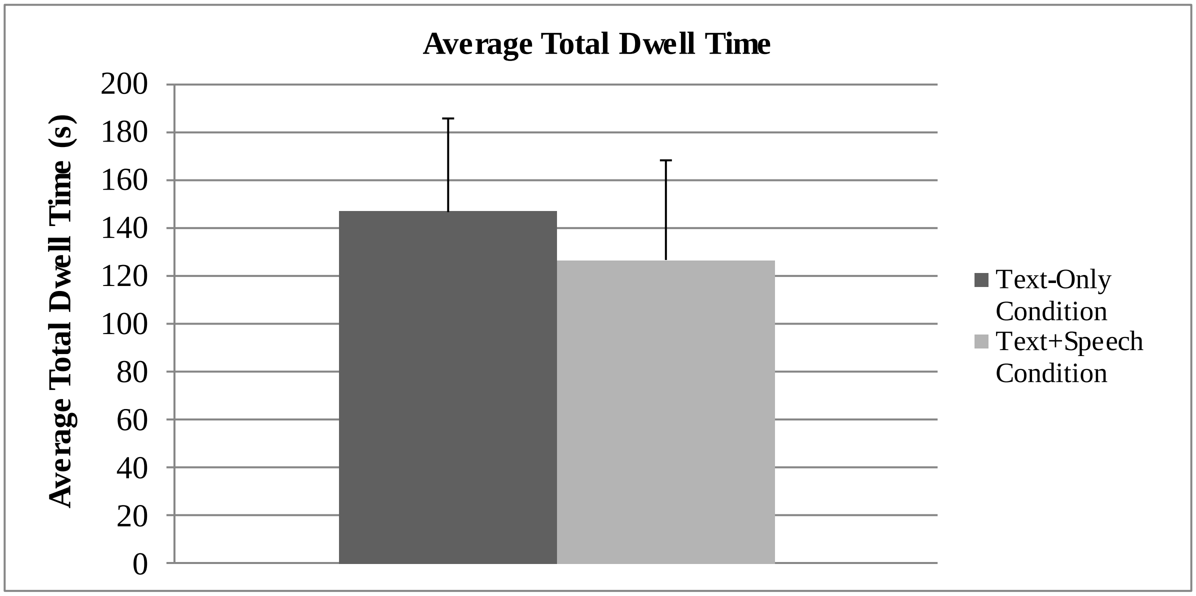

Figure 37. Mean total dwell time on the touch-screen tablet by Data Comm condition (whiskers=SD).

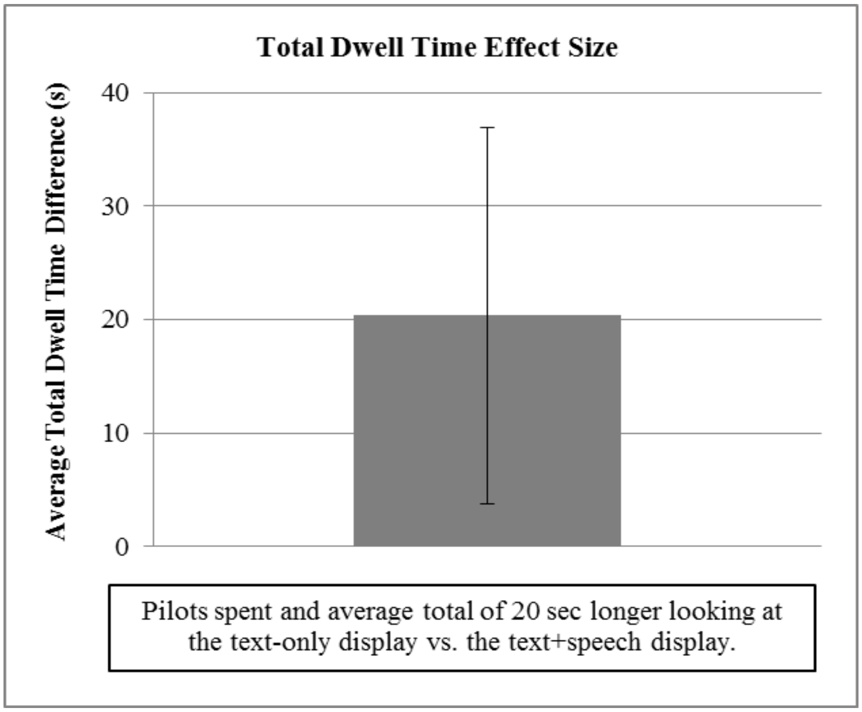

Figure 38. Effect sizes (average difference) and 95% confidence intervals (whiskers) for average total dwell time.

Further analysis of the total dwell-time data revealed that the text+speech advantage occurred regardless of event type (key or stability) or specific event (in repeated-measures ANOVAs, p = .27 and .48, respectively) (using the first 10 sec following message onset to represent dwells in response to a message) There was, however, an overall difference in dwell time by event type and by specific event, regardless of Data Comm condition. Dwell time for key events was significantly lower than dwell time for stability events, $F(1,443) = 85.02$, $p < .0001$, but only by about .6 seconds (see Figure 39). Dwell time also differed by event, $F(13,431)= 8.76$, $p < .0001$ (Figure 40).

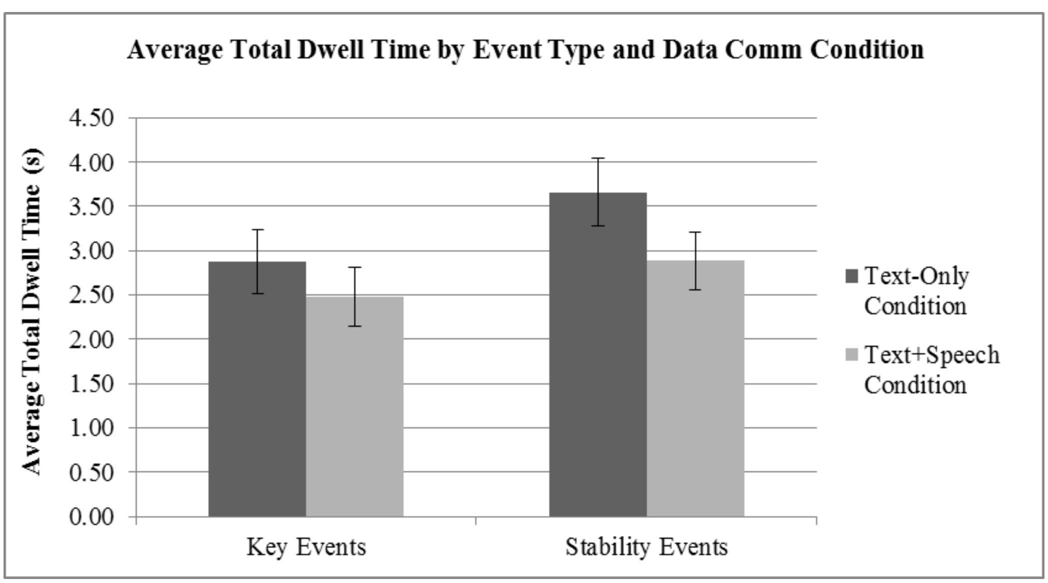

Figure 39. Average total dwell time in 10 seconds following message onset by Data Comm condition and event type (whiskers=95% confidence intervals).

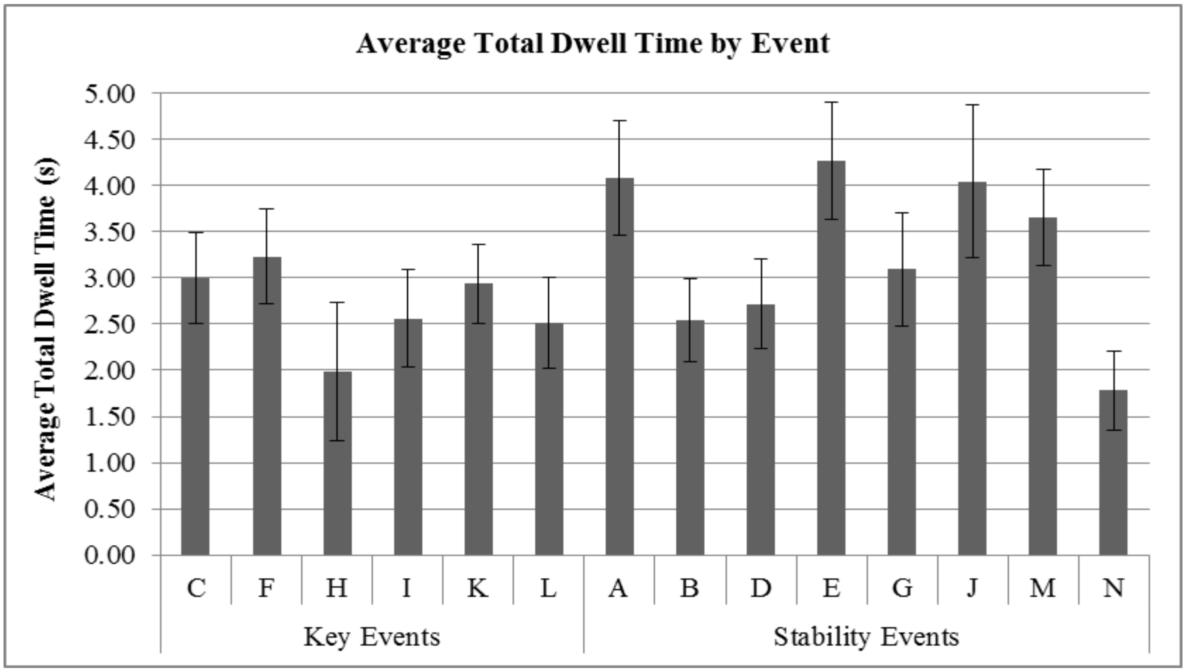

Figure 40. Average total dwell time in 10 seconds following message onset by event (whiskers=95% confidence intervals).

As the Figures 39 and 40 show, the average total dwell time in the 10 seconds following the onset of Data Comm messages was much lower than the overall average total dwell time shown in Figure 37. On average, pilots only spent an average of 12% of their total dwell time looking at the display in response to a message. In other words, 88% of total dwell duration occurred between messages. These percentages did not differ by Data Comm condition (repeated-measures ANOVA, $p = .73$). Across both Data Comm conditions, the percentage of total dwell time spent looking at the display in response to stability-event messages was significantly greater than the percentage of total dwell time in response to key-event messages, $F(1,62) = 45.91$, $p < .0001$ (Figure 41).

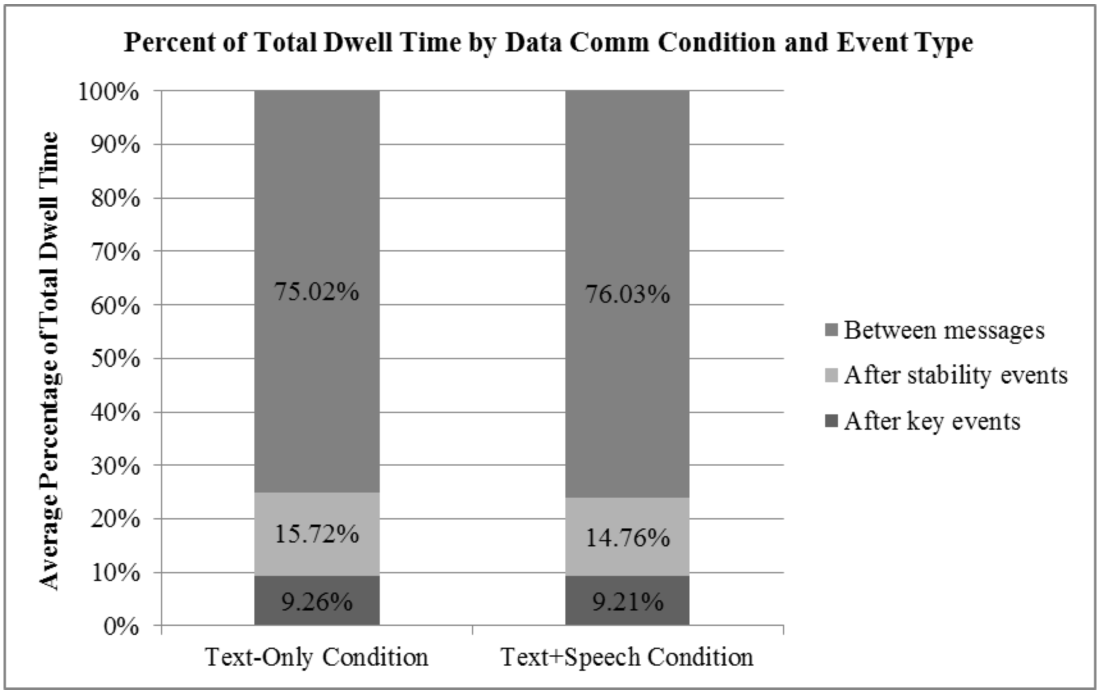

Figure 41. Average percentage of total dwell time by Data Comm condition and event type.

2. Flight Precision

Of interest was whether flight precision was affected by looking down at and responding via the touch-screen tablet (and spending less time scanning the instruments and the sky), and whether or not synthetic speech would alleviate some of the impact. Flight precision is best measured by looking at the Stability Events, during which pilots are expected to maintain precision within Practical Test Standards (i.e., not to disturb the flight controls). If using the touch-screen tablet impacted flight precision, it was expected that pilots would exhibit less-steady control inputs, i.e. "wobble," immediately following a Data Comm message from ATC. If the auxiliary synthetic speech alleviated some of this effect (presumably, by shortening the time spent reading the incoming message), there should be less wobble during the text+speech condition than during the text-only condition.

To investigate wobble, pitch control loading (fore/aft force applied to the control column) from a few participants was graphed and visually inspected. The graphs provided a close-up view of pitch control loading within the time frame that potential wobble would be expected (from several seconds before to several seconds after the onset of a Data Comm message from ATC). Upon inspection, it was difficult to determine whether small changes were wobble or whether they were intentional changes made by the pilot to keep a drifting airplane steady. Moreover, all of the observed changes (in both text-only and text+speech conditions) were too small to be deemed operationally relevant: Inspection of the graphs indicated only very small fluctuations in pitch control loading which occurred just prior and immediately following the message onset; these fluctuations represent the smallest measurable movement (approximately .00013 inches), and therefore are just measurement "noise."[5] In some cases, the graphs showed a slight increase in pitch control loading (which might be associated with a push on the column) following message onset. These increases were very small (e.g., .04 inches). In conclusion, wobble did not seem to be an issue in either of the Data Comm conditions.

3. Conditional Clearance

Recall that the experimental scenarios included one conditional clearance ("At Ormond VOR Climb to 3,000"). These clearances are known to be problematic—pilots tend to act immediately, rather than when the condition is satisfied, or forget to remember (prospective memory is notoriously inadequate for any task; Dismukes & Nowinski, 2006; for an operational perspective, see Portugal, WP/22, 2010; United Kingdom, WP/18, 2010). The former may especially be a problem in Data Comm, because pilots may overlook the "At Ormond." It was hypothesized that the extra cue present in the synthetic speech display may prevent pilots from acting erroneously to the text-only display. An inspection of the total number of errors, as shown in Figure 39, suggests that pilots were indeed more likely to respond incorrectly to the conditional clearance in the text-only condition relative to the text+speech one.

Of the seven errors made by pilots communicating via text only, three pilots climbed immediately rather than at Ormond, and four pilots failed to climb at Ormond. In the text+speech condition, one pilot failed to climb at Ormond, and one pilot climbed immediately. Thus, more pilots committed fewer errors when communicating via text+speech than with text-only Data Comm than vice versa (see Figure 37), a trend that approached significance, $Z = -1.89$, $p = .06$.

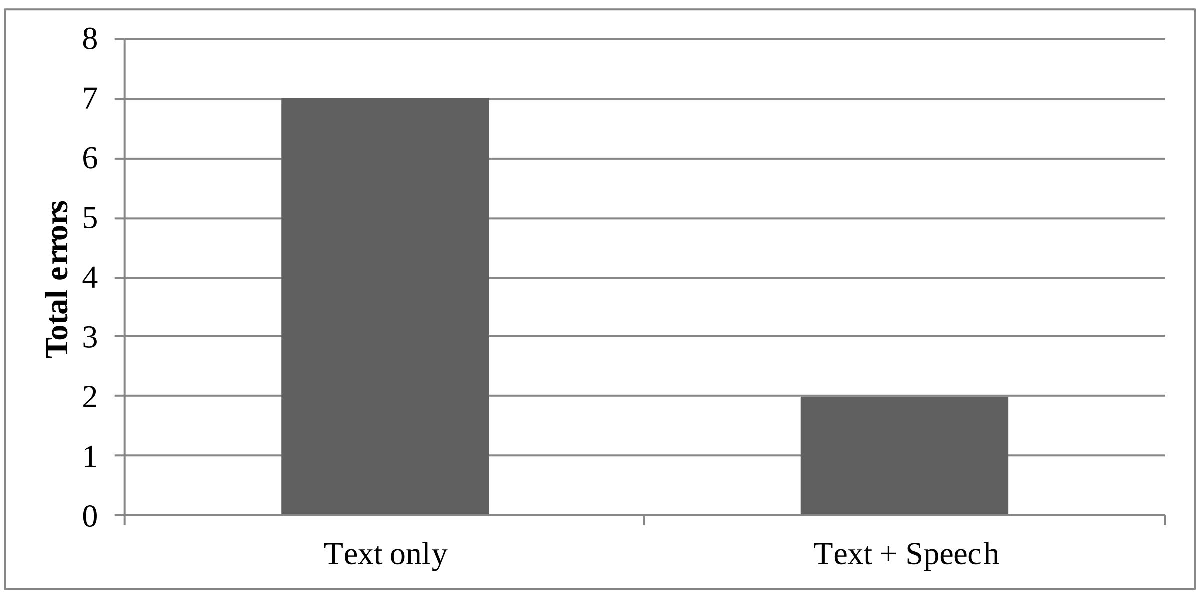

Figure 42. Total number of errors by Data Comm condition to the conditional clearance.

[5] The most forward column position is 8.7 inches and farthest aft position is 14.7 inches, resulting in a range of column travel fore to aft of 6 inches.

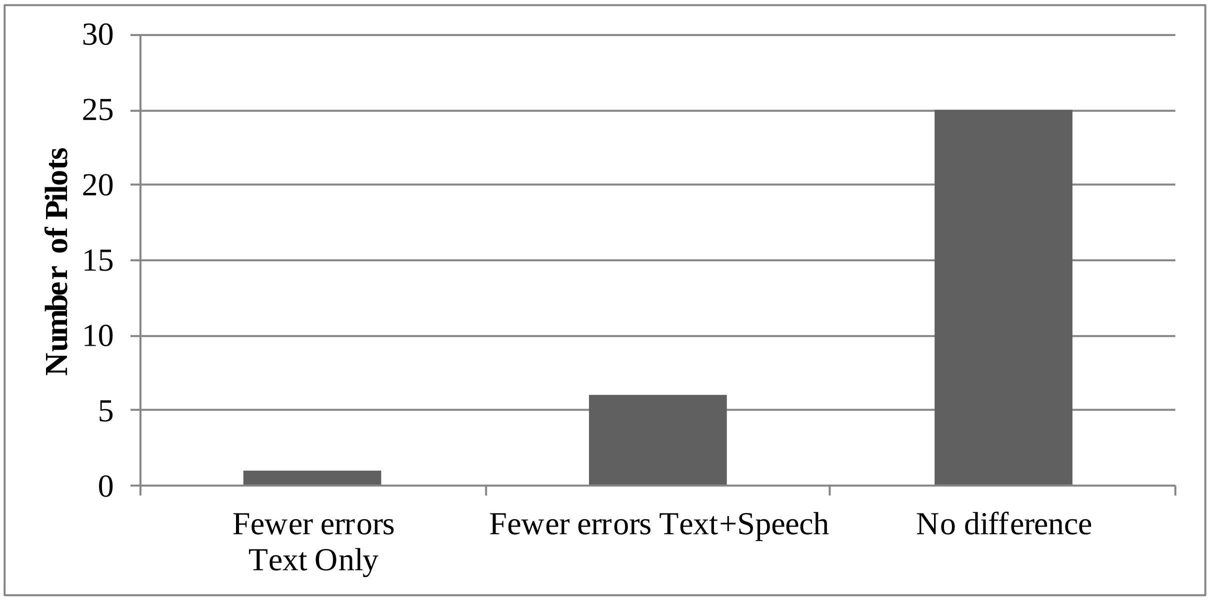

Figure 43. Comparison of pilot performance by Data Comm condition to the conditional clearance.

C. Pilot Opinion

1. Communications Workload – Post-Scenario Only

Pilot opinion regarding communications workload was solicited via post-scenario surveys. Pilots were asked to rate their ATC communications workload after flying each experimental scenario. Specifically, they were asked to indicate their agreement with the following statements: (A) Communication (receiving and replying to instructions) with TOWER CONTROL was easy; and (B) Communication (receiving and replying to instructions) with DEPARTURE CONTROL was easy. Agreement was indicated by choosing from one of five levels of agreement: Strongly Agree, Agree, Undecided, Disagree, or Strongly Disagree. Recall that Data Comm was used when communicating with Departure Control, but not with the Tower. Of interest is whether communication workload ratings differ in Departure Control for the text-only and text+speech conditions.[6] Pilots communicating with ATC via text+speech were expected to perceive a lower communications workload.

Results of pilot-rated communications workload were analyzed using sign tests. When communicating with Departure Control, there were only three pilots who felt that communicating with text only was easier, compared to nine pilots who felt that communicating with text+speech was easier. This difference, while in the predicted direction, did not reach significance, $p = .15$. The results of this analysis are depicted in Figure 38.

[6] The question on communications workload with Tower was included to ensure that participants differentiated between typical voice communication and Data Comm in their responses. That they did so was shown by the fact that the majority of pilots (30/32) rated the Tower communication workload identically regardless of Data Comm modality used with Departure Control.

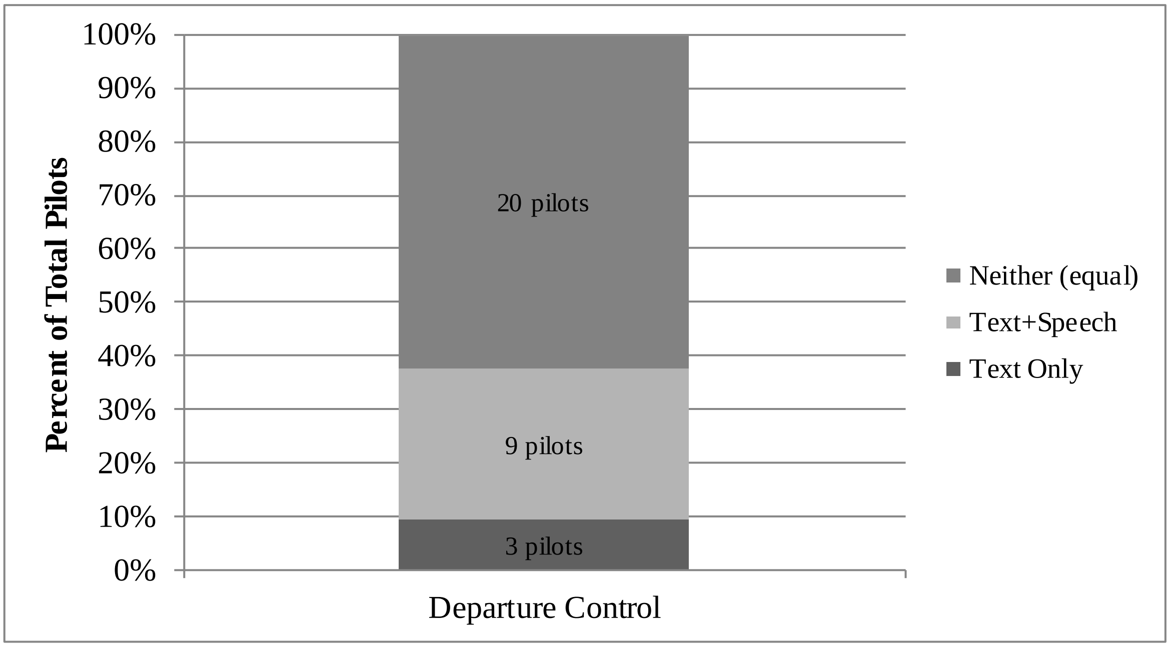

Figure 44. Number of pilots who agreed that communication was easier with text only vs. text+speech.

The average ratings were also calculated by Data Comm condition (see Figure 39). To calculate the average, numerical values were assigned to the level-of-agreement choices, with 5 representing "Strongly Agree" and 1 representing "Strongly Disagree." On average, pilots gave high ratings of agreement (that communication was easy). When communicating with Departure Control, ratings were slightly higher for the text+speech condition (M = 4.44, SD = .72) than for the text-only condition (M = 4.19, SD = .93). The means could not be statistically compared (e.g., using a paired-samples t-test) due to the skewed distribution of the ratings, which violates the assumptions for most parametric tests.[7]

[7] When communicating with Tower Control, pilots were in perfect agreement, with an average rating of 4.72 (SD = .46) given to both the text-only and the text+speech condition.

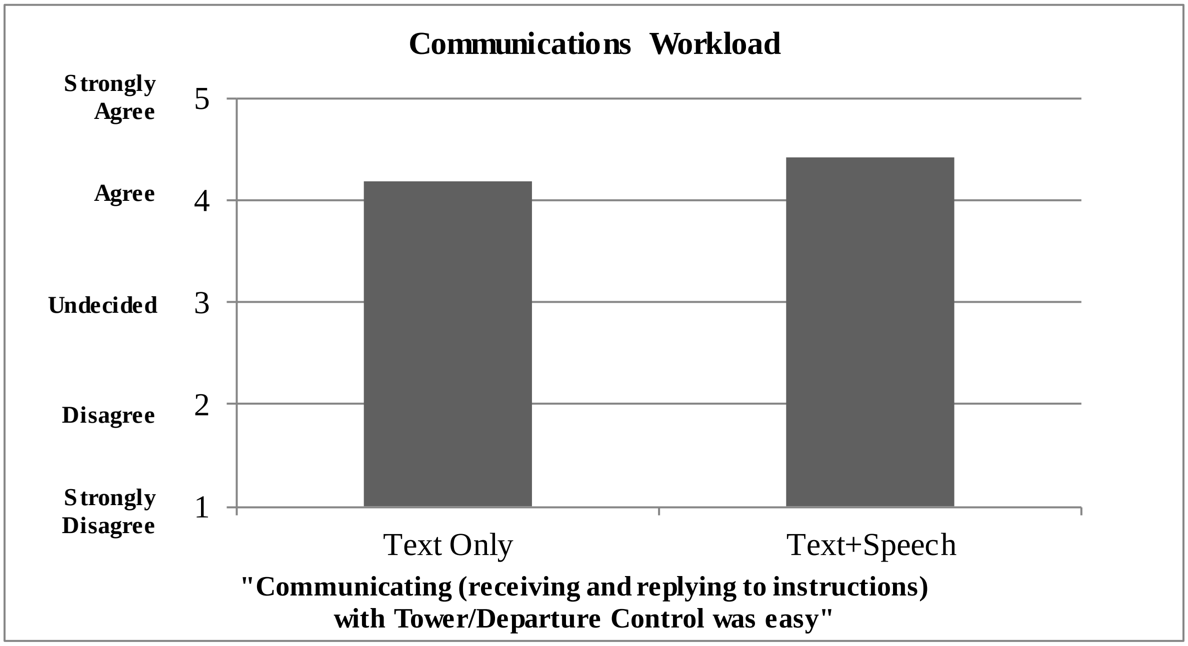

Figure 45. Average communications workload ratings when communicating with departure control by Data Comm condition.

2. Using the System – Post Scenario

Pilots were asked to rate the ease of use of the entire system following both the text-only condition and the text+speech condition. Average ratings indicate that the pilots felt the system was easy to use. There were no differences between ratings made after using the system in the text-only condition vs. the text+speech condition (paired-samples *t*-tests, all $p > .37$).

As shown in Figure 40, pilots agreed that they felt confident using the system and that most people would learn to use the system quickly (with average ratings between "Agree" and "Strongly Agree"). They disagreed that the system was awkward (average ratings just above "Disagree," between "Disagree" and "Undecided"). They also disagreed that they needed to learn a lot before they could get going with the system (average ratings just below "Disagree," between "Disagree" and "Strongly Disagree").

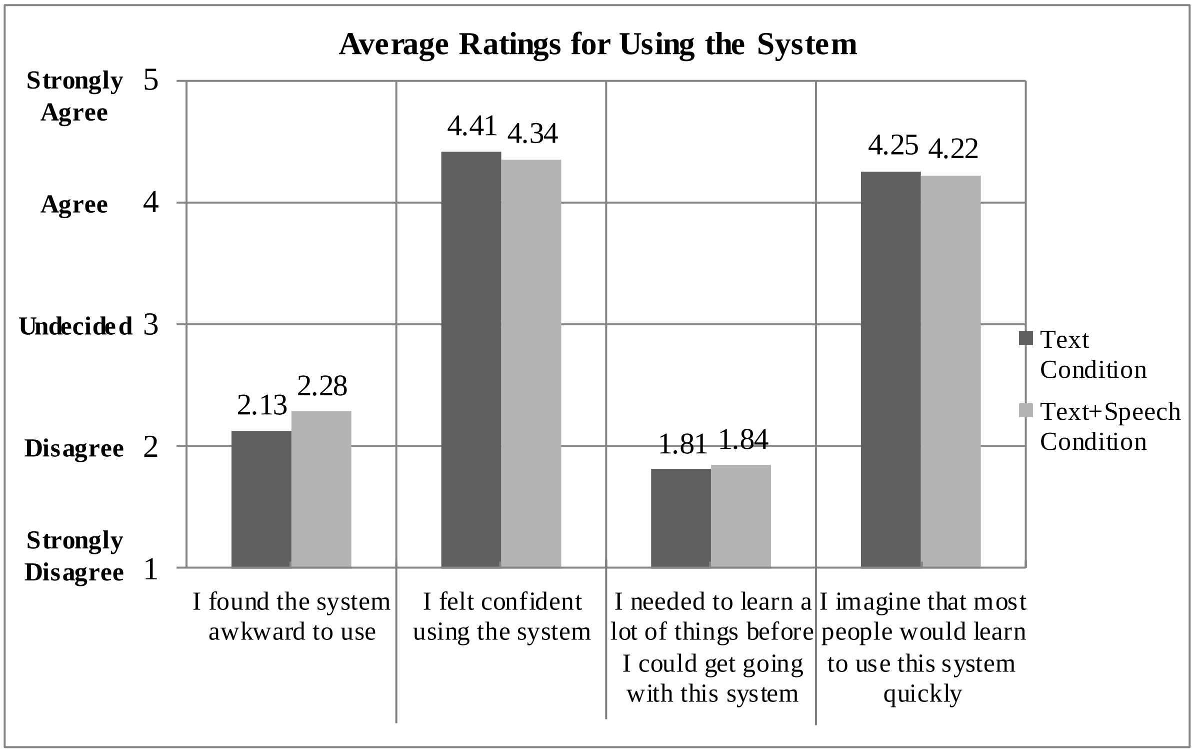

Figure 46. Average ratings for using the system by question and Data Comm condition.

Pilots were also asked whether they used the Log window on the touch-screen display. All 32 pilots reported that they used the Log window during the text-only condition and 30 of those pilots reported using it during the text+speech condition. In general, participants often indicated that the Log window was used to review or verify instructions. See Table 12 in Appendix H for a full listing of participants' uses of the Log window.

3. Using the System – Post Experiment

At the end of the experiment, pilots were asked to give their opinions of the two Data Comm systems. Recall that each participant completed this survey after experiencing both conditions; this final survey inquired about participants' preferences between the text-only and text+speech displays. When asked to rate how helpful each system was, the pilots were in agreement that both the text display and the computer-generated speech, in addition to the text display, were helpful (see Figure 41).

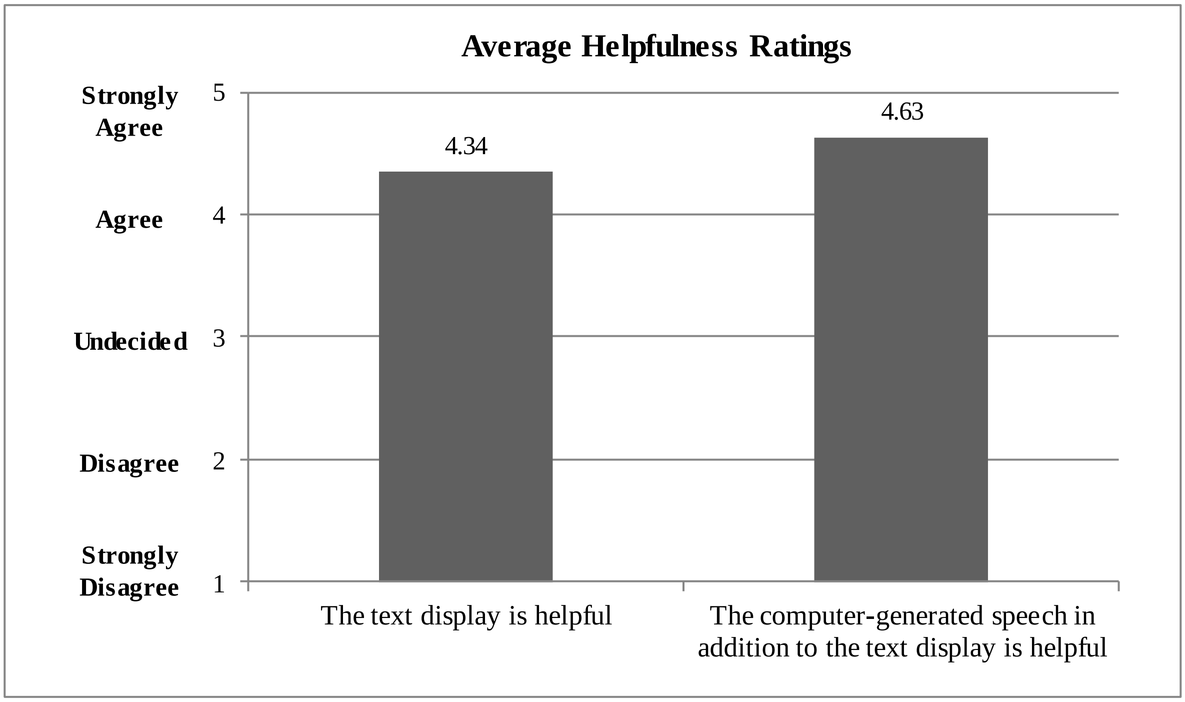

Figure 47. Average ratings for helpfulness by question.

Thirteen pilots gave the exact same agreement rating for the helpfulness of the text display alone as for helpfulness of the text display with the addition of computer-generated speech. Thirteen pilots gave higher agreement ratings to the helpfulness of the text+speech display than to the helpfulness of the text-only display. The other six pilots gave higher agreement ratings to the helpfulness of the text-only display. However, a sign test revealed no significant differences between the number of pilots who gave higher ratings to the text-only display and the number of pilots who gave higher ratings to the text+speech display, $p = .17$.

Pilots were in overall disagreement with the statement “The computer-generated speech in addition to the text display is distracting.” The average agreement rating was 1.75 ($SD = .76$), which is closest to “Disagree,” between “Disagree and “Strongly Disagree.” Only two pilots agreed that the addition of computer-generated speech was distracting. Both pilots gave additional comments: One pilot thought that the computer-generated speech was distracting when the computer-generated voice did not talk as fast as the pilot could read; the other pilot believed that pilots will read the text anyway, so the addition of the computer-generated speech may not be effective (see Appendix H).

Pilots were asked whether they preferred communicating with ATC using the text display or the text display with computer-generated speech over a live controller. On average, pilots disagreed when it came to having a preference for text only over a live controller, giving an average agreement rating of 2 ($SD = .98$), which corresponds to “Disagree.” Pilots were in slightly more agreement when asked whether they preferred communicating via the text display with computer-generated speech, compared to a live controller. On average, pilots gave an agreement rating of 3.53 ($SD = 1.34$), which falls between “Undecided” and “Agree” (see Figure 42).

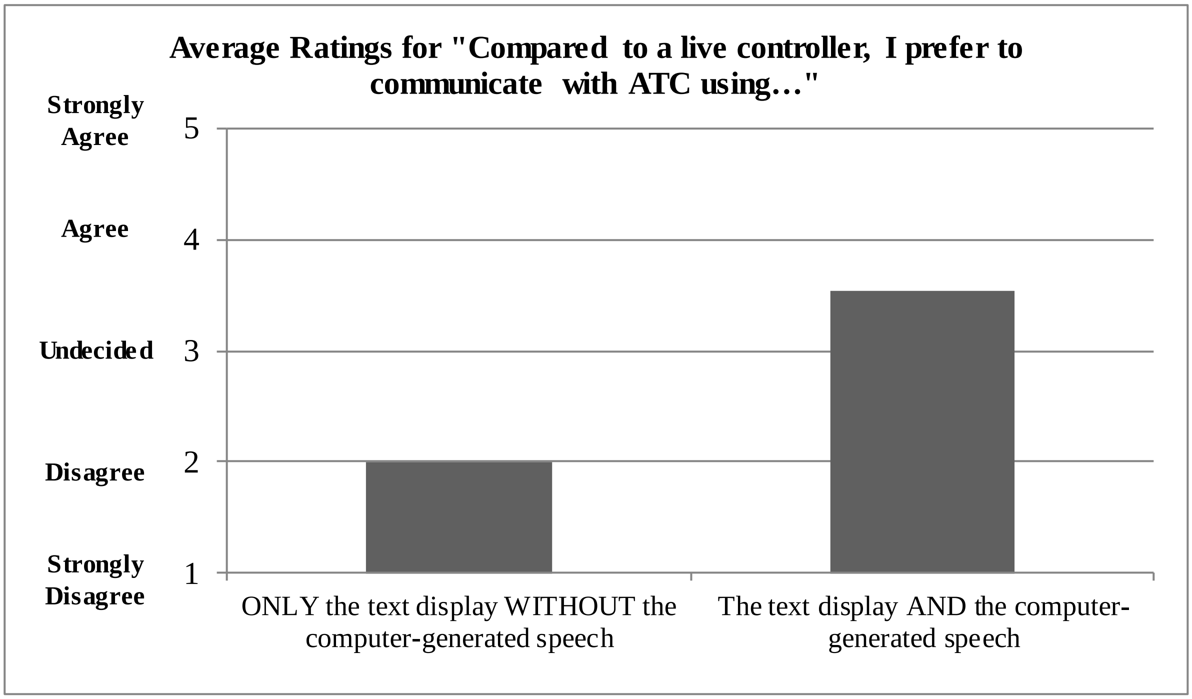

Figure 48. Average ratings for communication preference by question.

Seven pilots showed no difference in their agreement ratings between preferring text-only and text+speech communication vs. communication with a live controller. For those seven pilots with no preference for either configuration, the average agreement rating was 1.86 (*SD* = .90), between "Disagree" and "Strongly Disagree," indicating that these pilots prefer neither of the two Data Comm modes to live ATC. Twenty-four pilots gave a higher agreement rating when asked whether they prefer text+speech over a live controller than they did when asked whether they preferred text only over a live controller. Only one pilot agreed more highly with the statement that he preferred text only over live ATC than with the statement that he preferred text+speech over live ATC. A sign test indicated that this difference of 24 vs. 1 was highly significant ($p < .001$).

Pilots were also asked whether they preferred communicating with ATC using text+speech more than text only. The average agreement rating was 3.53 (*SD* = 1.46), which was significantly higher than the neutral scale anchor of "undecided," $t(31) = 2.06$, $p < .05$.

Additional results regarding pilot opinion, including all participant comments, are included in Appendix H.

IV. Discussion

A. Summary of Results

Data Comm is expected to yield several benefits in the NAS: it is hoped to alleviate frequency congestion, reduce problems associated with speech rate and accent, reduce call-sign confusions, reduce pilots' reliance on memory, and reduce errors and workload by allowing clearances to be autoloaded into the FMS. The ability to successfully communicate with Data Comm, however, may be limited in a general aviation environment, given that the pilot must interact with a display outside the primary field of view. This may yield an operationally significant increase in head-down time. This proof-of-concept study examined the feasibility of implementing an auxiliary synthetic speech display, and whether such a display may mitigate some of the potential challenges associated with Data Communication. Of interest is whether a text+speech display—compared to a text-only display—aids single-pilot performance (e.g., reducing head-down time, increasing compliance with conditional clearances) without introducing additional complications (e.g., failing to acknowledge a countermanded clearance, responding to similar call signs on the party line).

In many ways, the results of the current study indicated that an auxiliary synthetic speech display helped single-pilot performance compared to a display with text only. Similar to the findings of Lancaster and Casali (2008), results from the current study indicated that the addition of a speech display offers several benefits and did not hinder pilot performance. Moreover, the text+speech display yielded a shorter total dwell time on the touch-screen tablet compared to text only, and it was not associated with less precise flying (as was previously observed by McCarley et al., 2010). Pilots in the text-only condition spent an average total of 20 seconds longer looking at the touch-screen tablet relative to pilots in the text+speech condition during the approximately 30-minute flight—a result that is both statistically and operationally significant. Self-reported measures further corroborated this result. When pilots spend more time looking at the touch-screen tablet, this translates into less time spent looking out the window or at the instrument panel. In the NextGen environment, Data Comm is one of many displays and applications that will compete for pilots' attention. For example, NextGen cockpits may also be equipped with a Cockpit Display of Traffic Information (CDTI), that a pilot will interact with to perform envisioned procedures such as Interval Management or the In-Trail Procedure. These applications may occur while the pilot is communicating with ATC via Data Comm. How the flight crew will allocate their limited resources across applications remains an open question. Consequently, any additional time spent looking at the touch-screen tablet rather than the instrument panel or elsewhere in the cockpit is operationally relevant.

The addition of the speech display may have also prevented pilots from acting early on a conditional clearance. Recall that in the text-only Data Comm environment, pilots have difficulty with such clearances—acting on them early (rather than when the condition is satisfied) or forgetting to act on them at a later time. Interestingly, when communication was via text only, such errors were also observed in the current experiment. Pilots either missed the initial condition and climbed early, or seemed to notice the initial condition, but forgot it upon reaching its fulfillment (i.e., Ormond). With the addition of the speech display, both types of errors were less common. No difference was observed in the number of pilot queries to ATC (e.g., requests for clarification, repeat instructions) or in the number calls made by ATC to pilots (e.g., to correct an error).

Importantly, the auxiliary synthetic speech display did not appear to harm pilot performance.[8] Pilots were not more likely to respond to similar call signs on the party line when communicating

[8] A National Transportation Safety Board (NTSB)-like rendering of the flight control results (airspeed, altitude, pitch, roll) in a text+speech experimental flying scenario is available at:

via the text-plus-speech display compared to text only. Likewise, similar performance was observed under both Data Comm conditions in responding to the countermanded clearance. Thus, the implementation of synthetic speech does not appear to make pilots more susceptible to similar call sign confusions, or more likely to ignore/confuse a live voice countermand. Moreover, the addition of a synthetic speech display did not hinder pilots' time to initiate input to the flight controls or to complete ATC instructions. Given that the current study examined the feasibility of implementing a synthetic speech auxiliary display, a baseline condition (i.e., current day operations with live voice ATC) was not included. Thus, it is unclear whether pilots are faster to initiate an input to flight controls with text Data Comm compared to live voice (as observed in past simulation research). In some cases, pilots were faster to acknowledge ATC via the touch-screen tablet in the text-only condition, suggesting that pilots in the text+speech condition may wait to acknowledge the message until they have heard the full annunciated instruction, as they may do with live ATC. However, in general, the addition of the synthetic speech display did not delay pilot response time. Lastly, participants tended to view the synthetic speech display favorably—it was deemed to be both helpful and not distracting. Recall that the pilots in this current study were mainly students—a group that routinely uses text messages to communicate, often while being engaged in other tasks. That this group still preferred the text+speech display relative to the text-only display suggests that older pilots, who are used to communicating with ATC via voice, may prefer the text+speech display to an even greater extent.

B. Limitations and Future Research

This proof-of-concept study had several inherent biases, some of which may have attenuated the advantages of having an auxiliary synthetic speech display. One of them, the student participants proficient in texting, has already been mentioned, although that advantage could have been balanced by their inexperience, with previous research results indicating that novice GA pilots experience higher visual workload from Data Comm than experienced pilots. Another one may lie in the user-friendly design of the touch-screen tablet: The tablet was relatively large and with color-coded responses (i.e., green for "affirmative" and magenta for "negative"). Actual Data Comm displays (e.g., the Control Display Unit [CDU] of the Flight Management System [FMS]), are smaller and may not make use of color to code responses. Actual displays are typically shared with other applications (e.g., waypoint entry) and may require the flight crew to scroll through several menu hierarchies before viewing or sending a Data Comm message. The format of the Data Comm messages was also ideal—messages comprised both upper and lower case letters in uniform shape with appropriate line breaks (e.g., "Turn Left Heading 100"). Envisioned implementations of Data Comm comprise only capital letters (e.g., "TURN LEFT HEADING 100") and the constrained display may create unnatural line breaks (e.g., between rather than at the end of a message). The use of such an idealized display may underestimate dwell time. Pilot performance with a less-optimal interface remains an open question.

Other biases may have favored the Data Comm concept in general, regardless of mode. In the current study, the pilot never initiated data communications with ATC—pilot use of Data Comm

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http://www.volpe.dot.gov/media/coi/hfrsa/datacomm/. This video includes all pilot-controller communications that took place during the scenario—including the synthetic speech—and an image of the touch-screen tablet.

was limited to replying to ATC messages with one of only six simple button presses. Pilots could choose the response for an uplink message (e.g., Wilco, Roger). In real implementations, the response that a pilot can send is constrained by the message. In addition, during real operations, pilots will need to send messages to ATC, for example to request a specific altitude or a weather deviation, requiring some sort of alphanumeric input device. The kneeboard plus touch-screen tablet solution presented in this experiment does not afford the ability to compose messages, and the implementation of such a capability may reveal itself as impractical. Moreover, the use of the touch-screen tablet for communication might be particularly difficult in detrimental weather (e.g., turbulence); in such cases it might be easy to inadvertently tap the incorrect button.

The Data Comm messages used in the current study were tailored to the experimental scenarios—not all messages are proposed for inclusion in the RTCA SC-214/ EUROCAE WG-78 message set. In reality, such specific uplink messages would have to be entered by the controller as free text or pre-formatted for the controller by ground-side automation. The complexity of these messages in real operations, and the ability of pilots to comprehend and respond to them appropriately, may elicit a decrement in performance.

However, the current study also had some biases that may have favored the auxiliary synthetic speech concept, such as testing the concept in a single-pilot context, where the synthetic speech can function as a co-pilot communicating the Data Comm message. Future work should extend the use of a synthetic-speech display to a commercial as opposed to a general aviation environment. In such an environment, synthetic speech may actually interfere with intra-crew communications. On the other hand, it may support some of the procedures regarding Data Comm clearances. For example, current guidance (e.g., in the Global Operations Data Link Document, First Edition) recommends that in a two-person crew, each pilot should silently read the Data Comm message before responding. The implementation of a synthetic-speech display may reduce the need for such a procedure given that both pilots hear the message at the same time. Both of these questions require further examination.

Of further interest is the interaction between the instructions issued by the live controller and synthetic speech. It is feasible that the controller may contact the pilot while the synthetic speech is annunciating a Data Comm message. This scenario was avoided in the current study: the live controller never contacted the pilot when the synthetic speech was annunciating a message. This may, however, occur in real operations and it is unclear how the two modes of communication will interact. Given that the controller would only contact the flight crew via voice in a time-critical situation—if Data Comm is the primary mode of communication—it is likely that the live voice should inhibit the synthetic speech display. Realistic pilot performance under such a scenario, however, remains to be seen. It is anticipated that follow-up work will entail looking at the effect of auxiliary synthetic speech in a multi-crew, en-route environment using legacy interfaces, while further examining the potential of synthetic speech to interfere with live oral ATC instructions.

Finally, the current study was conducted in the terminal environment. This airspace was chosen to 1) allow for a short, realistic flight scenario that can accommodate both take-off and landing, and 2) examine the use of Data Comm in a relatively fast-paced environment. It is likely, however, that Data Comm will be implemented en route before terminal airspace. Future work should examine the use of auxiliary synthetic speech in the en route environment.

References

Blassic, E. J. & Kerns, K. (1990). *Controller evaluation of terminal data link services: Study I* (MITRE Tech. Report MTR90W215). McLean, VA: MITRE Corporation.

Bürki-Cohen, J. (1995). Say again? How complexity and format of air traffic control instructions affect pilot recall. *40th Annual Air Traffic Control Association Proceedings*, September, 225-229.

Bürki-Cohen, J. (1996). *An analysis of tower (ground) controller - pilot voice communications* (Report No. DOT/FAA/AR-96/19). Washington, DC: U.S. Department of Transportation, Federal Aviation Administration.

Cardosi, K. (1993). *An analysis of en route controller-pilot communications.* (Report No. DOT/FAA/RD-93/11). Washington, DC: U.S. Department of Transportation, Federal Aviation Administration.

Dismukes, K., & Nowinski, J. (2006). Prospective memory, concurrent task management, and pilot error. In A. Kramer, D. Wiegmann, & A. Kirlik (Eds.), *Attention: From Theory to Practice* (pp. 225-236). New York: Oxford.

DeMik, R. J. (2009). Text communications in single-pilot general aviation operations: Evaluating pilot errors and response times. *International Journal of Applied Aviation Studies*, *9*, 29-42.

Diehl, J. M. (1975). *Human factors experiments for data link, Interim Report No. 6: An evaluation of data link input/output devices using airline flight simulators* (Report No. FAA-RD-75-160). Washington, DC: US Department of Transportation, Federal Aviation Administration.

Grayson, R. L., & Billings, C. E. (1981). Information transfer between air traffic control and aircraft: communication problems in flight operations. In C. E. Billings & E. S. Cheaney (Eds.), *Information transfer problems in the aviation system* (NASA Tech. Paper 1875). Moffett Field, CA: NASA Ames Research Center.

Global Operational Data Link Document (2010). First Edition. Available: http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/enroute/oceanic/data_link/

Groce, J. L., & Boucek, G. P. (1987). *Air transport crew tasking in an ATC Data Link environment.* Warrendale, PA: SAE International.

Helleberg, J. R., & Wickens, C. D. (2003). Effects of data-link modality and display Redundancy on pilot performance: An attentional perspective. *International Journal of Aviation Psychology*, *13*, 189-210.

Hilborn, E. H. (1972). *Human factors experiments for data link*. (Report No. FAA-RD-75-170). Washington, DC: US Department of Transportation, Federal Aviation Administration.

Hinton, D.A., & Lohr, G.W. (1988). *Simulator investigation of digital data link ATC communications in a single-pilot operation.* (NASA Tech. Paper 2837). Hampton, VA: National Aeronautics and Space Administration, Langley Research Center.

Kerns, K. (1999). Human factors in air traffic control/flight deck integration: Implications of datalink simulation research. In J. A. Wise, V. D. Hopkin & D. J. Garland (Eds.), *Handbook of Aviation Human Factors* (pp. 519-546). Mahwah, NJ: Lawrence Erlbaum.

Kerns, K. (1991). Data-link communication between controllers and pilots: A review and synthesis of simulation literature. *Journal of Aviation Psychology, 1*, 181-204.

Lancaster, J.A., & Casali, J.G. (2008). Investigating pilot performance using mixed modality simulated data link. *Human Factors, 50*(2), 183-193.

Latorella, K. (1998). Effects of modality on interrupted flight performance: Implications for data link. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*.

Logsdon, E. W. (1996). *An examination of data link autoload and message length.* Unpublished Master's Thesis, San Jose State University.

Logsdon, E. W., Lozito, S., Mackintosh, M. A., McGann, A., Infield, S. E., & Possolo, A. (1995). Cockpit data link technology and flight crew communication procedures. In R. S. Jensen (Ed.) *Proceedings of the 8th Symposium on Aviation Psychology*, (pp. 324-329). Ohio State University: Columbus, OH.

Lozito, S., McGann, A., & Corker, K. (1993). *Datalink ATC flight deck environment: Experiment in flight crew performance.* Paper presented at the 7th International Symposium of Aviation Psychology.

McCarley, J. S., Talleur, D., & Steelman-Allen, K. S. (2010). *Effects of data link display format and position on flight performance.* Univ. of Illinois Urbana-Champaign.

Morrow, D., Lee, A., & Rodvold, M. (1993). Analysis of problems in routine controller-pilot communication. *The International Journal of Aviation Psychology, 3*, 285-302.

Navarro, C. & Sikorski, S. (1999). Datalink communication flight deck operations: A synthesis of recent studies. *The International Journal of Aviation Psychology, 9*, 361-376.

Portugal. (8-12 March, 2010). *Use of AT and BY in CPDLC Messages.* Presented at the 35th Meeting of North Atlantic Air Traffic Management Group, WP/22, Paris.

Rehmann, A. J. & Mogford, R. H. (1996). *Airborne data link study report* (Report No. DOT/FAA/CT-95/62). Atlantic City, NJ: US Department of Transportation, Federal Aviation Administration Technical Center.

RTCA. Draft Safety and Performance Requirements (SPR). Available: http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/atc_comms_services/sc214/current_docs/.

Talotta, N. J., et al. (1990). *Operational evaluation of initial data link air traffic control services* (Report No. DOT/FAA/CT-90/1). Atlantic City, NJ: US Department of Transportation, Federal Aviation Administration Technical Center.

United Kingdom. (8-12 March, 2010). *Ambiguous CPDLC phraseology*. Presented at the 35th Meeting of North Atlantic Air Traffic Management Group, WP/18, Paris.

Wickens, C. D., Mavor, A. S., Parasuraman, R., & McGee, J. P. (1998). *The future of air traffic control: Human operators and automation*. Washington, D. C.: National Academy.

Wickens, C. D., Goh, J., Helleberg, J., Horrey, W. J., & Talleur, D. A. (2003). Attentional models of multi-task pilot performance using advanced display technology. *Human Factors, 45*, 360-380.

Waller, M. C. (1992). *Flight deck benefits of integrated data link communication* (NASA Tech. Paper 3219). Hampton, VA: National Aeronautics and Space Administration, Langley Research Center.

Waller, M. C., & Lohr, G. W. (1989) *A piloted simulation study of data link ATC message exchange* (NASA Tech. Paper 2859). Hampton, VA: National Aeronautics and Space Administration, Langley Research Center.

Appendices

Appendix A

Appendix A contains the four surveys administered to each participant.

- Pre-experiment survey
- Text+speech post-scenario survey
- Text-only post-scenario survey
- Post-experiment survey

1. Pre-Experiment Survey

SSVDD_Pre-Experiment Survey-Revised

1. Introduction

The purpose of this survey is to identify participants for a study on the use of computer-generated speech and a text display for ATC communications on the flight deck. Your name and responses will not be shared with anyone but the research team.

The study itself will provide you with the opportunity to fly the Cessna 172 Flight Training Device and will take no more than 4 hours. You will be compensated for your time.

You will need your pilot log book to complete this survey. It should take no more than 5 minutes.

If you meet the criteria, someone will contact you. You will be asked for a current email/phone number at the end of the survey.

For questions, contact Dr. Jason Kring at jason.kring@erau.edu.

Thank you very much.

Page 1

SSVDD_Pre-Experiment Survey-Revised

2. Demographic Information

1. Age

2. Current year in school:

- Freshman
- Sophomore
- Junior
- Senior
- Graduate student

Other (please specify)

*** 3. Gender**

- Male
- Female

*** 4. Do you possess a Commercial Certificate for Airplane Single Engine Land?**

- Yes
- No

*** 5. What is your total flight time?**
(Note, flight time does NOT include simulator time)

*** 6. What is your total loggable simulator time?**

*** 7. How much time do you have in the Cessna 172 Flight Training Device?**

*** 8. Do you meet the currency criteria of six instrument approaches in the last six months?**

- Yes
- No

SSVDD_Pre-Experiment Survey-Revised

*** 9. Have you flown any instrument approaches in the last 30 days?**

- ○ Yes
- ○ No

*** 10. How many months have passed since your last flight review?**

____

Note, if you are selected to participate in this study, you will need to bring your log book with you on your assigned day so that we can verify your currency.

*** 11. Did you learn to speak English before or after age five?**
(Note, this question is for information only and will not determine your eligibility for the study)

- ○ Before age five
- ○ After age five

*** 12. Confirm that you have 20/20 vision or better by selecting one of the following. Note that if you hold a 1st or 2nd Class Medical Certificate you have at least 20/20 vision.**

- ○ 20/20 or better uncorrected
- ○ 20/20 or better corrected with procedure (e.g., Lasik)
- ○ 20/20 or better corrected with glasses
- ○ 20/20 or better with contact lenses

*** 13. Which of the following best describes your handedness?**

- ○ Left-handed
- ○ Right-handed
- ○ Ambidextrous left-hand dominant
- ○ Ambidextrous right-hand dominant
- ○ Ambidextrous no dominance

Page 3

SSVDD_Pre-Experiment Survey-Revised

3. Availability

Please indicate ALL of the times below you would be available to participate in the study.

*** 1. Please check ALL times you would be available to participate in this study.**

	0700-1100	0800-1200	0900-1300	1000-1400	1100-1500	1200-1600	1300-1700	1400-1800	1500-1900	1600-2000	1700-2100	1800-2200	1900-2300	2000-2400
Monday	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Tuesday	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Wednesday	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Thursday	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Friday	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

SSVDD_Pre-Experiment Survey-Revised

4. Contact Information

If you meet the criteria for this study, one of the researchers will contact you. Please provide us with the following contact information.

1. Name

2. Email address

3. Phone number

4. What is the best time to reach you?

Thank you for your time today. If you meet the criteria for this study, one of the researchers will contact you shortly.

SSVDD_Post TEXT + SPEECH Scenario-Revised

1. Participant Number

* 1. Participant Number

Page 1

SSVDD_Post TEXT + SPEECH Scenario-Revised

2. ATC Communications Workload

In this part of the survey, you will assess your communications workload (separate for Tower Control and Departure Control) for the flight you just completed.

For each statement, please indicate the degree to which you agree or disagree using the scale below.

*** 1. The following statements relate to your ATC communications workload.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A. Communicating (receiving and replying to instructions) with TOWER CONTROL was easy.	○	○	○	○	○
B. Communicating (receiving and replying to instructions) with DEPARTURE CONTROL was easy.	○	○	○	○	○

If you disagree with any of the statements above, please note your suggestions.

SSVDD_Post TEXT + SPEECH Scenario-Revised

3. Scan Pattern

In this part of the survey, we ask about your scan pattern during the flight you just completed. That is, what percent of your time you spent looking out the window, what percent of your time you spent look at the flight instruments, and what percent of your time you spent looking at the touch screen. Note, your responses need to add up to 100%.

*** 1. While controlled by DEPARTURE, what percent of time did you look at the touch screen?**

*** 2. While controlled by DEPARTURE, what percent of time did you look at the flight instruments?**

*** 3. While controlled by DEPARTURE, what percent of time did you look out the window?**

*** 4. While controlled by DEPARTURE, what percent of the time did you look at "OTHER" (that is NOT at the touch screen, NOT at the flight instruments, or NOT out the window)?**

5. If you did look at "OTHER", please indicate what it was.

SSVDD_Post TEXT + SPEECH Scenario-Revised

4. Usability of computer-generated speech

In this part of the survey, we seek your opinion about the computer-generated speech you heard during the flight you just completed.

For each statement, please indicate the degree to which you agree or disagree using the scale below.

*** 1. The following statements relate to the computer-generated speech heard during the flight you just completed.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A. The loudness of the computer-generated speech is sufficient.	○	○	○	○	○
B. It is easy for me to understand the computer-generated speech.	○	○	○	○	○
C. It is easy for me to determine whether the computer generated speech is male or female.	○	○	○	○	○
D. The speaking rate of the computer-generated speech is appropriate.	○	○	○	○	○
E. I can easily tell the difference between the computer-generated speech and a human voice.	○	○	○	○	○

If you disagree with any of the statements above, please note your suggestions.

SSVDD_Post TEXT + SPEECH Scenario-Revised

5. Usability of the Touch-Screen Display

In this part of the survey, we seek your opinion about the touch-screen display you used during the flight you just completed. Please refer to the touch-screen display example provided by the experimenter.

For each statement, please indicate the degree to which you agree or disagree using the scale below.

*** 1. The following statements relate to the SIZE of parts of the touch screen.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A. The response buttons are the right size.	○	○	○	○	○
B. The size of the text on the response buttons supports easy reading.	○	○	○	○	○
C. The size of the text in the Log box supports easy reading.	○	○	○	○	○
D. The size of the text in the ATC box supports easy reading.	○	○	○	○	○
E. The size of the text in the Pilot Response box supports easy reading.	○	○	○	○	○

If you disagree with any of the statements above, please note your suggestions

*** 2. The following statement relates to the RESPONSIVENESS of the touch screen.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A. The sensitivity of the response buttons is effective.	○	○	○	○	○

If you disagree with the statement above, please note your suggestions

SSVDD_Post TEXT + SPEECH Scenario-Revised

*** 3. The following statements relate to the LAYOUT of the touch screen.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A. I like that the ATC box is at the top of the touch screen.	○	○	○	○	○
B. I like that the response buttons are at the bottom of the touch screen.	○	○	○	○	○
C. I like that the Pilot Response box is above the response buttons.	○	○	○	○	○
D. I like the location of the Send button.	○	○	○	○	○
E. I like that the Log box is between the ATC and Pilot Response boxes.	○	○	○	○	○

If you disagree with any of the statements above, please note your suggestions.

SSVDD_Post TEXT + SPEECH Scenario-Revised

*** 4. The following statements relate to the COLORS of the touch screen.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A. I find the color of the WILCO/ROGER/AFFIRMATIVE response buttons effective.	○	○	○	○	○
B. I find the color of the UNABLE/STANDBY/NEGATIVE response buttons effective.	○	○	○	○	○
C. I find the color of the Send button effective.	○	○	○	○	○
D. I find the background color of the ATC box supports easy reading.	○	○	○	○	○
E. I find the background color of the Log box supports easy reading.	○	○	○	○	○
F. I find the background color of the Pilot Response box supports easy reading.	○	○	○	○	○

If you disagree with any of the statements above, please note your suggestions.

SSVDD_Post TEXT + SPEECH Scenario-Revised

6. Using the system

In this part of the survey, we seek your opinion about how easy it was to use the entire system (that is, the touch screen with text display and computer-generated speech).

For each statement, please indicate the degree to which you agree or disagree using the scale below.

*** 1. The following statements relate to how easy it was to use the entire system (that is, the touch screen with text display and computer-generated speech).**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A. I imagine that most people would learn to use this system quickly.	○	○	○	○	○
B. I found the system awkward to use.	○	○	○	○	○
C. I felt confident using the system.	○	○	○	○	○
D. I needed to learn a lot of things before I could get going with this system.	○	○	○	○	○

If you disagree with any of the statements above, please note your suggestions.

*** 2. During the flight, did you use the Log window of the touch-screen display?**

○ Yes

○ No

3. If you answered "Yes" to the previous question, briefly describe how you used the log window during the flight.

SSVDD_Post TEXT + SPEECH Scenario-Revised

7. Thank you!

Thank you for completing this survey. Please tell the experimenter you are finished.

SSVDD_Post TEXT Only-Revised

1. Participant Number

* 1. Participant Number

Page 1

SSVDD_Post TEXT Only-Revised

2. ATC Communications Workload

In this part of the survey, you will assess your communications workload (separate for Tower Control and Departure Control) for the flight you just completed.

For each statement, please indicate the degree to which you agree or disagree using the scale below.

*** 1. The following statements relate to your ATC communications workload.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A. Communicating (receiving and replying to instructions) with TOWER CONTROL was easy.	○	○	○	○	○
B. Communicating (receiving and replying to instructions) with DEPARTURE CONTROL was easy.	○	○	○	○	○

If you disagree with any of the statements above, please note your suggestions.

SSVDD_Post TEXT Only-Revised

3. Scan Pattern

In this part of the survey, we ask about your scan pattern during the flight you just completed. That is, what percent of your time you spent looking out the window, what percent of your time you spent look at the flight instruments, and what percent of your time you spent looking at the touch screen. Note, your responses need to add up to 100%.

*** 1. While controlled by DEPARTURE, what percent of time did you look at the touch screen?**

*** 2. While controlled by DEPARTURE, what percent of time did you look at the flight instruments?**

*** 3. While controlled by DEPARTURE, what percent of time did you look out the window?**

*** 4. While controlled by DEPARTURE, what percent of the time did you look at "OTHER" (that is NOT at the touch screen, NOT at the flight instruments, or NOT out the window)?**

5. If you did look at "OTHER", please indicate what it was.

SSVDD_Post TEXT Only-Revised

4. Usability of the Touch-Screen Display

In this part of the survey, we seek your opinion about the touch-screen display you used during the flight you just completed. Please refer to the touch-screen display example provided by the experimenter.

For each statement, please indicate the degree to which you agree or disagree using the scale below.

* 1. The following statements relate to the SIZE of parts of the touch screen.

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A. The response buttons are the right size.	○	○	○	○	○
B. The size of the text on the response buttons supports easy reading.	○	○	○	○	○
C. The size of the text in the Log box supports easy reading.	○	○	○	○	○
D. The size of the text in the ATC box supports easy reading.	○	○	○	○	○
E. The size of the text in the Pilot Response box supports easy reading.	○	○	○	○	○

If you disagree with any of the statements above, please note your suggestions

* 2. The following statement relates to the RESPONSIVENESS of the touch screen.

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A. The sensitivity of the response buttons is effective.	○	○	○	○	○

If you disagree with the statement above, please note your suggestions

*** 3. The following statements relate to the LAYOUT of the touch screen.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A. I like that the ATC box is at the top of the touch screen.	◌	◌	◌	◌	◌
B. I like that the response buttons are at the bottom of the touch screen.	◌	◌	◌	◌	◌
C. I like that the Pilot Response box is above the response buttons.	◌	◌	◌	◌	◌
D. I like the location of the Send button.	◌	◌	◌	◌	◌
E. I like that the Log box is between the ATC and Pilot Response boxes.	◌	◌	◌	◌	◌

If you disagree with any of the statements above, please note your suggestions.

SSVDD_Post TEXT Only-Revised

*** 4. The following statements relate to the COLORS of the touch screen.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A. I find the color of the WILCO/ROGER/AFFIRMATIVE response buttons effective.	○	○	○	○	○
B. I find the color of the UNABLE/STANDBY/NEGATIVE response buttons effective.	○	○	○	○	○
C. I find the color of the Send button effective.	○	○	○	○	○
D. I find the background color of the ATC box supports easy reading.	○	○	○	○	○
E. I find the background color of the Log box supports easy reading.	○	○	○	○	○
F. I find the background color of the Pilot Response box supports easy reading.	○	○	○	○	○

If you disagree with any of the statements above, please note your suggestions.

SSVDD_Post TEXT Only-Revised

5. Using the system

In this part of the survey, we seek your opinion about how easy it was to use the entire system (that is, the touch screen with text display).

For each statement, please indicate the degree to which you agree or disagree using the scale below.

*** 1. The following statements relate to how easy it was to use the entire system (that is, the touch screen with text display).**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A. I imagine that most people would learn to use this system quickly.	○	○	○	○	○
B. I found the system awkward to use.	○	○	○	○	○
C. I felt confident using the system.	○	○	○	○	○
D. I needed to learn a lot of things before I could get going with this system.	○	○	○	○	○

If you disagree with any of the statements above, please note your suggestions.

*** 2. During the flight, did you use the Log window of the touch-screen display?**

○ Yes

○ No

3. If you answered "Yes" to the above question, briefly describe how you used the log window during the flight.

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SSVDD_Post TEXT Only-Revised

6. Thank you!

Thank you for completing this survey. Please tell the experimenter you are finished.

SSVDD_Post Experiment Survey-Revised

1. Participant Number

* 1. Participant Number

SSVDD_Post Experiment Survey-Revised

2. System Usability Scale

In this short final survey, we seek your opinion about the two ATC communication systems you used while flying: the text display system only or the text display with computer-generated speech system.

Please indicate the degree to which you agree or disagree with each statement.

*** 1. The text display is helpful.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
-	○	○	○	○	○

Additional Comments

*** 2. The computer-generated speech in addition to the text display is helpful.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
-	○	○	○	○	○

Additional Comments

*** 3. The computer-generated speech in addition to the text display is distracting.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
-	○	○	○	○	○

Additional Comments

*** 4. I prefer the text display only, without the computer-generated speech.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
-	○	○	○	○	○

Additional Comments

Page 2

SSVDD_Post Experiment Survey-Revised

*** 5. I would prefer the computer-generated speech only, without the text display.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
-	○	○	○	○	○

Additional Comments

*** 6. Compared to a live controller, I prefer to communicate with ATC using the text display AND the computer-generated speech.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
-	○	○	○	○	○

Additional Comments

*** 7. Compared to a live controller, I prefer to communicate with ATC using ONLY the text display WITHOUT the computer-generated speech.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
-	○	○	○	○	○

Additional Comments

*** 8. I prefer to communicate with ATC using the text display and the computer-generated speech, rather than the text display alone.**

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
-	○	○	○	○	○

Additional Comments

Page 3

SSVDD_Post Experiment Survey-Revised

3. Thank you!

Thank you for your time today. Please let the experimenter know you are finished.

Appendix B

Appendix B contains the:

- Consent form
- Withdrawal form
- Participant payment form

1. Participant Consent Form

Aeronautical Science Department
Human Factors & Systems Department
Embry-Riddle Aeronautical University
Daytona Beach, FL

Experiment Summary

The purpose of this study is to explore the feasibility of supplementing air traffic control data communications with computer-generated speech in single pilot operations. In this study, you will interact with a touch-screen display coupled with computer generated speech while flying a scenario in a computer-based flight simulation.

Although we do not anticipate any negative reactions to this experiment, a small number of individuals have experienced symptoms of "simulator sickness" when interacting with computer-based simulations.

For this study, you will be assigned a number so that your responses and actions remain anonymous and your name will not be associated or published with your data. Also know that we are not judging or evaluating your performance as a pilot. We are evaluating new systems and you are our test pilot.

Thank you for your participation. If you have any questions, please contact Jason Kring at jason.kring@erau.edu.

Statement of Consent

I acknowledge that my participation in this experiment is entirely voluntary and that I am free to withdraw at any time. I have been informed as to the general scientific purpose of the study. I understand that I will be video, audio, and flight recorded for data collection and analysis purposes.

Participant's name (please print):____

Signature of Participant:__________________________ Date:________________

Experimenter:_______________________________ Date:________________

2. **Participant Withdrawal Form**

Aeronautical Science Department
Human Factors & Systems Department
Embry-Riddle Aeronautical University
Daytona Beach, FL

Statement of Withdrawal

I acknowledge that my withdrawal in this experiment is entirely voluntary and that I am choosing to do so. I understand that any data collected for the experiment will be deleted and in no way will I be associated with this experiment.

Participant's name (please print):____

Signature of Participant:______________________________ Date:____________________

Experimenter:_____________________________________ Date:____________________

3. **Participant Payment Form**

COMPLETE TO RECEIVE PAYMENT

Have you been working on campus since January 2011 and receive a pay check from Student Employment?

Circle: YES NO

(Please print legibly)

Student Name_____________________________________

Student ID#_____________________________

Student Local Mailing Address:

Street:____

City/State/Zip____

Date:____________________

OK to Process for Payment:______________________________

Note: If you are currently working for Student Employment, $50 will be added to your next pay check. If you are not working for Student Employment, you will receive a $50 check in the mail.

Appendix C

Appendix C contains all material given to participants prior to flying the practice and experimental scenarios. This includes the pilot briefing brochure and necessary approach plates (i.e., for an ILS approach on runway 7L, and VOR runway 23).

PILOT BRIEFING

Thank you for volunteering to be a test pilot for this FAA research project! The research focuses on the usefulness of datalink and computer generated speech on the flight deck. We are using a Frasca Level 6 C-172 flight simulator which you have logged time in for your ERAU training. Please fly your best but know we are *NOT* grading *YOU* – rather we are primarily collecting data from the simulator and the touch screen tablet for further analysis. The data will go directly to the researchers and your name will be removed. The data will be used to make future improvements.

We hope that it will be fun for you. You are trained to perform all the flight maneuvers we will ask you to do such as holding, proceeding direct to a fix, or shooting a precision approach. The profiles take place in the Daytona Beach Airport traffic area. There are no malfunctions, abnormal procedures, or emergencies planned. In addition, there are no NOTAMS that affect you. Use all your normal flight procedures and techniques.

After you have become familiar with the touch screen tablet via a non-flying tutorial we will have you fly a practice scenario. In the practice scenario you will experience both datalink alone and datalink plus a computer generated voice while flying a GPS approach to Runway 16. After a short break we will then have you fly two research scenarios one of which will be datalink alone and another will be datalink plus computer generated voice. Both research scenarios are similar with radar vectors to the ILS Runway 07L in IMC conditions. Each scenario starts with you on the runway ready for takeoff and ends upon landing. We will ask you to evaluate specific items from each scenario on a questionnaire. It is important you give us your honest answers.

We would like you to fly as precisely as possible. For example, you should do all you can to fly the assigned headings and altitudes. Use 100 knots at cruise, climb/descend at 500 feet per minute, and use normal bank angles. During approach, you should follow the glide slope and localizer as accurately as possible. Make all normal radio calls – you can expect standardized ATC replies. You will also hear "party" radio traffic like a normal DAB day including similar sounding call signs. There will be little or no experimenter interaction so that you can concentrate on flying. In short, role play your part as though you were in the actual aircraft. Remember that even if it doesn't go well despite your best effort, this is *NOT* for grading *YOU*, but to *TEACH US* something about *THE TECHNOLOGIES WE ARE USING IN THE RESEARCH*.

We know that you will be tempted to tell your colleagues about this experience. But to draw valid conclusions from this research, it is critical that all participants are fresh to the experiment without any expectations. Thus, we would really appreciate it if you could refrain from telling them what you did.

We hope you will enjoy the challenge! From the entire research team - thank you very much!

Local Area Flight Plan for *SKYHAWK 345 ECHO ROMEO*

This is a training flight remaining in the Daytona Beach Airport traffic area.

Weather and equipment are legal for takeoff and landing.

Airport, Aircraft, and Weather Information

Daytona Beach Airport, FL		
	Runway	**16 - 6,000 feet**
	Runway	**07L - 10,500 feet**
	Elevation	**34 feet MSL**
	Time of Day	**Day**
	Tower	**120.7**
	Departure	**125.35 (16) or 125.8 (07L)**
Airplane		
	Inoperative Systems	**None**
	Squawk	**As Assigned**
	Call Sign	**Skyhawk 345 ER**
	Fuel	**Fully Fueled**
	Wt & Balance	**Within Limits**
Weather		
	Ceiling	**600 feet**
	Visibility	**1SM**
	Temperature	**15 ^{o}C**
	Wind	**Calm**
	Altimeter Setting	**30.00 or As Assigned**

Alternate	Ormond Beach

SE-3, 10 MAR 2011 to 07 APR 2011

ILS or LOC RWY 7L
DAYTONA BEACH INTL (DAB)

LOC I-DAB	APP CRS	Rwy Idg	9600
109.7	070°	TDZE	30
		Apt Elev	34

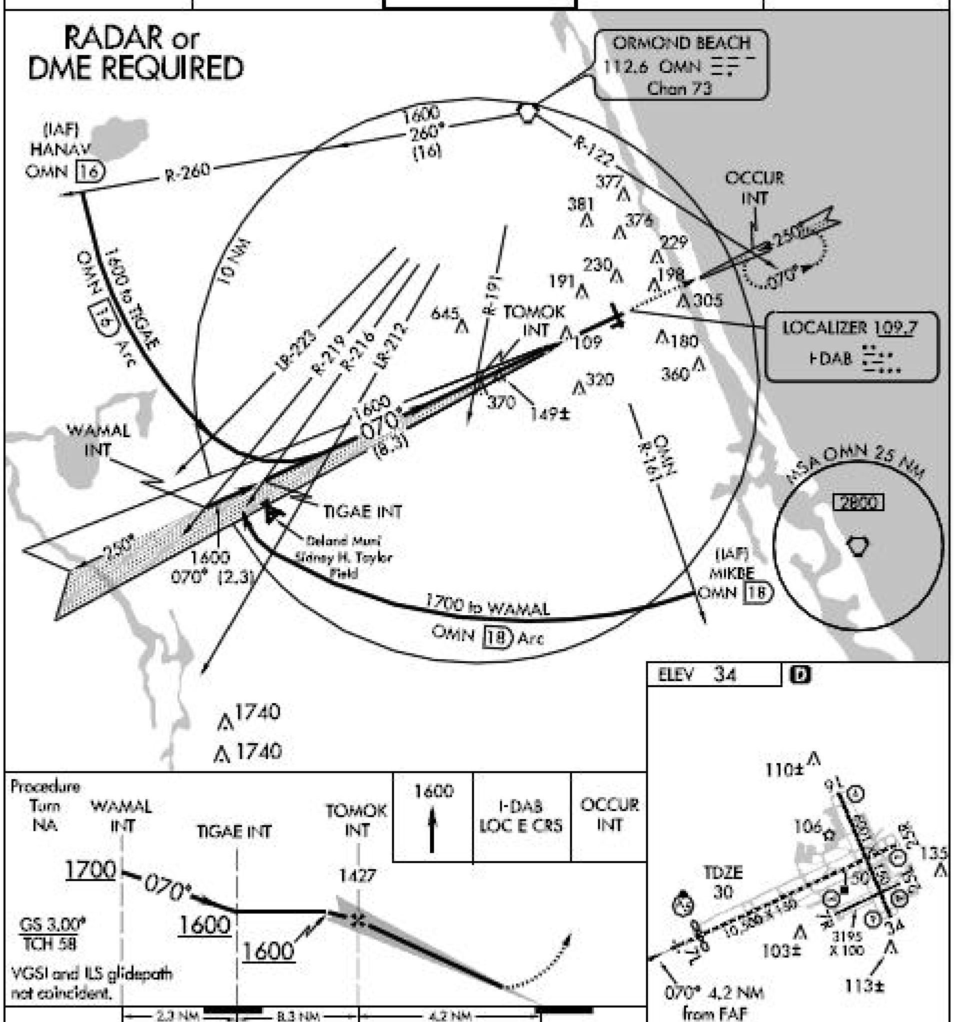
If local altimeter setting not received, use Ormond Beach altimeter setting and increase DA to 274 feet and all MDAs 20 feet. Inoperative table does not apply to S-ILS 7L. For inoperative MALSR increase S-LOC 7L Cats A, B, and C visibility to RVR 5000. Visibility reduction by helicopters NA.

ASR

MALSR

MISSED APPROACH: Climb to 1600 via I-DAB East course to OCCUR Int and hold.

ATIS	DAYTONA APP CON	DAYTONA TOWER	GND CON	CLNC DEL
120.05	125.72 379.95	120.7 257.8	121.9 348.6	119.3



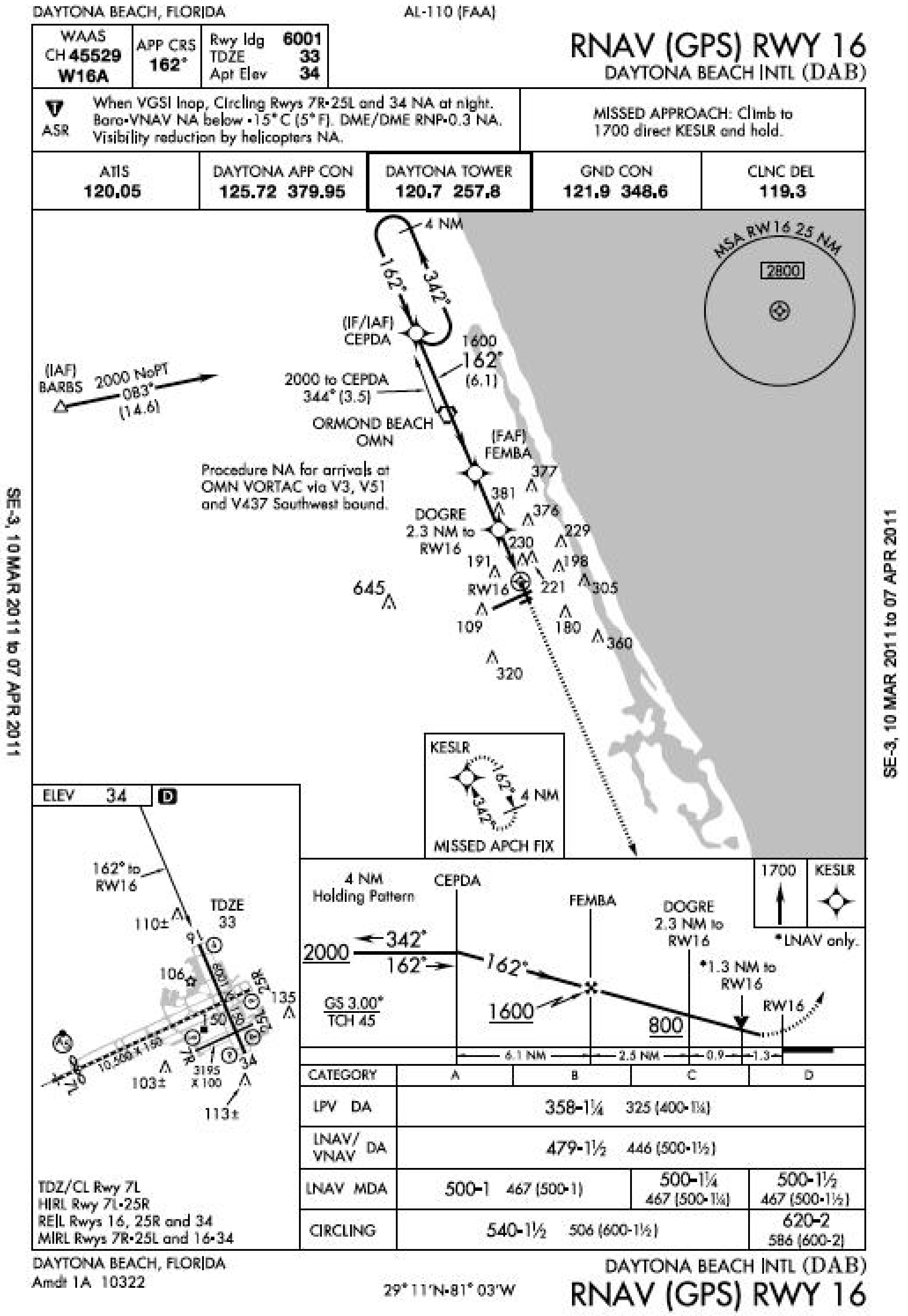
TDZ/CL Rwy 7L
HIRL Rwy 7L 25R
REIL Rwys 16, 25R and 34
MIRL Rwys 7R-25L and 16-34

CATEGORY	A	B	C	D
S-ILS 7L	230/40 200 (200-½)			
S-LOC 7L	400/40 370 (400-½)			
CIRCLING	540-1 506 (600-1)		540-1½ 506 (600-1½)	620-2 586 (600-2)

FAF to MAP 4.2 NM

Knots	60	90	120	150	180
Min:Sec	4:12	2:48	2:06	1:41	1:24

SE-3, 10 MAR 2011 to 07 APR 2011


DAYTONA BEACH, FLORIDA
AL-110 (FAA)
WAAS CH 45529 W16A
APP CRS 162°
Rwy Idg 6001
TDZE 33
Apt Elev 34
RNAV (GPS) RWY 16
DAYTONA BEACH INTL (DAB)
When VGSI Inop, Circling Rwys 7R-25L and 34 NA at night. Baro-VNAV NA below -15° C (5° F). DME/DME RNP-0.3 NA. Visibility reduction by helicopters NA.
ASR
MISSED APPROACH: Climb to 1700 direct KESLR and hold.
ATIS 120.05
DAYTONA APP CON 125.72 379.95
DAYTONA TOWER 120.7 257.8
GND CON 121.9 348.6
CLNC DEL 119.3
MSA RW16 25 NM
2800
4 NM
162°
342°
(IF/IAF) CEPDA
1600
162°
(6.1)
(IAF) BARBS
2000 NoPT
083°
(14.6)
2000 to CEPDA 344° (3.5)
ORMOND BEACH OMN
(FAF) FEMBA
Procedure NA for arrivals at OMN VORTAC via V3, V51 and V437 Southwest bound.
DOGRE 2.3 NM to RW16
RW16
KESLR
4 NM
MISSED APCH FIX
ELEV 34
162° to RW16
TDZE 33
TDZ/CL Rwy 7L
HIRL Rwy 7L-25R
REIL Rwys 16, 25R and 34
MIRL Rwys 7R-25L and 16-34
4 NM Holding Pattern
CEPDA
FEMBA
DOGRE 2.3 NM to RW16
1700
KESLR
*LNAV only.
2000
342°
162°
GS 3.00°
TCH 45
1600
800
*1.3 NM to RW16
RW16
6.1 NM
2.5 NM
0.9
1.3
CATEGORY A B C D
LPV DA 358-1¼ 325 (400-1¼)
LNAV/VNAV DA 479-1½ 446 (500-1½)
LNAV MDA 500-1 467 (500-1) 500-1¼ 467 (500-1¼) 500-1½ 467 (500-1½)
CIRCLING 540-1½ 506 (600-1½) 620-2 586 (600-2)
SE-3, 10 MAR 2011 to 07 APR 2011
DAYTONA BEACH, FLORIDA
Amdt 1A 10322
29° 11'N-81° 03'W
DAYTONA BEACH INTL (DAB)
RNAV (GPS) RWY 16

DELAND, FLORIDA AL-483 (FAA)

VORTAC OMN 112.6 Chan 73	APP CRS 212°	Rwy ldg 4301 TDZE 78 Apt Elev 80

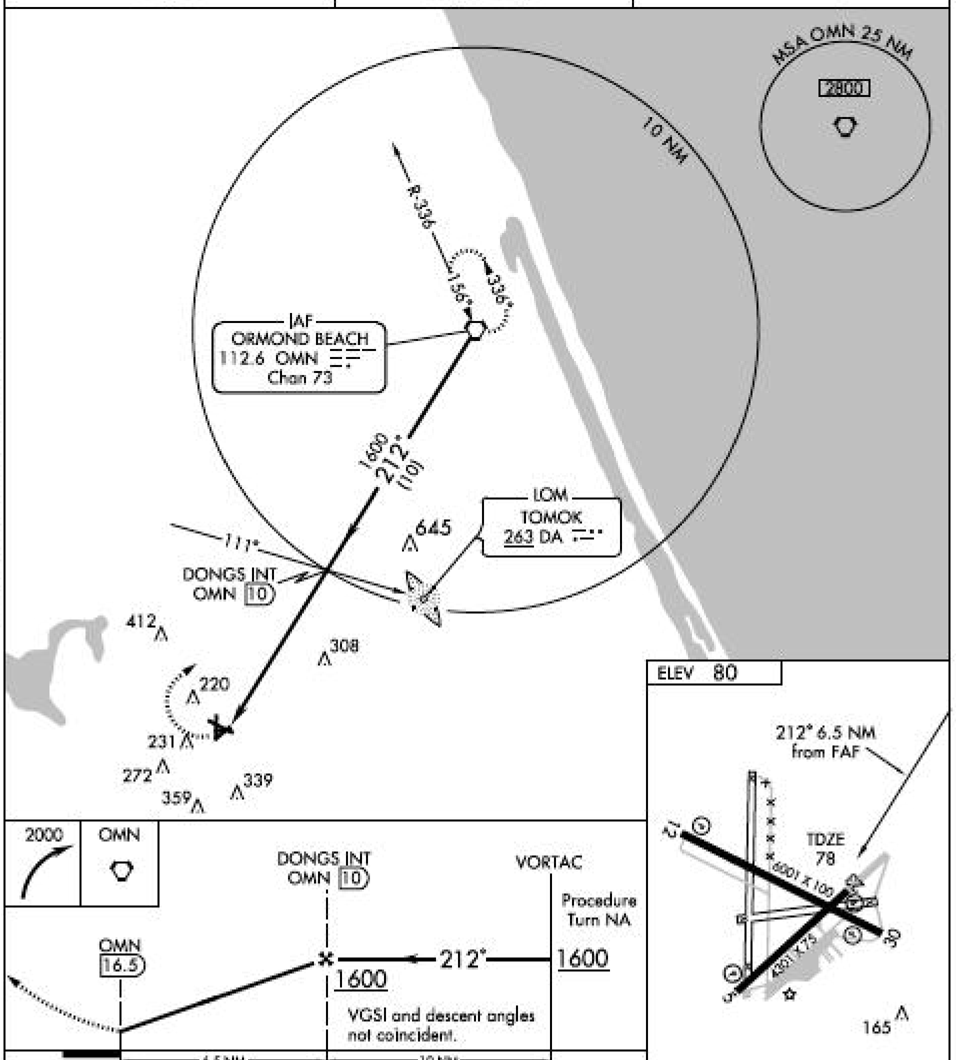
VOR RWY 23

DELAND MUNI-SIDNEY H. TAYLOR FIELD (DED)

DME or ADF REQUIRED.
NA ASR
If local altimeter setting not received, use Daytona Beach Intl altimeter setting and increase all MDAs 40 feet.

MISSED APPROACH: Climbing right turn to 2000 direct OMN VORTAC and hold.

AWOS-3	DAYTONA APP CON	UNICOM
119.575	125.35 322.3	123.075 (CTAF)



CATEGORY	A	B	C	D
S-23	580-1 502 (500-1)		580-1½ 502 (500-1½)	
CIRCLING	580-1 500 (500-1)		580-1½ 500 (500-1½)	640-2 560 (600-2)

REIL Rwys 12 and 30
MIRL Rwys 5-23 and 12-30

FAF to MAP 6.5 NM

Knots	60	90	120	150	180
Min:Sec	6:30	4:20	3:15	2:36	2:10

SE-3, 10 MAR 2011 to 07 APR 2011

SE-3, 10 MAR 2011 to 07 APR 2011

DELAND, FLORIDA
Amdt 3 10322

29° 04'N-81°17'W

DELAND MUNI-SIDNEY H. TAYLOR FIELD (DED)

VOR RWY 23

Appendix D

This Appendix contains the scripts used for the practice scenario and the four experimental scenarios, as well as the counterbalancing scheme. Note that the scripts include intended participant responses.

Practice scenario

- Practice Scenario RNAV 16

Experimental scenarios

- Data Comm 1: Text only with Voice Override Absent
- Data Comm 2: Text Only with Voice Override Present
- Data Comm 3: Text + Annunciation with Voice Override Absent
- Data Comm 4: Text + Annunciation with Voice Override Present

DATACOMM

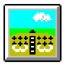
Practice Scenario with Text and Annunciation

Prior to initiating training in the FTD, the following scenario file must be opened so that the appropriate a/c pre-positions or “snap shots” will be loaded in the computer.

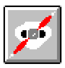
Lesson Objectives:

This module has been designed to provide a virtual practice scenario for DATACOMM. DATACOMM provides data link capability for en route pilot controller communications. The research will investigate data-link functionality in a single pilot environment. The purpose of this module is to create a simulated flight to allow participants the opportunity to become familiar with the DATACOMM display and synthetic speech. The primary task for this scenario is to depart KDAB Runway 16 and request radar vectors back to the RNAV Runway 16 approach into KDAB.

ISA Deviation: 0
Altimeter: 30.00
Verify Wind/Turb: Light 7 Variable
Meteorological Conditions: **IMC**



Edit Environment
Time Of Day: Day



Set Engine Temp: N/A

Runway-16
Call Sign- Skyhawk 345 Echo Romeo

SCRIPT

ATC	Participant	Other traffic	Comments
	345 Echo Romeo: Daytona Tower, Skyhawk 345 Echo Romeo, ready for takeoff Runway 16		
ATC-Tower: Skyhawk 345 Echo Romeo. Climb and Maintain 1,200. Maintain Runway Heading. Runway 16, Cleared for Takeoff.			
	345 Echo Romeo: Cleared for takeoff 16, Climb and maintain 1,200 maintain runway heading, Skyhawk 345 Echo Romeo		

ATC	Participant	Other traffic	Comments
ATC-Tower: Skyhawk 345 Echo Romeo, Turn Right Heading 250, Contact Departure Control on 125.35			
	345 Echo Romeo: Turn right heading 250, Contact Departure Control on 125.35, Skyhawk 345 Echo Romeo		
	345 Echo Romeo: Daytona Beach Departure, Skyhawk 345 Echo Romeo, request vectors for the GPS Runway 16		
ATC-Departure/Approach Control: Skyhawk 345 Echo Romeo, Roger, Radar Contact, Standby for CPDLC Uplink			
	345 Echo Romeo: Roger, standby for CPDLC uplink Skyhawk 345 Echo Romeo		
Uplink Message: CPDLC Now In Use, Acknowledge Now			
	Downlink Message: ROGER		
Uplink Message: Climb and Maintain 2,000			
	Downlink Message: WILCO		

ATC	Participant	Other traffic	Comments
ATC-Departure/Approach Control: Skyhawk 375 Echo Romeo Turn Right Heading 210			
		375 Echo Romeo: Turn Right Heading 210, Skyhawk 375 Echo Romeo	
Uplink Message: Turn Right Heading 340			
	Downlink Message: WILCO		
ATC-Departure/Approach Control: November 354 Echo Romeo Climb and Maintain 2,000			
		354 Echo Romeo: Climb and Maintain 2,000 November 354 Echo Romeo	
Uplink Message: Turn Left 10 Degrees to Heading 330			
	Downlink Message: WILCO		
Uplink Message: Maintain Current Heading, Expect Vectors for GPS Runway 16.			
	Downlink Message: WILCO		
ATC-Departure/Approach Control: Skyhawk 375 Echo Romeo, Climb and Maintain 2,500			

ATC	Participant	Other traffic	Comments
		375 Echo Romeo: Climb and Maintain 2,500, Skyhawk 375 Echo Romeo	
Uplink Message: Climb and Maintain 2500			
	Downlink Message: WILCO		
ATC-Departure/Approach Control: November 476 Delta Bravo, Descend and Maintain 3,000			
		476 Delta Bravo: Descend and Maintain 3,000, November 476 Delta Bravo	
Uplink Message: Turn Right 10 Degrees to 340			
	Downlink Message: WILCO		
ATC-Departure/Approach Control: Skyhawk 375 Echo Romeo, Proceed Direct Barbs			
		375 Echo Romeo: Proceed Direct Barbs, Skyhawk 375 Echo Romeo	
ATC-Departure/Approach Control: November 476 Delta Bravo, Radar Contact, Turn Right Heading 340			

ATC	Participant	Other traffic	Comments
		476 Delta Bravo: Daytona Departure, November 476 Delta Bravo, Requesting Radar Vectors for the GPS Approach Runway 16	
		476 Delta Bravo: Turn Right Heading 340, November 476 Delta Bravo	
Uplink Message: Descend and Maintain 2000			
	Downlink Message: WILCO		
ATC-Departure/Approach Control: November 354 Echo Romeo Proceed Direct Barbs			
		354 Echo Romeo: Proceed Direct Barbs, November 354 Echo Romeo	
ATC-Departure/Approach Control: Skyhawk 375 Echo Romeo, Cleared for the GPS Approach Runway 16			
		375 Echo Romeo: Cleared for the GPS Approach Runway 16, Skyhawk 375 Echo Romeo	
Uplink Message: Turn Right Heading 070			
	Downlink Message: WILCO		

ATC	Participant	Other traffic	Comments
Uplink Message: Descend To 1,600			
	Downlink Message: WILCO		
Uplink Message: Turn Right Heading 130, Maintain 1,600 Until Established, Cleared For The GPS Approach Runway 16			
	Downlink Message: WILCO		
Uplink Message: Contact Tower Voice Now On 120.7			
	Downlink Message: WILCO		
	345 Echo Romeo: Daytona Beach Tower, Skyhawk 345 Echo Romeo is XXX Nautical Miles from the airport		
ATC-Tower: Skyhawk 345 Echo Romeo, Roger, Continue, Altimeter is 29.98, Report FEMBA Inbound			
	345 Echo Romeo: 29.98, Report FEMBA Skyhawk 345 Echo Romeo		
	345 Echo Romeo: Daytona Tower, Skyhawk 345 Echo Romeo is FEMBA inbound		
ATC-Tower: Skyhawk 345 Echo Romeo, Runway 16, Cleared to Land			

ATC	Participant	Other traffic	Comments
	345 Echo Romeo: Cleared to land 16, Skyhawk 345 Echo Romeo		
	-END-		

DATACOMM 1

Text Only, Voice Override Absent

Prior to initiating training in the FTD, the following scenario file must be opened so that the appropriate a/c pre-positions or "snap shots" will be loaded in the computer.

Lesson Objectives:

This module has been designed to provide a virtual scenario for DATACOMM. DATACOMM provides data link capability for en route pilot controller communications. The research will investigate data-link functionality in a single pilot environment. The purpose of this module is to create a simulated flight with a moderate to heavy work load that will allow researchers to investigate data-link technologies for NextGen applications. The primary task for this scenario is to depart KDAB and request radar vectors to precision final back to KDAB. The scenario contains **"**Text Only with Voice Override Absent."

ISA Deviation: 0
Altimeter: 30.00
Verify Wind/Turb: Light 7 Variable
Meteorological Conditions: **IMC**

Edit Environment
Time Of Day: Day

Set Engine Temp: N/A

Runway-7Left
Call Sign- Skyhawk 345 Echo Romeo

SCRIPT

ATC	Participant	Other traffic	Observations
	345 Echo Romeo: Daytona Tower, Skyhawk 345 Echo Romeo, ready for takeoff runway 7 left		
ATC-Tower: Skyhawk 345 Echo Romeo. Climb and Maintain 1,200. Maintain runway heading. Runway 7 left, cleared for takeoff.			
	345 Echo Romeo: Cleared for takeoff 7 left, Climb and maintain 1,200 maintain runway heading, Skyhawk 345 Echo Romeo		

ATC	Participant	Other traffic	Observations
		9963 Echo Romeo: Daytona Tower, Skyhawk 9963 Echo Romeo is turning base to final runway 7 Left	
ATC-Tower: Skyhawk 9963 Echo Romeo, Daytona tower, runway 7 Left, cleared to land			
		9963 Echo Romeo: Cleared to land runway 7 Left, Skyhawk 9963 Echo Romeo	
		421 Delta Bravo: Daytona tower, Skyhawk 421 Delta Bravo is midfield downwind 7 Left	
ATC-Tower: Skyhawk 421 Delta Bravo, Daytona Tower, cleared for the option runway 7 Left			
		421 Delta Bravo: Daytona Tower, Skyhawk 421 Delta Bravo will be a full stop	
ATC-Tower: Skyhawk 421 Delta bravo, number 2 following traffic short final runway 7L cleared to land			
		421 Delta Bravo: Cleared to land number 2 following traffic short final runway 7 Left, Skyhawk 421 Delta Bravo	

ATC	Participant	Other traffic	Observations
ATC-Tower: Skyhawk 345 Echo Romeo, contact Departure Control on 125.8			
	345 Echo Romeo: Contact Departure Control on 125.8, Skyhawk 345 Echo Romeo		
	345 Echo Romeo: Daytona Beach Departure, Skyhawk 345 Echo Romeo, request vector for the ILS runway 7 Left		
ATC-Departure Control: Skyhawk 345 Echo Romeo, roger, radar contact, standby for CPDLC uplink			
	345 Echo Romeo: Roger, standby for CPDLC uplink Skyhawk 345 Echo Romeo		
Uplink Message: CPDLC Now In Use, Acknowledge Now			
	Downlink Message: ROGER		
Uplink Message: Climb and Maintain 2,000			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn Left Heading 340			

ATC	Participant	Other traffic	Observations
		354 Echo Romeo: Turn Left Heading 340, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo turn left heading 250			
		345 Delta Bravo: Turn Left heading 250 November 345 Delta Bravo	
Uplink Message: Turn Left Heading 310			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Proceed Direct Ormond Beach VOR due to traffic			
		354 Echo Romeo: Proceed Direct Ormond VOR, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Proceed Direct Dongs			
		345 Delta Bravo: Proceed Direct Dongs, November 345 Delta Bravo	
Uplink Message: Proceed Direct Ormond Beach VOR Due To Traffic			
	Downlink Message: WILCO		

ATC	Participant	Other traffic	Observations
ATC-Departure Control: Skyhawk 354 Echo Romeo Hold East Of The Ormond VOR On The 090 Radial, Maintain 2,000, Expect Further Clearance in 5 Minutes			
		354 Echo Romeo: Hold East Of The Ormond VOR On The 090 Radial, Maintain 2,000, Expect Further Clearance in 5 Minutes, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Descend and Maintain 1,600			
		345 Delta Bravo: Descend and Maintain 1,600, November 345 Delta Bravo	
Uplink Message: Hold East Of The Ormond VOR On The 090 Radial, Maintain 2,000, EFC In 10 Minutes			
	Downlink Message: WILCO		
Uplink Message: At Ormond VOR Climb To 3,000			
Conditional Clearance			
	Downlink Message: WILCO		

ATC	Participant	Other traffic	Observations
ATC-Departure Control: November 345 Delta Bravo Turn Left Heading 160			
		345 Delta Bravo: Turn Left Heading 160, November 345 Delta Bravo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Depart the Hold at Ormond, Fly Heading 210			
		354 Echo Romeo: Depart the Hold at Ormond, Fly Heading 210, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Turn left Heading 130			
		345 Delta Bravo: Turn left Heading 130 November 345 Delta Bravo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Proceed Direct Dongs			
		354 Echo Romeo: Proceed Direct Dongs Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, You are cleared for the ILS Runway 07L.			

ATC	Participant	Other traffic	Observations
		345 Delta Bravo: Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, Cleared for the ILS Runway 07L, November 345 Delta Bravo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Descend and Maintain 1,600			
		354 Echo Romeo: Descend and Maintain 1,600 Skyhawk 354 Echo Romeo	
Uplink Message: Depart hold at OMN Proceed Direct Dongs Expect Radar Vectors for the ILS 7 L			
	Downlink Message: WILCO		
ATC-Departure Control: November 345 Delta Bravo Report TOMOK Inbound			
		345 Delta Bravo: Report TOMOK Inbound November 345 Delta Bravo	
Uplink Message: Descend And Maintain 2,000			
	Downlink Message: WILCO		
Uplink Message: Descend To 1,600			
	Downlink Message: WILCO		

ATC	Participant	Other traffic	Observations
ATC-Departure Control: Delta 781 Radar Contact Climb and Maintain 2,000			
		Delta 781: Radar contact, Climb and Maintain 2,000 Delta 781	
ATC-Departure Control: November 345 Delta Bravo Contact Tower now on 120.7			
		345 Delta Bravo: Contact Tower 120.7 November 345 Delta Bravo	
ATC-Departure Control: Delta 781 turn left heading 340			
		Delta 781: Turn left heading 340, Delta 781	
Uplink Message: At DONGS, Expect Radar Vectors I L S 7 Left			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn Left Heading 160			
		354 Echo Romeo: Turn Left Heading 160 Skyhawk 354 Echo Romeo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn Left Heading 130			

ATC	Participant	Other traffic	Observations
		354 Echo Romeo: Turn Left Heading 130 Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 737 Echo Romeo Radar Contact, Climb and Maintain 2,000			
		737 Echo Romeo: Radar Contact, Climb and Maintain 2,000, November 737 Echo Romeo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, You are cleared for the ILS Runway 7L.			
		354 Echo Romeo: Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, Cleared for the ILS Runway 7L, Skyhawk 354 Echo Romeo	
ATC-Departure Control: Delta 781 Contact Jacksonville Center on 126.7			
		Delta 781: Contact Jacksonville Center on 126.7, Delta 781	
ATC-Departure Control: November 345 Delta Bravo Radar Contact Climb and Maintain 2,000			

ATC	Participant	Other traffic	Observations
		345 Delta Bravo: Climb and Maintain 2,000 November 345 Delta Bravo	
ATC-Departure Control: November 345 Delta Bravo Turn Right Heading 160			
		345 Delta Bravo: Turn Right Heading 160 November 345 Delta Bravo	
ATC-Departure Control: November 345 Delta Bravo Turn Right Heading 250			
		345 Delta Bravo: Turn Right Heading 250 November 345 Delta Bravo	
ATC-Departure Control: November 345 Delta Bravo Climb and Maintain 3,000			
		345 Delta Bravo: Climb and Maintain 3,000 November 345 Delta Bravo	
Uplink Message: Turn Left Heading 160			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Contact Tower now on 120.7			
		354 Echo Romeo: Contact Tower on 120.7 Skyhawk 354 Echo Romeo	

ATC	Participant	Other traffic	Observations
ATC-Departure Control: November 737 Echo Romeo Turn Left Heading 340			
		737 Echo Romeo: Turn Left Heading 340 November 737 Echo Romeo	
Uplink Message: Turn Left Heading 100			
	Downlink Message: WILCO		
ATC-Departure Control: November 737 Echo Romeo Climb and Maintain 3,000			
		737 Echo Romeo: Climb and Maintain 3,000, November 737 Echo Romeo	
Uplink Message: Maintain Heading 100, Maintain 1,600 Until Established On The Localizer, Cleared For The ILS Runway 7 Left			
	Downlink Message: WILCO		
ATC-Departure Control: November 737 Echo Romeo Turn Left Heading 250			
		737 Echo Romeo: Turn Left Heading 250 November 737 Echo Romeo	
Uplink Message: Contact Tower Voice Now On 120.7			

ATC	Participant	Other traffic	Observations
	Downlink Message: WILCO		
	345 Echo Romeo: Daytona Beach Tower, Skyhawk 345 Echo Romeo is XXX Nautical Miles from TOMOK		
ATC-Tower: Skyhawk 345 Echo Romeo, Roger, report TOMOK inbound, altimeter is 29.98			
	345 Echo Romeo: Report TOMOK inbound, Skyhawk 345 Echo Romeo		
ATC-Tower: Skyhawk 416 Echo Romeo maintain runway heading, runway 7 Left, cleared for takeoff			
		416 Echo Romeo: Maintain runway heading, Cleared for takeoff runway 7 left, Skyhawk 416 Echo Romeo	
	345 Echo Romeo: Daytona Tower, Skyhawk 345 Echo Romeo is TOMOK inbound		
ATC-Tower: Skyhawk 345 Echo Romeo, runway 7 left, cleared to land			
	345 Echo Romeo: Cleared to land 7 Left, Skyhawk 345 Echo Romeo		

ATC	Participant	Other traffic	Observations
ATC-Tower: Skyhawk 427 Whiskey Tango, hold short runway 7 Left, landing traffic			
		427 Whiskey Tango: Hold short runway 7 Left for traffic, Skyhawk 427 Whiskey Tango	
		9963 Echo Romeo: Daytona Tower, Skyhawk 9963 Echo Romeo is turning base to final runway 7 Left	
ATC-Tower: Skyhawk 9963 Echo Romeo, Daytona tower runway 7 Left, cleared to land			
		9963 Echo Romeo: Cleared to land runway 7 Left, Skyhawk 9963 Echo Romeo	
ATC-Tower: Skyhawk 357 Echo Romeo, number 2 following traffic short final, runway 7 L, cleared to land			
		357 Echo Romeo: Number 2 cleared to land following traffic short final, Skyhawk 357 Echo Romeo	
	-END-		

DATACOMM 2

Text Only, Voice Override Present

Prior to initiating training in the FTD, the following scenario file must be opened so that the appropriate a/c pre-positions or "snap shots" will be loaded in the computer.

Lesson Objectives:

This module has been designed to provide a virtual scenario for DATACOMM. DATACOMM provides data link capability for en route pilot controller communications. The research will investigate data-link functionality in a single pilot environment. The purpose of this module is to create a simulated flight with a moderate to heavy work load that will allow researchers to investigate data-link technologies for NextGen applications. The primary task for this scenario is to depart KDAB and request radar vectors to precision final back to KDAB. The scenario contains **"**Text Only with Voice Override Present."

ISA Deviation: 0
Altimeter: 30.00
Verify Wind/Turb: Light 7 Variable
Meteorological Conditions: **IMC**

Edit Environment
Time Of Day: Day

Set Engine Temp: N/A

Runway-7Left
Call Sign- Skyhawk 345 Echo Romeo

SCRIPT

ATC	Participant	Other traffic	Observations
	345 Echo Romeo: Daytona Tower, Skyhawk 345 Echo Romeo, ready for takeoff runway 7 left		
ATC-Tower: Skyhawk 345 Echo Romeo. Climb and Maintain 1,200. Maintain runway heading. Runway 7 left, cleared for takeoff.			

ATC	Participant	Other traffic	Observations
	345 Echo Romeo: Cleared for takeoff 7 left, Climb and maintain 1,200 maintain runway heading, Skyhawk 345 Echo Romeo		
		9963 Echo Romeo: Daytona Tower, Skyhawk 9963 Echo Romeo is turning base to final runway 7 Left	
ATC-Tower: Skyhawk 9963 Echo Romeo, Daytona tower, runway 7 Left, cleared to land			
		9963 Echo Romeo: Cleared to land runway 7 Left, Skyhawk 9963 Echo Romeo	
		421 Delta Bravo: Daytona tower, Skyhawk 421 Delta Bravo is midfield downwind 7 Left	
ATC-Tower: Skyhawk 421 Delta Bravo, Daytona Tower, cleared for the option runway 7 Left			

ATC	Participant	Other traffic	Observations
		421 Delta Bravo: Daytona Tower, Skyhawk 421 Delta Bravo will be a full stop	
ATC-Tower: Skyhawk 421 Delta bravo, number 2 following traffic short final runway 7L cleared to land			
		421 Delta Bravo: Cleared to land number 2 following traffic short final runway 7 Left, Skyhawk 421 Delta Bravo	
ATC-Tower: Skyhawk 345 Echo Romeo, contact Departure Control on 125.8			
	345 Echo Romeo: Contact Departure Control on 125.8, Skyhawk 345 Echo Romeo		
	345 Echo Romeo: Daytona Beach Departure, Skyhawk 345 Echo Romeo, request vector for the ILS runway 7 Left		

ATC	Participant	Other traffic	Observations
ATC-Departure Control: Skyhawk 345 Echo Romeo, roger, radar contact, standby for CPDLC uplink			
	345 Echo Romeo: Roger, standby for CPDLC uplink Skyhawk 345 Echo Romeo		
Uplink Message: CPDLC Now In Use, Acknowledge Now			
	Downlink Message: ROGER		
Uplink Message: Climb and Maintain 2,000			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn Left Heading 340			
		354 Echo Romeo: Turn Left Heading 340, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo turn left heading 250			
		345 Delta Bravo: Turn Left heading 250 November 345 Delta Bravo	

ATC	Participant	Other traffic	Observations
Uplink Message: Turn Left Heading 310			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Proceed Direct Ormond Beach VOR due to traffic			
		354 Echo Romeo: Proceed Direct Ormond VOR, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Proceed Direct Dongs			
		345 Delta Bravo: Proceed Direct Dongs, November 345 Delta Bravo	
Uplink Message: Proceed Direct Ormond Beach VOR Due To Traffic			
	Downlink Message: WILCO		

ATC	Participant	Other traffic	Observations
ATC-Departure Control: Skyhawk 354 Echo Romeo Hold East Of The Ormond VOR On The 090 Radial, Maintain 2,000, Expect Further Clearance in 5 Minutes			
		354 Echo Romeo: Hold East Of The Ormond VOR On The 090 Radial, Maintain 2,000, Expect Further Clearance in 5 Minutes, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Descend and Maintain 1,600			
		345 Delta Bravo: Descend and Maintain 1,600, November 345 Delta Bravo	
Uplink Message: Hold East Of The Ormond VOR On The 090 Radial, Maintain 2,000, EFC In 10 Minutes			
	Downlink Message: WILCO		

ATC	Participant	Other traffic	Observations
Uplink Message: At Ormond VOR Climb To 3,000 **Conditional Clearance**			
	Downlink Message: WILCO		
ATC-Departure Control: November 345 Delta Bravo Turn Left Heading 160			
		345 Delta Bravo: Turn Left Heading 160, November 345 Delta Bravo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Depart the Hold at Ormond, Fly Heading 210			
		354 Echo Romeo: Depart the Hold at Ormond, Fly Heading 210, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Turn left Heading 130			
		345 Delta Bravo: Turn left Heading 130 November 345 Delta Bravo	

ATC	Participant	Other traffic	Observations
ATC-Departure Control: Skyhawk 354 Echo Romeo Proceed Direct Dongs			
		354 Echo Romeo: Proceed Direct Dongs Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, You are cleared for the ILS Runway 07L.			
		345 Delta Bravo: Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, Cleared for the ILS Runway 07L, November 345 Delta Bravo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Descend and Maintain 1,600			
		354 Echo Romeo: Descend and Maintain 1,600 Skyhawk 354 Echo Romeo	

ATC	Participant	Other traffic	Observations
Uplink Message: Depart hold at OMN Proceed Direct Dongs Expect Radar Vectors for the ILS 7 L			
	Downlink Message: WILCO		
ATC-Departure Control: November 345 Delta Bravo Report TOMOK Inbound			
		345 Delta Bravo: Report TOMOK Inbound November 345 Delta Bravo	
ATC-Departure Control: Skyhawk 345 Echo Romeo, disregard CPDLC message to descend to 2,000, maintain 3,000			**Contradictory Clearance- Voice Override** **NOTE: This will be counterbalanced between text + annunciation and text-only conditions, but participants will receive the voice override in only one condition but not both**
	345 Echo Romeo: WILCO Maintain 3,000, Skyhawk 345 Echo Romeo		
Uplink Message: Descend And Maintain 2,000			
	Downlink Message: UNABLE		
Uplink Message: Clear Of Traffic, Descend To 1,600			
	Downlink Message: WILCO		

ATC	Participant	Other traffic	Observations
ATC-Departure Control: Delta 781 Radar Contact Climb and Maintain 2,000			
		Delta 781: Radar contact, Climb and Maintain 2,000 Delta 781	
ATC-Departure Control: November 345 Delta Bravo Contact Tower now on 120.7			
		345 Delta Bravo: Contact Tower 120.7 November 345 Delta Bravo	
ATC-Departure Control: Delta 781 turn left heading 340			
		Delta 781: Turn left heading 340, Delta 781	
Uplink Message: At DONGS, expect Radar Vectors I L S 7 Left			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn Left Heading 160			
		354 Echo Romeo: Turn Left Heading 160 Skyhawk 354 Echo Romeo	

ATC	Participant	Other traffic	Observations
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn Left Heading 130			
		354 Echo Romeo: Turn Left Heading 130 Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 737 Echo Romeo Radar Contact, Climb and Maintain 2,000			
		737 Echo Romeo: Radar Contact, Climb and Maintain 2,000, November 737 Echo Romeo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, You are cleared for the ILS Runway 7L.			
		354 Echo Romeo: Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, Cleared for the ILS Runway 7L, Skyhawk 354 Echo Romeo	

ATC	Participant	Other traffic	Observations
ATC-Departure Control: Delta 781 Contact Jacksonville Center on 126.7			
		Delta 781: Contact Jacksonville Center on 126.7, Delta 781	
ATC-Departure Control: November 345 Delta Bravo Radar Contact Climb and Maintain 2,000			
		345 Delta Bravo: Climb and Maintain 2,000 November 345 Delta Bravo	
ATC-Departure Control: November 345 Delta Bravo Turn Right Heading 160			
		345 Delta Bravo: Turn Right Heading 160 November 345 Delta Bravo	
ATC-Departure Control: November 345 Delta Bravo Turn Right Heading 250			
		345 Delta Bravo: Turn Right Heading 250 November 345 Delta Bravo	
ATC-Departure Control: November 345 Delta Bravo Climb and Maintain 3,000			

ATC	Participant	Other traffic	Observations
		345 Delta Bravo: Climb and Maintain 3,000 November 345 Delta Bravo	
Uplink Message: Turn Left Heading 160			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Contact Tower now on 120.7			
		354 Echo Romeo: Contact Tower on 120.7 Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 737 Echo Romeo Turn Left Heading 340			
		737 Echo Romeo: Turn Left Heading 340 November 737 Echo Romeo	
Uplink Message: Turn Left Heading 100			
	Downlink Message: WILCO		
ATC-Departure Control: November 737 Echo Romeo Climb and Maintain 3,000			

ATC	Participant	Other traffic	Observations
		737 Echo Romeo: Climb and Maintain 3,000, November 737 Echo Romeo	
Uplink Message: Maintain Heading 100, Maintain 1,600 Until Established On The Localizer, Cleared For The ILS Runway 7 Left			
	Downlink Message: WILCO		
ATC-Departure Control: November 737 Echo Romeo Turn Left Heading 250			
		737 Echo Romeo: Turn Left Heading 250 November 737 Echo Romeo	
Uplink Message: Contact Tower Voice Now On 120.7			
	Downlink Message: WILCO		
	345 Echo Romeo: Daytona Beach Tower, Skyhawk 345 Echo Romeo is XXX Nautical Miles from TOMOK		

ATC	Participant	Other traffic	Observations
ATC-Tower: Skyhawk 345 Echo Romeo, Roger, report TOMOK inbound, altimeter is 29.98			
	345 Echo Romeo: Report TOMOK inbound, Skyhawk 345 Echo Romeo		
ATC-Tower: Skyhawk 416 Echo Romeo maintain runway heading, runway 7 Left, cleared for takeoff			
		416 Echo Romeo: Maintain runway heading, Cleared for takeoff runway 7 left, Skyhawk 416 Echo Romeo	
	345 Echo Romeo: Daytona Tower, Skyhawk 345 Echo Romeo is TOMOK inbound		
ATC-Tower: Skyhawk 345 Echo Romeo, runway 7 left, cleared to land			
	345 Echo Romeo: Cleared to land 7 Left, Skyhawk 345 Echo Romeo		

ATC	Participant	Other traffic	Observations
ATC-Tower: Skyhawk 427 Whiskey Tango, hold short runway 7 Left, landing traffic			
		427 Whiskey Tango: Hold short runway 7 Left for traffic, Skyhawk 427 Whiskey Tango	
		9963 Echo Romeo: Daytona Tower, Skyhawk 9963 Echo Romeo is turning base to final runway 7 Left	
ATC-Tower: Skyhawk 9963 Echo Romeo, Daytona tower runway 7 Left, cleared to land			
		9963 Echo Romeo: Cleared to land runway 7 Left, Skyhawk 9963 Echo Romeo	
ATC-Tower: Skyhawk 357 Echo Romeo, number 2 following traffic short final, runway 7 L, cleared to land			
		357 Echo Romeo: Number 2 cleared to land following traffic short final, Skyhawk 357 Echo Romeo	
	-END-		

DATACOMM 3

Text + Annunciation, Voice Override Absent

Prior to initiating training in the FTD, the following scenario file must be opened so that the appropriate a/c pre-positions or “snap shots” will be loaded in the computer.

Lesson Objectives:

This module has been designed to provide a virtual scenario for DATACOMM. DATACOMM provides data link capability for en route pilot controller communications. The research will investigate data-link functionality in a single pilot environment. The purpose of this module is to create a simulated flight with a moderate to heavy work load that will allow researchers to investigate data-link technologies for NextGen applications. The primary task for this scenario is to depart KDAB and request radar vectors to precision final back to KDAB. The scenario contains **“**Text + Annunciation with Voice Override Absent.”

ISA Deviation: 0
Altimeter: 30.00
Verify Wind/Turb: Light 7 Variable
Meteorological Conditions: **IMC**

Edit Environment
Time Of Day: Day

Set Engine Temp: N/A

Runway-7Left
Call Sign- Skyhawk 345 Echo Romeo

SCRIPT

ATC	Participant	Other traffic	Observations
	345 Echo Romeo: Daytona Tower, Skyhawk 345 Echo Romeo, ready for takeoff runway 7 left		
ATC-Tower: Skyhawk 345 Echo Romeo. Climb and Maintain 1,200. Maintain runway heading. Runway 7 left, cleared for takeoff.			
	345 Echo Romeo: Cleared for takeoff 7 left, Climb and maintain 1,200 maintain runway heading, Skyhawk 345 Echo Romeo		

ATC	Participant	Other traffic	Observations
		9963 Echo Romeo: Daytona Tower, Skyhawk 9963 Echo Romeo is turning base to final runway 7 Left	
ATC-Tower: Skyhawk 9963 Echo Romeo, Daytona tower, runway 7 Left, cleared to land			
		9963 Echo Romeo: Cleared to land runway 7 Left, Skyhawk 9963 Echo Romeo	
		421 Delta Bravo: Daytona tower, Skyhawk 421 Delta Bravo is midfield downwind 7 Left	
ATC-Tower: Skyhawk 421 Delta Bravo, Daytona Tower, cleared for the option runway 7 Left			
		421 Delta Bravo: Daytona Tower, Skyhawk 421 Delta Bravo will be a full stop	
ATC-Tower: Skyhawk 421 Delta bravo, number 2 following traffic short final runway 7L cleared to land			
		421 Delta Bravo: Cleared to land number 2 following traffic short final runway 7 Left, Skyhawk 421 Delta Bravo	

ATC	Participant	Other traffic	Observations
ATC-Tower: Skyhawk 345 Echo Romeo, contact Departure Control on 125.8			
	345 Echo Romeo: Contact Departure Control on 125.8, Skyhawk 345 Echo Romeo		
	345 Echo Romeo: Daytona Beach Departure, Skyhawk 345 Echo Romeo, request vector for the ILS runway 7 Left		
ATC-Departure Control: Skyhawk 345 Echo Romeo, roger, radar contact, standby for CPDLC uplink			
	345 Echo Romeo: Roger, standby for CPDLC uplink Skyhawk 345 Echo Romeo		
Uplink Message: CPDLC Now In Use, Acknowledge Now			
	Downlink Message: ROGER		
Uplink Message: Climb and Maintain 2,000			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn Left Heading 340			

ATC	Participant	Other traffic	Observations
		354 Echo Romeo: Turn Left Heading 340, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo turn left heading 250			
		345 Delta Bravo: Turn Left heading 250 November 345 Delta Bravo	
Uplink Message: Turn Left Heading 310			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Proceed Direct Ormond Beach VOR due to traffic			
		354 Echo Romeo: Proceed Direct Ormond VOR, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Proceed Direct Dongs			
		345 Delta Bravo: Proceed Direct Dongs, November 345 Delta Bravo	
Uplink Message: Proceed Direct Ormond Beach VOR Due To Traffic			
	Downlink Message: WILCO		

ATC	Participant	Other traffic	Observations
ATC-Departure Control: Skyhawk 354 Echo Romeo Hold East Of The Ormond VOR On The 090 Radial, Maintain 2,000, Expect Further Clearance in 5 Minutes			
		354 Echo Romeo: Hold East Of The Ormond VOR On The 090 Radial, Maintain 2,000, Expect Further Clearance in 5 Minutes, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Descend and Maintain 1,600			
		345 Delta Bravo: Descend and Maintain 1,600, November 345 Delta Bravo	
Uplink Message: Hold East Of The Ormond VOR On The 090 Radial, Maintain 2,000, EFC In 10 Minutes			
	Downlink Message: WILCO		
Uplink Message: At Ormond VOR Climb To 3,000			
Conditional Clearance			
	Downlink Message: WILCO		
ATC-Departure Control: November 345 Delta Bravo Turn Left Heading 160			

ATC	Participant	Other traffic	Observations
		345 Delta Bravo: Turn Left Heading 160, November 345 Delta Bravo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Depart the Hold at Ormond, Fly Heading 210			
		354 Echo Romeo: Depart the Hold at Ormond, Fly Heading 210, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Turn left Heading 130			
		345 Delta Bravo: Turn left Heading 130 November 345 Delta Bravo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Proceed Direct Dongs			
		354 Echo Romeo: Proceed Direct Dongs Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, You are cleared for the ILS Runway 07L.			

ATC	Participant	Other traffic	Observations
		345 Delta Bravo: Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, Cleared for the ILS Runway 07L, November 345 Delta Bravo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Descend and Maintain 1,600			
		354 Echo Romeo: Descend and Maintain 1,600 Skyhawk 354 Echo Romeo	
Uplink Message: Depart hold at OMN Proceed Direct Dongs Expect Radar Vectors for the ILS 7 L			
	Downlink Message: WILCO		
ATC-Departure Control: November 345 Delta Bravo Report TOMOK Inbound			
		345 Delta Bravo: Report TOMOK Inbound November 345 Delta Bravo	
Uplink Message: Descend And Maintain 2,000			
	Downlink Message: WILCO		
Uplink Message: Descend To 1,600			
	Downlink Message: WILCO		

ATC	Participant	Other traffic	Observations
ATC-Departure Control: Delta 781 Radar Contact Climb and Maintain 2,000			
		Delta 781: Radar contact, Climb and Maintain 2,000 Delta 781	
ATC-Departure Control: November 345 Delta Bravo Contact Tower now on 120.7			
		345 Delta Bravo: Contact Tower 120.7 November 345 Delta Bravo	
ATC-Departure Control: Delta 781 turn left heading 340			
		Delta 781: Turn left heading 340, Delta 781	
Uplink Message: At DONGS, Expect Radar Vectors I L S 7 Left			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn Left Heading 160			
		354 Echo Romeo: Turn Left Heading 160 Skyhawk 354 Echo Romeo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn Left Heading 130			

ATC	Participant	Other traffic	Observations
		354 Echo Romeo: Turn Left Heading 130 Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 737 Echo Romeo Radar Contact, Climb and Maintain 2,000			
		737 Echo Romeo: Radar Contact, Climb and Maintain 2,000, November 737 Echo Romeo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, You are cleared for the ILS Runway 7L.			
		354 Echo Romeo: Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, Cleared for the ILS Runway 7L, Skyhawk 354 Echo Romeo	
ATC-Departure Control: Delta 781 Contact Jacksonville Center on 126.7			
		Delta 781: Contact Jacksonville Center on 126.7, Delta 781	
ATC-Departure Control: November 345 Delta Bravo Radar Contact Climb and Maintain 2,000			

ATC	Participant	Other traffic	Observations
		345 Delta Bravo: Climb and Maintain 2,000 November 345 Delta Bravo	
ATC-Departure Control: November 345 Delta Bravo Turn Right Heading 160			
		345 Delta Bravo: Turn Right Heading 160 November 345 Delta Bravo	
ATC-Departure Control: November 345 Delta Bravo Turn Right Heading 250			
		345 Delta Bravo: Turn Right Heading 250 November 345 Delta Bravo	
ATC-Departure Control: November 345 Delta Bravo Climb and Maintain 3,000			
		345 Delta Bravo: Climb and Maintain 3,000 November 345 Delta Bravo	
Uplink Message: Turn Left Heading 160			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Contact Tower now on 120.7			

ATC	Participant	Other traffic	Observations
		354 Echo Romeo: Contact Tower on 120.7 Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 737 Echo Romeo Turn Left Heading 340			
		737 Echo Romeo: Turn Left Heading 340 November 737 Echo Romeo	
Uplink Message: Turn Left Heading 100			
	Downlink Message: WILCO		
ATC-Departure Control: November 737 Echo Romeo Climb and Maintain 3,000			
		737 Echo Romeo: Climb and Maintain 3,000, November 737 Echo Romeo	
Uplink Message: Maintain Heading 100, Maintain 1,600 Until Established On The Localizer, Cleared For The ILS Runway 7 Left			
	Downlink Message: WILCO		
ATC-Departure Control: November 737 Echo Romeo Turn Left Heading 250			
		737 Echo Romeo: Turn Left Heading 250 November 737 Echo Romeo	

ATC	Participant	Other traffic	Observations
Uplink Message: Contact Tower Voice Now On 120.7			
	Downlink Message: WILCO		
	345 Echo Romeo: Daytona Beach Tower, Skyhawk 345 Echo Romeo is XXX Nautical Miles from TOMOK		
ATC-Tower: Skyhawk 345 Echo Romeo, Roger, report TOMOK inbound, altimeter is 29.98			
	345 Echo Romeo: Report TOMOK inbound, Skyhawk 345 Echo Romeo		
ATC-Tower: Skyhawk 416 Echo Romeo maintain runway heading, runway 7 Left, cleared for takeoff			
		416 Echo Romeo: Maintain runway heading, Cleared for takeoff runway 7 left, Skyhawk 416 Echo Romeo	
	345 Echo Romeo: Daytona Tower, Skyhawk 345 Echo Romeo is TOMOK inbound		
ATC-Tower: Skyhawk 345 Echo Romeo, runway 7 left, cleared to land			

ATC	Participant	Other traffic	Observations
	345 Echo Romeo: Cleared to land 7 Left, Skyhawk 345 Echo Romeo		
ATC-Tower: Skyhawk 427 Whiskey Tango, hold short runway 7 Left, landing traffic			
		427 Whiskey Tango: Hold short runway 7 Left for traffic, Skyhawk 427 Whiskey Tango	
		9963 Echo Romeo: Daytona Tower, Skyhawk 9963 Echo Romeo is turning base to final runway 7 Left	
ATC-Tower: Skyhawk 9963 Echo Romeo, Daytona tower runway 7 Left, cleared to land			
		9963 Echo Romeo: Cleared to land runway 7 Left, Skyhawk 9963 Echo Romeo	
ATC-Tower: Skyhawk 357 Echo Romeo, number 2 following traffic short final, runway 7 L, cleared to land			
		357 Echo Romeo: Number 2 cleared to land following traffic short final, Skyhawk 357 Echo Romeo	
	-END-		

DATACOMM 4

Text + Annunciation, Voice Override Present

Prior to initiating training in the FTD, the following scenario file must be opened so that the appropriate a/c pre-positions or "snap shots" will be loaded in the computer.

Lesson Objectives:

This module has been designed to provide a virtual scenario for DATACOMM. DATACOMM provides data link capability for en route pilot controller communications. The research will investigate data-link functionality in a single pilot environment. The purpose of this module is to create a simulated flight with a moderate to heavy work load that will allow researchers to investigate data-link technologies for NextGen applications. The primary task for this scenario is to depart KDAB and request radar vectors to precision final back to KDAB. The scenario contains **"**Text + Annunciation with Voice Override Present."

ISA Deviation: 0
Altimeter: 30.00
Verify Wind/Turb: Light 7 Variable
Meteorological Conditions: **IMC**

Edit Environment
Time Of Day: Day

Set Engine Temp: N/A

Runway-7Left
Call Sign- Skyhawk 345 Echo Romeo

SCRIPT

ATC	Participant	Other traffic	Observations
	345 Echo Romeo: Daytona Tower, Skyhawk 345 Echo Romeo, ready for takeoff runway 7 left		
ATC-Tower: Skyhawk 345 Echo Romeo. Climb and Maintain 1,200. Maintain runway heading. Runway 7 left, cleared for takeoff.			
	345 Echo Romeo: Cleared for takeoff 7 left, Climb and maintain 1,200 maintain runway heading, Skyhawk 345 Echo Romeo		

ATC	Participant	Other traffic	Observations
		9963 Echo Romeo: Daytona Tower, Skyhawk 9963 Echo Romeo is turning base to final runway 7 Left	
ATC-Tower: Skyhawk 9963 Echo Romeo, Daytona tower, runway 7 Left, cleared to land			
		9963 Echo Romeo: Cleared to land runway 7 Left, Skyhawk 9963 Echo Romeo	
		421 Delta Bravo: Daytona tower, Skyhawk 421 Delta Bravo is midfield downwind 7 Left	
ATC-Tower: Skyhawk 421 Delta Bravo, Daytona Tower, cleared for the option runway 7 Left			
		421 Delta Bravo: Daytona Tower, Skyhawk 421 Delta Bravo will be a full stop	
ATC-Tower: Skyhawk 421 Delta bravo, number 2 following traffic short final runway 7L cleared to land			
		421 Delta Bravo: Cleared to land number 2 following traffic short final runway 7 Left, Skyhawk 421 Delta Bravo	

ATC	Participant	Other traffic	Observations
ATC-Tower: Skyhawk 345 Echo Romeo, contact Departure Control on 125.8			
	345 Echo Romeo: Contact Departure Control on 125.8, Skyhawk 345 Echo Romeo		
	345 Echo Romeo: Daytona Beach Departure, Skyhawk 345 Echo Romeo, request vector for the ILS runway 7 Left		
ATC-Departure Control: Skyhawk 345 Echo Romeo, roger, radar contact, standby for CPDLC uplink			
	345 Echo Romeo: Roger, standby for CPDLC uplink Skyhawk 345 Echo Romeo		
Uplink Message: CPDLC Now In Use, Acknowledge Now			
	Downlink Message: ROGER		
Uplink Message: Climb and Maintain 2,000			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn Left Heading 340			

ATC	Participant	Other traffic	Observations
		354 Echo Romeo: Turn Left Heading 340, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo turn left heading 250			
		345 Delta Bravo: Turn Left heading 250 November 345 Delta Bravo	
Uplink Message: Turn Left Heading 310			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Proceed Direct Ormond Beach VOR due to traffic			
		354 Echo Romeo: Proceed Direct Ormond VOR, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Proceed Direct Dongs			
		345 Delta Bravo: Proceed Direct Dongs, November 345 Delta Bravo	
Uplink Message: Proceed Direct Ormond Beach VOR Due To Traffic			
	Downlink Message: WILCO		

ATC	Participant	Other traffic	Observations
ATC-Departure Control: Skyhawk 354 Echo Romeo Hold East Of The Ormond VOR On The 090 Radial, Maintain 2,000, Expect Further Clearance in 5 Minutes			
		354 Echo Romeo: Hold East Of The Ormond VOR On The 090 Radial, Maintain 2,000, Expect Further Clearance in 5 Minutes, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Descend and Maintain 1,600			
		345 Delta Bravo: Descend and Maintain 1,600, November 345 Delta Bravo	
Uplink Message: Hold East Of The Ormond VOR On The 090 Radial, Maintain 2,000, EFC In 10 Minutes			
	Downlink Message: WILCO		
Uplink Message: At Ormond VOR Climb To 3,000 **Conditional Clearance**			
	Downlink Message: WILCO		
ATC-Departure Control: November 345 Delta Bravo Turn Left Heading 160			

ATC	Participant	Other traffic	Observations
		345 Delta Bravo: Turn Left Heading 160, November 345 Delta Bravo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Depart the Hold at Ormond, Fly Heading 210			
		354 Echo Romeo: Depart the Hold at Ormond, Fly Heading 210, Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Turn left Heading 130			
		345 Delta Bravo: Turn left Heading 130 November 345 Delta Bravo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Proceed Direct Dongs			
		354 Echo Romeo: Proceed Direct Dongs Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 345 Delta Bravo Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, You are cleared for the ILS Runway 07L.			

ATC	Participant	Other traffic	Observations
		345 Delta Bravo: Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, Cleared for the ILS Runway 07L, November 345 Delta Bravo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Descend and Maintain 1,600			
		354 Echo Romeo: Descend and Maintain 1,600 Skyhawk 354 Echo Romeo	
Uplink Message: Depart hold at OMN Proceed Direct Dongs Expect Radar Vectors for the ILS 7 L			
	Downlink Message: WILCO		
ATC-Departure Control: November 345 Delta Bravo Report TOMOK Inbound			
		345 Delta Bravo: Report TOMOK Inbound November 345 Delta Bravo	

ATC	Participant	Other traffic	Observations
ATC-Departure Control: Skyhawk 345 Echo Romeo, disregard CPDLC message to descend to 2,000, maintain 3,000			**Contradictory Clearance- Voice Override** **NOTE: This will be counterbalanced between text + annunciation and text-only conditions, but participants will receive the voice override in only one condition but not both**
	345 Echo Romeo: WILCO Maintain 3,000, Skyhawk 345 Echo Romeo		
Uplink Message: Descend And Maintain 2,000			
	Downlink Message: UNABLE		
Uplink Message: Clear Of Traffic, Descend To 1,600			
	Downlink Message: WILCO		
ATC-Departure Control: Delta 781 Radar Contact Climb and Maintain 2,000			
		Delta 781: Radar contact, Climb and Maintain 2,000 Delta 781	
ATC-Departure Control: November 345 Delta Bravo Contact Tower now on 120.7			
		345 Delta Bravo: Contact Tower 120.7 November 345 Delta Bravo	
ATC-Departure Control: Delta 781 turn left heading 340			
		Delta 781: Turn left heading 340, Delta 781	

ATC	Participant	Other traffic	Observations
Uplink Message: At DONGS, expect Radar Vectors I L S 7 Left			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn Left Heading 160			
		354 Echo Romeo: Turn Left Heading 160 Skyhawk 354 Echo Romeo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn Left Heading 130			
		354 Echo Romeo: Turn Left Heading 130 Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 737 Echo Romeo Radar Contact, Climb and Maintain 2,000			
		737 Echo Romeo: Radar Contact, Climb and Maintain 2,000, November 737 Echo Romeo	
ATC-Departure Control: Skyhawk 354 Echo Romeo Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, You are cleared for the ILS Runway 7L.			

ATC	Participant	Other traffic	Observations
		354 Echo Romeo: Turn left Heading 070, Maintain 1,600 Until Established on the Localizer, Cleared for the ILS Runway 7L, Skyhawk 354 Echo Romeo	
ATC-Departure Control: Delta 781 Contact Jacksonville Center on 126.7			
		Delta 781: Contact Jacksonville Center on 126.7, Delta 781	
ATC-Departure Control: November 345 Delta Bravo Radar Contact Climb and Maintain 2,000			
		345 Delta Bravo: Climb and Maintain 2,000 November 345 Delta Bravo	
ATC-Departure Control: November 345 Delta Bravo Turn Right Heading 160			
		345 Delta Bravo: Turn Right Heading 160 November 345 Delta Bravo	
ATC-Departure Control: November 345 Delta Bravo Turn Right Heading 250			
		345 Delta Bravo: Turn Right Heading 250 November 345 Delta Bravo	

ATC	Participant	Other traffic	Observations
ATC-Departure Control: November 345 Delta Bravo Climb and Maintain 3,000			
		345 Delta Bravo: Climb and Maintain 3,000 November 345 Delta Bravo	
Uplink Message: Turn Left Heading 160			
	Downlink Message: WILCO		
ATC-Departure Control: Skyhawk 354 Echo Romeo Contact Tower now on 120.7			
		354 Echo Romeo: Contact Tower on 120.7 Skyhawk 354 Echo Romeo	
ATC-Departure Control: November 737 Echo Romeo Turn Left Heading 340			
		737 Echo Romeo: Turn Left Heading 340 November 737 Echo Romeo	
Uplink Message: Turn Left Heading 100			
	Downlink Message: WILCO		
ATC-Departure Control: November 737 Echo Romeo Climb and Maintain 3,000			

ATC	Participant	Other traffic	Observations
		737 Echo Romeo: Climb and Maintain 3,000, November 737 Echo Romeo	
Uplink Message: Maintain Heading 100, Maintain 1,600 Until Established On The Localizer, Cleared For The ILS Runway 7 Left			
	Downlink Message: WILCO		
ATC-Departure Control: November 737 Echo Romeo Turn Left Heading 250			
		737 Echo Romeo: Turn Left Heading 250 November 737 Echo Romeo	
Uplink Message: Contact Tower Voice Now On 120.7			
	Downlink Message: WILCO		
	345 Echo Romeo: Daytona Beach Tower, Skyhawk 345 Echo Romeo is XXX Nautical Miles from TOMOK		
ATC-Tower: Skyhawk 345 Echo Romeo, Roger, report TOMOK inbound, altimeter is 29.98			
	345 Echo Romeo: Report TOMOK inbound, Skyhawk 345 Echo Romeo		

ATC	Participant	Other traffic	Observations
ATC-Tower: Skyhawk 416 Echo Romeo maintain runway heading, runway 7 Left, cleared for takeoff			
		416 Echo Romeo: Maintain runway heading, Cleared for takeoff runway 7 left, Skyhawk 416 Echo Romeo	
	345 Echo Romeo: Daytona Tower, Skyhawk 345 Echo Romeo is TOMOK inbound		
ATC-Tower: Skyhawk 345 Echo Romeo, runway 7 left, cleared to land			
	345 Echo Romeo: Cleared to land 7 Left, Skyhawk 345 Echo Romeo		
ATC-Tower: Skyhawk 427 Whiskey Tango, hold short runway 7 Left, landing traffic			
		427 Whiskey Tango: Hold short runway 7 Left for traffic, Skyhawk 427 Whiskey Tango	
		9963 Echo Romeo: Daytona Tower, Skyhawk 9963 Echo Romeo is turning base to final runway 7 Left	

ATC	Participant	Other traffic	Observations
ATC-Tower: Skyhawk 9963 Echo Romeo, Daytona tower runway 7 Left, cleared to land			
		9963 Echo Romeo: Cleared to land runway 7 Left, Skyhawk 9963 Echo Romeo	
ATC-Tower: Skyhawk 357 Echo Romeo, number 2 following traffic short final, runway 7 L, cleared to land			
		357 Echo Romeo: Number 2 cleared to land following traffic short final, Skyhawk 357 Echo Romeo	
	-END-		

Counterbalancing Scheme

Group	Participant Number	Data Comm Condition	Voice Override Condition	Scenario
A	1, 5, 9, 13, 17, 21, 25, 29	Run 1: Text	ABSENT	1
		Run 2: Text + Annunciation	PRESENT	2
B	2, 6, 10, 14, 18, 22, 26, 30	Run 1: Text	PRESENT	3
		Run 2: Text + Annunciation	ABSENT	4
C	3, 7, 11, 15, 19, 23, 27, 31	Run 1: Text + Annunciation	ABSENT	4
		Run 2: Text	PRESENT	3
D	4, 8, 12, 16, 20, 24, 28, 32	Run 1: Text + Annunciation	PRESENT	2
		Run 2: Text	ABSENT	1

Participant Log

Group A DATACOMM 1,2	Group B DATACOMM 3,4	Group C DATACOMM 4,3	Group D DATACOMM 2,1
1: FT1	**2: FT3**	**3: FT4**	**4: FT2**
5: ST1	**6: ST3**	**7: ST4**	**8: ST2**
9:	**10:**	**11:**	**12:**
13: F1	**14: F3**	**15: F4**	**16: F2**
17:	**18:**	**19:**	**20:**
21:	**22:**	**23:**	**24:**
25:	**26:**	**27:**	**28:**
29:	**30:**	**31:**	**32:**

Demographic Counter Balance Priorities: 1. Flight Time (FT) 2. Sim Time (ST) 3. English as a Second Language (ESL) 4. Gender (F)

Appendix E

Appendix E contains the error handling script. It served to anticipate participant errors during the experiment, that is, concrete, observable actions that would constitute an error, and to provide guidance to the experimenters on how to respond to these errors by impersonating live ATC interventions. This included list of potential errors, a solution for each error, and a script for how the experimenter should handle each error during the experiment. The script ensured that all participants received the same guidance regarding a particular error.

Script for Handling Errors

Participant Errors

For all errors, use ATC-role play as the primary tool and abandon script when necessary. Also, the researchers must **pause SAFTE-VAT** to ensure it will **not play a WAV file** while they are speaking and **then resume SAFTE-VAT** after they have read the script to correct the error. Most errors will require immediate intervention by the experimenter. However, a flight error such as forgetting to turn, climb, or descend would take approximately 30 seconds before ATC would realize a deviation. Therefore we will allow 30 seconds to pass before correcting the participant for such errors. Researchers will also use the ATC Voice application to re-send a CPDLC message to the participant when appropriate. All errors will be documented on the checklist and script with error # and time.

1. Problem: Participant forgets assigned altitude in takeoff clearance.

Solution: The researcher acting as ATC will have to reread the assigned altitude in the clearance.

Script: *"Skyhawk 345ER your assigned altitude was 1,200."*

2. Problem: Participant turns to wrong heading on takeoff.

Solution: The researcher acting as ATC will have to remind the participant that they were assigned runway heading.

Scrip: *"Skyhawk 345ER, you were assigned runway heading on departure, please maintain heading 160."*

3. Problem: Participant contacts wrong frequency for departure.

Solution: The researcher acting as ATC will have to direct participant to correct frequency of 125.8.

Script: *"Skyhawk 345ER if you are looking for Daytona Departure, try 125.8."*

4. Problem: Participant request vectors for incorrect approach.

Solution: The researcher acting as ATC will prompt participant to request vectors for the ILS 7L.

Script: *"Skyhawk 345ER, it was my understanding that you wanted vectors for the ILS 7L, not _______."*

5. Problem: Participant requests instructions to be repeated after standby for CPDLC uplink voice message.

Solution: The researcher acting as ATC will have to tell participant to stand by for CPDLC uplink.

Script: *"Skyhawk 345ER standby for CPDLC uplink."*

6. Problem: During the initial climb, the participant looses complete situational awareness and needs delay vectors.

Solution: Upon realizing the complete loss of situational awareness, the researcher will pause SAFTE-VAT and send the participant delay vectors by the ATC voice application. This will give the participant time to regain their situational awareness.

Script: "Turn Left Heading 3 6 0
Turn Left Heading 2 7 0
Turn Left Heading 1 8 0
Turn Left Heading 0 7 0"
(All CPDLC messages with approximately 90 seconds between each)

7. Problem: Participant replies STANDBY to any CPDLC message.

Solution: The researcher will have to pause SAFTE-VAT, wait for 20 seconds to elapse after receiving the standby response and then repeat the CPDLC message as a conventional voice ATC message.

Script: "Skyhawk 345 Echo Romeo … "

8. Problem: Participant requests new CPDLC message that they had previously replied STANDBY to before 20 seconds has elapsed.

Solution: The researcher acting as ATC will repeat the CPDLC message as a conventional voice ATC message.

Script: "Skyhawk 345 Echo Romeo …"

9. Problem: Participant replies by voice to CPLDC message that they have replied to with STANDBY.

Solution: The researcher acting as ATC will acknowledge the participant's response.

Script: "Skyhawk 345 Echo Romeo, Roger."

10. Problem: Participant replies UNABLE/NEGATIVE to any CPDLC message.

Solution: The researcher acting as ATC will query the participant as to why they responded UNABLE/NEGATVE. After listening to their response, the researcher acting as ATC will have to accommodate the participants request.

Script: "Skyhawk 345 Echo Romeo, I show you replied UNABLE/NEGATIVE to last CPDLC message. Will you state the reason you will not complete the instruction/clearance?"

11. Problem: Participant replies UNABLE/NEGATIVE to CPDLC holding instruction due to conflicting traffic.

Solution: The researcher acting as ATC will advise participant that the conflicting traffic will be departing prior to their arrival.

Script: "Skyhawk 345Echo Romeo, I show you replied UNABLE/NEGATIVE to the holding CPDLC message. Will you state the reason you are unable to perform the hold?"

"There is a traffic conflict, the aircraft ahead of me was given the same holding instructions."

"Skyhawk 345 Echo Romeo, that traffic will be departing prior to your arrival and not be a factor. Can you hold according to previous instructions?"

"Yes, No, or resend the instructions"

"Skyhawk 345 Echo Romeo, standby for re-issuance of holding instructions."

12. Problem: Participant climbs to wrong altitude after receiving CPDLC message.

Solution: The researcher acting as ATC will have to prompt participant to climb or descend to correct altitude.

Script: "Skyhawk 345ER I currently show your altitude as _________. You were assigned _______. Please climb/descend to your assigned altitude of______."

13. Problem: Participant incorrectly responds to 354ER's instruction to fly heading 340.

Solution: The researcher acting as ATC will have to instruct participant that that instruction was for 354ER, not 345ER.

Script: *"N345ER, that last instruction was for 354ER. Please maintain your current heading of 070."*

14. Problem: Participant incorrectly responds to 354ER's instruction to proceed to Ormond Beach VOR due to traffic.

Solution: The researcher acting as ATC will have to instruct participant that that instruction was for 354ER, not 345ER.

Script: *"Skyhawk 345ER, the last instruction to proceed to OMN VOR was for 354ER. Please maintain your current heading of 310."*

15. Problem: Participant incorrectly responds to 354ER's holding instructions.

Solution: The researcher acting as ATC will have to instruct participant that that instruction was for 354ER, not 345ER.

Script: *"Skyhawk 345ER, those holding instructions were for 354ER. Please proceed to OMN VOR and standby for your holding instructions."*

16. Problem: En-route to OMN, the participant looses complete situational awareness and needs delay vectors.

Solution: Upon realizing the complete loss of situational awareness, the researcher will pause SAFTE-VAT and send the participant delay vectors by the ATC voice application. This will give the participant time to regain their situational awareness.

Script: "Turn Right Heading 0 9 0
Turn Right Heading 1 8 0
Turn Right Heading 2 7 0
Proceed Direct Ormond Beach VOR
Hold East of the Ormond VOR on the 090 Radial, Maintain 2,000, EFC in 10 Minutes
At Ormond VOR Climb to 3,000"
(All CPDLC messages with approximately 90 seconds between each)

17. Problem: Participant queries ATC for the direction of the holding pattern.

Solution: The researcher acting as ATC will have to instruct the participant to make right turns in the hold.

Script: "*Skyhawk 345ER make right hand turns in the hold."*

18. Problem: Participant makes a left holding pattern instead of a right holding pattern.

Solution: The researcher acting as ATC will instruct participant to make a right turn for the holding pattern.

Script: "*Skyhawk 345ER you should have made right turns while holding but you may proceed with making left turns."*

19. Problem: Participant holds on the wrong radial and at the wrong altitude.

Solution: The researcher acting as ATC will advise participant to maintain current radial for holding.

Script: *"Skyhawk 345ER, your holding instructions were right turns on the 090 radial, it appears you are holding on the ___ radial. Please maintain holding on the ___ radial."*

20. Problem: Participant executes wrong holding entry.

Solution: The researcher acting as ATC will prompt participant to correct entry on the hold.

Script: *"Skyhawk 345ER, you will need to execute a direct entry to the 090 radial for the hold."*

21. Problem: Participant reports established in the hold over Ormond and there is no WAV file to respond to the participant.

Solution: This is not really a problem as it is a required report once one is established in a hold. However, most pilots will not make this report.

Script: "Skyhawk 345 Echo Romeo, roger."

22. Participant queries ATC whether to climb at 500fpm or 85Kts

Solution: Researcher acting as ATC will advise participant to climb at pilot's discretion.

Script: *"N345ER, climb at your discretion."*

23. Problem: In the hold, participant looses complete situational awareness and needs delay vectors.

Solution: Upon realizing the complete loss of situational awareness, the researcher will pause SAFTE-VAT and send the participant delay vectors by the ATC voice application. This will give the participant time to regain their situational awareness.

Script: "Turn Right Heading 3 6 0
Turn Right Heading 0 9 0
Turn Right Heading 1 8 0
Proceed Direct DONGS Expect Radar Vectors for the ILS 7L"
(All CPDLC messages with approximately 90 seconds between each)

24. Problem: Participant does not comply with CPDLC instruction to climb to 3,000 at Ormond VOR.

Solution: The researcher acting as ATC will have to instruct participant to climb to 3,000 once at the Ormond VOR.

Script: *"Skyhawk 345ER climb and maintain 3,000"*

25. Problem: Participant responds to N354ER instructions to "depart the hold at Ormond."

Solution: The researcher acting as ATC will have to prompt participant that those instructions were for 354ER.

Script: *"Skyhawk 345ER that instruction was for N354ER, please proceed with the hold."*

26. Problem: Participant responds to N354ER instructions to "proceed direct to DONGS."

Solutions: The researcher acting as ATC will have to advice participant that those instructions were for 354ER.

Script: *"Skyhawk 345ER that last instruction was for N354ER, please proceed as instructed by the last CPDLC message received."*

27. Problem: Participant responds to 354ER instructions to descend to 1,600.

Solution: The researcher acting as ATC will have to advice the participant that that instruction was for 354ER.

Script: "Skyhawk 345ER, that last instruction was for 354ER, please maintain 3,000."

28. Problem: Participant is confused by the location of DONGS

Solution: Researcher acting as ATC will give the location of DONGS, as OMN VOR 212°/10 NM and prompt student to enter DONGS into the GPS.

Script: *"N345ER, DONGS is located at OMN VOR 212°/10 NM. I understand you are a GPS equipped aircraft, are you unable to navigate directly to DONGS?"*

29. Problem: En-route to DONGS, the participant loses complete situational awareness and needs delay vectors.

Solution: Upon realizing the complete loss of situational awareness, the researcher will pause SAFTE-VAT and send the participant delay vectors by the ATC voice application. This will give the participant time to regain their situational awareness.

Script: "Turn Right Heading 3 6 0
Turn Right Heading 0 9 0
Turn Right Heading 2 1 0
Proceed Direct DONGS Expect Radar Vectors for the ILS 7L"
(All CPDLC messages with approximately 90 seconds between each)

30. Problem: Participant does not respond to voice instruction to disregard next CPDLC message to descend to 2,000.

Solution: The researcher acting as ATC will have to repeat the instruction.

Script: *"Skyhawk 345ER, disregard CPDLC message to descend to 2,000, maintain 3,000 for now.*

31. Problem: Participant ignores CPDLC message to descend to 2,000.

Solution: Researcher acting as ATC will have to prompt student to reply with NEGATIVE.

Script: *"Skyhawk 345ER, please reply NEGATIVE to the CPDLC message to descend to 2,000."*

32. Problem: Participant replies WILCO/ROGER/AFFIRMATIVE for instruction to descend to 2,000 when they were instructed not to do so.

Solution: Researcher acting as ATC will have to verify with participant that they will not descend, even though their response indicated that they will.

Script: "Skyhawk 345 Echo Romeo, you replied WILCO/ROGER/AFFIRMATIVE to the instruction to descend and maintain 2,000 when I told you to disregard it. Verify that you will maintain 3,000 as instructed."

33. Problem: Participant replies UNABLE/NEGATIVE for instruction to descend to 1,600.

Solution: Researcher acting as ATC will have to instruct participant to descend to 1,600."

Script: *"Skyhawk 345ER, descend and maintain 1,600 as instructed by your last CPDLC message."*

34. Problem: Participant responds to 354ER instructions to turn left heading 160.

Solution: The researcher acting as ATC will have to advice the participant that that instruction was for 354ER.

Script: *"Skyhawk 345ER, that instruction was for 354ER, please continue proceeding direct DONGS at 1,600."*

35. Problem: Participant responds to 354ER instructions to turn left heading 130.

Solution: The researcher acting as ATC will have to advice the participant that that instruction was for 354ER.

Script: *"Skyhawk 345ER, that instruction was for 354ER, please continue proceeding direct DONGS at 1,600."*

36. Problem: Participant responds to 354ER approach clearance instructions.

Solution: The researcher acting as ATC will have to advice the participant that that approach clearance was for 354ER.

Script: *"Skyhawk 345ER, that last approach clearance was for 354ER, please continue proceeding direct DONGS at 1,600."*

37. Problem: Participant queries ATC before reaching DONGS about further instructions

Solution: Researcher acting as ATC will have to instruct participant to stand by for CPDLC message.

Script: *"N345ER, standby for further instructions."*

38. Problem: Participant turns to a heading other than 160.

Solution: The researcher acting as ATC will have to prompt the participant to turn to the correct heading of 160.

Script: *"Skyhawk 345ER, please turn to heading 160."*

39. Problem: While receiving vectors for the ILS, the participant looses complete situational awareness and needs delay vectors.

Solution: Upon realizing the complete loss of situational awareness, the researcher will pause SAFTE-VAT and send the participant delay vectors by the ATC voice application. This will give the participant time to regain their situational awareness.

Script: "Turn Left Heading 3 6 0
Turn Left Heading 2 5 0
Turn Left Heading 1 6 0
Turn Left Heading 1 0 0
Maintain Heading 1 0 0, Maintain 1,600 Until Established on the Localizer, Cleared for the ILS Runway 7L."
(All CPDLC messages with approximately 90 seconds between each)

40. Problem: Participant contacts Daytona Tower for 354ER.

Solution: The researcher acting as ATC will have to instruct the participant back to Daytona Approach.

Script: *"Skyhawk 345ER, you were not handed off to my frequency yet, please contact Daytona Approach on 125.8."*

"Roger, going back to Daytona Approach on 125.8, Skyhawk 345ER. … Daytona Approach, Skyhawk 345 ER, checking back in. I accidentally switched to tower."

"Skyhawk 345 Echo Romeo roger."

41. Problem: Participant turns to a heading other than 100.

Solution: The researcher acting as ATC will have to prompt the participant to turn to the correct heading of 100.

Script: *"Skyhawk 345ER, please turn to heading 100."*

42. Problem: Participant flies approach on wrong heading and altitude.

Solution: Researcher acting as ATC will have to prompt participant the correct heading and altitude that he/she should be at.

Script: "*Skyhawk 345ER, currently you should be on a heading of ___ and an altitude of ____."*

43. Problem: Participant does not contact tower.

Solution: Researcher acting as ATC will have to prompt student to contact Daytona Tower.

Script: *"Skyhawk 345ER contact tower on 120.7."*

44. Problem: Participant tunes in wrong frequency when contacting Daytona Tower.

Solution: Researcher acting as ATC will have to direct participant to correct frequency of 120.7.

Script*: "Skyhawk 345ER, if you are looking for Daytona Tower, try 120.7."*

45. Problem: Participant does not report TOMOK.

Solution: Researcher acting as ATC will have to prompt participant to report their position from TOMOK.

Script: *"Skyhawk 345ER please report your position from TOMOK."*

46. Problem: Participant does not switch altimeter setting.

Solution: Researcher acting as ATC will have to prompt participant to switch to new altimeter setting.

Script: *"Skyhawk 345ER, please set your altimeter setting to 29.98."*

47. Problem: Participant asks for new altimeter setting.

Solution: Researcher acting as ATC will give participant altimeter setting of 30.00.

"Current altimeter setting is 30.00"

48. Problem: Participant makes unstablized approach and executes go around

Solution: Researcher acting as ATC will have to instruct the participant back to DONGS and move SAFTE-VAT to corresponding position.

Script: *"N345ER, proceed direct DONGS and expect vectors for the ILS Runway 7L."*

49. Problem: Participant looses situational awareness

Solution: If the researcher feels that the participant may salvage the situation, the researcher may let the participant continue. However, if the situation is uncorrectable, the researcher will pause the simulator, let the student regain situational awareness and then resume the simulator. Also, the researcher will have to pause and reposition SAFTE-VAT to correspond to the correct position.

Script: *"I have paused the simulation to allow you to regain your situational awareness. At this point, you need to be at this altitude, heading, etc. Let me know when you are ready to resume."*

50. Problem: Participant sends incorrect touch screen display message in error

Solution: The researcher will have to act as ATC to correct the misunderstanding.

Script: *"Skyhawk 345ER, my touch screen display shows you replied _____ to the message_______. Are you unable to _______?"*

51. Problem: Participant queries ATC as to which intersection to turn off the runway.

Solution: The researcher acting at ATC will instruct participant to come to a stop on the runway.

Script: "Skyhawk 345ER, come to a stop on the runway."

52. Problem: Participant does not respond to CPDLC message and another message is about to be sent.

Solution: The researcher will pause SAFTE-VAT and allow an additional 20 seconds for the participant to respond. If the participant does not respond, the researcher acting as ATC will have to verbally prompt the participant to respond.

Script: "Skyhawk 345 Echo Romeo, please respond to the CPDLC message."

53. Problem: The TSD stops receiving messages.

Solution: The researchers acting as ATC will have to give live voice instructions to complete the scenario. The participant's data will have to be discarded.

Script: "Skyhawk 345 Echo Romeo, CPDLC data link has been lost, you will no longer receive any CPDLC messages. Please use and reply with conventional live voice instructions."

54. Problem: The participant is confused by the voice override to disregard the next CPDLC message because they have not received it yet.

Solution: The researcher acting as ATC will advise the participant that they may not have received the message yet and to standby for it.

Script: "Daytona approach, I do not have a message to descend to 2,000. So how am I supposed to disregard it?"
"Skyhawk 345 Echo Romeo, you may not have received it yet. Upon receipt, please disregard message."
"Wilco, 345 Echo Romeo."

Appendix F

Appendix F includes the briefing script used to standardize all experimental procedures and ensure that all participants received exactly the same instructions. The experimenter read the briefing script to each participant. This script included a description of the consent form, a broad description of the flight scenarios, and instructions for each survey. It was written in the first person.

1. Briefing room, pre-experiment briefing:

"Hello ______, my name is (Wayne Bushmaker/Jeff Alvarado)—I will be your experimenter today. Before we begin, I will briefly explain the consent form to you. This study explores the possibility of supplementing air traffic control data communications with computer-generated speech. We will call the communications Controller Pilot Data Link Communications and will refer to it as CPDLC throughout the experiment. The graphical interface you will use to receive and respond to the CPDLC messages is a touch-screen display coupled with computer-generated speech. You will use it while flying the Cessna 172 Flight Training Device. Your participation is voluntary, and you are free to withdraw at any time. Your personal information and responses will be anonymous. Also, know that we will be video, audio, and flight recording you for data collection and analysis purposes. We do not anticipate any negative reactions to this experiment. However, in few cases, individuals have experienced symptoms of "simulator sickness". Also, know that we are not evaluating or judging your flight performance as a pilot. We are evaluating new systems and you are our test pilot. Do you have any questions?

If you would like to participate, please print and sign your name on the consent form.

(Experimenter – also sign and date the consent form; also, give the participant a copy of the consent form).

Now, I'm going to tell you a bit about the experiment. You will fly three sessions in the Daytona Beach area. The first will be a practice session and the last two will be the experimental sessions. Since you are flying in the Daytona Beach area, be aware of similar sounding call signs, student pilots, and the large volume of training aircraft. You will experience a typical day at Daytona Beach International Airport. You can expect to perform all basic instrument flight maneuvers, holding, and flying approaches. The procedures in the cockpit, such as checklist usage and approach briefing, are at your discretion. Here is a flight brochure that you may read to become more familiar with the flight. (Hand them brochure) While you are reading that, may I look at your logbook to verify that you are current? **(Verify Currency and note last flight review or equivalent (circle one): yes no**

Date of last flight review or equivalent:______________________________________)

We will now go to the FTD and you will receive a short demonstration on how to use the touch screen display and your flight briefings. You will then fly a short practice session to become more familiar with the touch screen display operation.

(Bring participant to the FTD and have them sit in the left seat)

2. In the FTD, practice session briefing:

(Allow participant to get set up in the FTD. Hand them the touch screen display.)

Here is the touch screen display. You can attach it to whichever knee is more comfortable for you. **(Note: Left / Right).** Here is how the touch screen display operates. The top box entitled ATC (point to it) displays communication from ATC. New messages will appear here, blink, and be signaled with a chime. Sometimes, a computer-generated voice may be heard. The second box, here (point) called Log is a chronological history of your messages sent to ATC with the most recently sent message at the top. The bottom box, Pilot Response, will allow you to review your response before sending it to ATC. The green and light purple boxes are your possible responses. In general, the green boxes mean something like “yes” and the purple boxes mean something like “no.” As a reminder:

- WILCO means: You have received the ATC message, understand it, and will comply with it.
- ROGER means: You have received all of ATC’s last transmission. It should not be used to answer a question requiring a yes or no answer.
- AFFIRMATIVE means: Yes.
- UNABLE means: I am not able to comply with a specific instruction, request, or clearance. In other words, you cannot do something.
- STANDBY means: You need to pause for a few seconds, usually to attend to other duties of higher priorities. You should reestablish contact if a delay is lengthy. It is neither an approval nor a denial.

- NEGATIVE means: No or you will not do something.

We will conduct a short demonstration to familiarize you with the operation of the touch screen display. You must tap the buttons and messages firmly with your fingers in order to respond. (Conduct demo scenario while reading the script). Your response to a message should be as follows:

1. When you hear the chime and see a blinking message in the ATC box, firmly tap the message to acknowledge that it was received (guide the participant to do this). This will stop it from blinking and make it easier to read.

2. Next, you must select your reply from the options on the bottom. Firmly tap your selected reply button (guide the participant to do this). The message with your selected response will be displayed in the Pilot Response box.

3. The last step is to tap the Send button (guide the participant to do this). This will send the message back to ATC and move the message with your response to the Log box.

It is very important that you follow these three steps exactly. To respond to a message, you must tap the display a total of three times. Do not just tap the message and tap send. Remember to select a response word. Also, note that messages will only be coming from ATC, you cannot generate your own message or text. Here are few more examples for you to practice with the display. (After participant finishes with examples, ask: Do you have any questions about the operation of the touch screen?)

The touch screen display will be used with Daytona Departure/Approach only. You will not use it with Daytona Tower. Remember, the touch screen messages may be accompanied by a computer-generated voice. Put on the headphones and listen to the computer generated voice. **(Send them a message with voice).** Do not try to respond on the radio to this voice. You must respond with a message on the touch screen display. However, if you receive a LIVE voice message from ATC, you must respond with your live voice on the radio. When I say live, I mean a real human voice like myself speaking. Do you understand the difference between computer generated voice and live voice and how to respond to each of them? Simply put if you receive a message on the touch screen, you must respond with a touch screen message. If you hear a conventional live ATC voice message, you must respond with your own voice.

Now, you will fly a short practice session to become more familiar with the touch screen display. Fly using normal flight maneuvers. This means you should cruise at 100 knots and use standard rate turns. Climb and descend at 500 feet per minute, and fly according to the Embry-Riddle Standard Operating Procedures. You are expected to fly to Instrument Practical Test Standards and be able to proficiently use the G-1000. The session will start as soon as you request a takeoff clearance. Once I tell you to begin, you can request takeoff. Here is the approach chart, a pad of paper, pencil, and kneeboard to use in the cockpit. (Hand participant approach chart, paper, pencil, and kneeboards). Set up the cockpit, radio frequencies, and GPS to your liking prior to requesting takeoff clearance. The two things that we ask you not to change are the G-1000 time offset and the interior lights. Please leave the offset as LOCAL 24 -00:00 and leave the interior lights on full bright.

You will start on runway 16 at Daytona Beach Airport. Your call sign is "*Skyhawk* 345 ER" – as displayed on the placard here, (Point to placard in cockpit) and not "Riddle 345". The aircraft and weather are legal for your flight. You do not need to receive ATIS or request a clearance from Daytona Beach Clearance Delivery. The pertinent information in the ATIS is as follows: Clouds overcast 600, Visibility 2, temperature 15, winds calm, altimeter 30.00 runway 16 is in use. Your clearance is as follows: "Skyhawk 345 Echo Romeo you are cleared to the Daytona Beach airport via radar vectors. Maintain 1,200, departure frequency is 125.35, **squawk _ _ _ _**. I have your request for the GPS Runway 16 approach and you can expect that approach."

If needed, the volume on the headphones can also be adjusted using these knobs and the G-1000 volume can be adjusted using this knob. (Experimenter: double check that volume is set to initial level 9 and 71%).

Do you have any questions? During the practice session, feel free to ask me any questions at any time. At the end of the practice, I will give you further instructions.

(Experimenter will close and re open .bat file, exit the FTD, and return to GISt station)

3. In the FTD, at end of practice session:

You may come to a stop on the runway and I will freeze the device. Do you have any questions now that the practice session is over? Do you have any questions regarding the use of the touch screen display?

You may now take a ten minute break if you like before starting the next session. Would you like to take a break? Please meet me back here in ten minutes.

4. In the FTD, pre-experimental session 1 briefing:

We will now start Session 1. (Ensure participant has note pad and pencil). You will start on runway 7L at Daytona. Your aircraft and the weather are legal for the flight. Like the previous session, you do not need to receive ATIS or request a clearance from Daytona Beach Clearance Delivery. The pertinent information in the ATIS is as follows: clouds broken 600, visibility 1, temperature 15, winds calm, altimeter 30.00 runway 7L is in use. Your clearance is as follows: “Skyhawk 345 Echo Romeo you are cleared to the Daytona Beach airport via radar vectors. Maintain 1,200, departure frequency is 125.8, **squawk _ _ _ _.** I have your request for the ILS 7L approach and you can expect that approach.” As before, the session will begin after you request a take-off clearance. In this scenario, you will be instructed to perform a hold at Ormond before flying the ILS 7L. ATC will also instruct you to proceed to an intersection named DONGS using the G-1000 GPS. This is an intersection in Daytona’s airspace. However; you may be unfamiliar with it. It is the final approach fix for the VOR RWY 23 into Deland (Show participant the approach chart and intersection). Here is the approach chart for the ILS 7L and VOR RWY 23. (Hand them to the participant). During this session, please act as if you were in the actual aircraft. Following the session, I will provide you with further instructions. Do you have any questions?

(Experimenter closes and reopens .bat file, exits the FTD, and returns to the GISt station)

5. In the FTD, at end of experimental session 1:

You may come to a stop on the runway and I will freeze the device. Please step out of the FTD and follow me to the briefing room where you will complete an online survey. You may leave your belongings here since you will return.

6. In briefing room, survey 1 briefing:

For this online survey, please don't hesitate to give us your honest opinion. Please carefully read the instructions in the survey and ask me any questions that you may have. You may reference this hardcopy of the touch screen display to help you answer questions that pertain to it. I will be sitting over here, please let me know when you are finished.

7. In briefing room, after survey 1:

You may now take a ten minute break if you like (Experimenter: provide water). Would you like to take a break? Please meet me by the FTD in ten minutes to fly one more session.

8. In the FTD, pre-experiment session 2 briefing:

There is one more flying session that is very similar to the last. The ATIS information is the same as the previous session. Would you like me to repeat it for you? Your clearance is as follows: "Skyhawk 345 Echo Romeo you are cleared to the Daytona Beach airport via radar vectors. Maintain 1,200, departure frequency is 125.8, **squawk _ _ _ _.** I have your request for the ILS 7L approach and you can expect that approach."

You will start on runway 7L and it will begin after you request a take-off clearance. In this session you will be instructed to perform a hold before flying the ILS 7L. Do you have any questions? Following the session, I will provide you with further instructions.

(Experimenter closes and reopens .bat file, exits the FTD, and returns to the GISt station)

9. In the FTD, at end of experiment session 2:

You may come to a stop on the runway and I will freeze the device. Please step out of the FTD and follow me to the briefing room where you will complete two online surveys. You may collect all your belongings since you will not be returning

10. In briefing room, survey 2 briefing:

For this online survey, don’t hesitate to give us your honest opinion. Please carefully read the instructions in the survey and ask me any questions that you may have. You may reference this hardcopy of the touch screen display to help you answer questions that pertain to it. I will be over here sitting down, please let me know when you are finished.

11. In briefing room, survey 3 briefing:

For this online survey, don’t hesitate to give us your honest opinion. Please carefully read the instructions in the survey and ask me any questions that you may have. I will be over here sitting down, please let me know when you are finished.

12. In briefing room, final debrief:

Thank you for participating! Is there any feedback or opinions regarding your experience here today that you would like to mention? (Write down comments at end of Experimenters Checklist) Please keep in mind that confidentiality is important to the validity of the experiment. Please do not discuss the details of this experiment with any other participants or your friends. (Provide compensation, complete necessary paperwork).

Final Comments

What was the difference between the two scenarios? O.V. ________ Text only vs. Text+Speech ___

____

Did you ever consider rejecting the holding clearance because the aircraft ahead of you was given the same holding instructions? ____

____

In your scenario with synthetic speech, were you able to respond to the tsd message before the synthetic speech was done talking? ____

____

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Appendix G

Appendix G includes the experimental procedures checklist. To ensure that all materials were prepared (e.g., consent form, surveys) and the FTD was set-up prior to each participant's arrival, experimenters used a checklist. This step-by-step list specifies the order of events—before, during and after each experiment. The experimenter was also able to record key information (e.g., handedness, volume level, any errors/issues/concerns) on the checklist. It reminded the experimenter to collect and back-up data at the conclusion of each experiment. The checklist further ensured that any irregularities during the experiment were carefully recorded including time of occurrence.

Experiment Procedures Checklist

Participant Number: 30

Date:____________________Time:______ ____________

Counterbalancing Group:__________________________

Transponder codes:

Practice: _ _ _ _

Scenario 1: _ _ _ _

Scenario 2: _ _ _ _

Starting volume level:Headset:9   G-1000 (both comms): 71%   Sim: (always) 25%

Ending volume level:Headset:______G-1000:______

How does the participant use the touch-screen display (circle one):

Left knee-Left hand

Right knee-Right hand

Left knee-Right hand

Right knee-Left hand

Is the same hand/knee used consistently throughout the experiment: Yes   No

If no, describe change:

Also note cable bundle location:__________

Verify Log Book:

Current: Yes   No

Date of last flight review or equivalent:

Be sure to note the start/stop time of all flying sessions within script below.

Possible simulator abnormalities

	Action	**Responsibility and Time**	**Comments**
Failure to establish communication with ATC	Restart GISt GISt maintenance is Ctrl+Shift+L		
Failed to find action record	Press OK button and SAFTE-VAT will proceed		
The tablet does not show text. Only computer-generated voice is heard	Close .bat file and then restart file		
SAFTE-VAT lesson freezes and will not respond	Restart SAFTE-VAT lesson		
Tablet freezes	Restart tablet		
Survey freezes or is unable to be completed	Use provided hard copy of survey for participant and enter responses at a later time.		
Tornado/Fire/Weather Drill that requires participant to leave the FTD during a scenario	Evacuate the FTD and proceed to secure location. (participant data will be discarded)		

Day Before the Experiment

Time/Phase/Place	Action	Who is Responsible?	Check or Comments
	Check that there are enough tapes available for video recording		
	Determine participant number, experimental group using counterbalancing criteria		
	Make copies of consent form and withdrawal form, and flight brochure.		
	Check that the surveys are available online; Double check that hard-copies are available and placed in the correct order. Make sure the hard-copy image of the touch-screen display is available for the surveys.		
	Ensure note pad, pencil, flashlight, and two kneeboards are available.		
	Gather means for compensation		

Throughout the Experiment

Time/Phase/Place	Action	Who is Responsible?	Check or Comments
	Keep track of protocol and mark EST time in left hand column		
	Do not provide specific details about the experimental conditions		

Day of Experiment, before participant arrives

Time/Phase/Place	**Action**	**Who is Responsible?**	**Check or Comments**
Pre-flight inspection	Ensure FTD is free of discrepancies		
	Turn on all electronic devices and connect them with proper cables. Click on small computer icon on TSD toolbar and click on mirror to send signal to clone.		
	Check that video recorders are set up properly. TSD clone recorder must be on tape mode. Ensure that it as far against the wall as possible to minimize the possibility of getting the experimenter's shoulder in view.		
	Label tape with "YYMMDDhhmm_PXX_DATA COMM_XX&XX_Left/Right /TSD". (The hhmm time stamp will be the approximate time of experiment start. It will have to correspond with the Flight Data and TSD .csv file name)		
FTD Start/Launch Procedures	Select the Graphical Instructor Station (GISt) icon from the desktop shortcut (wait until GISt Loads).		
	Note the HOBBS time onto the FTD clipboard.		

Time/Phase/Place	**Action**	**Who is Responsible?**	**Check or Comments**
	Select projectors from the task bar and turn them on.		
	Activate Control Loading by pressing ACTIVATE on the console to the right of the PC monitors.		
	Speak and record the participant # and scenario # on the tape itself (not the label). • The G-1000 audio panel must be turned on • Make sure hot mike is selected and active freq. is 120.7.		
	Set sim volume to 25%. Set headset volume to 9 and set G-1000 volume to 71%		
Test TSD Functionality Prior to Start	Launch SAFTE-VAT Lesson Planner by clicking on the Lesson icon in the toolbar.		
	Open DATACOMM Demo and press play.		
	Verify that the touch screen displays message, voice, and doorbell chime is received from SAFTE-VAT.		
	Open ATC Voice application by selecting Ctrl+Shift+A. In the		

Time/Phase/Place	**Action**	**Who is Responsible?**	**Check or Comments**
	application, verify that Crystal 4.2 is the active voice, type in frequency of 120.7, select voice and text and send a message to verify operation.		
	Close DATACOMM Demo and close SAFTE-VAT.		
	Close and then reopen the .bat file on the touch screen display. (The purpose of this is to clear the touch screen display)		
	Verify that the FTD HOST is in time synch with the FTD GISt computer (automatic).		
	Verify that the FTD GISt computer is in time synch with the touch screen display (automatic).		
	Set G-1000 time offset to zero. Go to AUX page 4. Select the Time Format to LOCAL 24hr. Go to Time Offset and set to -00:00.		
	Set out snacks and water (if possible) in the briefing room.		

Once participant arrives in briefing room

Time/Phase/Place	**Action**	**Who is Responsible?**	**Check or Comments**
	Talk through the Experiment Briefing Script—up to "In the FTD, practice session briefing"		
	Describe consent form, obtain participant's signature		
	Experimenter signs consent form; provide copy of consent form to participant		
	Verify participant currency by reviewing logbook. (Exact date is noted in Briefing script and on first page of checklist)		
	Guide participant to FTD		

Once participant arrives in FTD

Time/Phase/Place	**Action**	**Who is Responsible?**	**Check or Comments**
	Instruct participant to attach the touch screen to their knee. Note **Left/Right. Also note cable bundle location:____________**		
	Adjust video cameras as needed, to have a clear view of the participant's eyes.		
	Complete practice briefing up to "**At end of practice session in FTD**". Walk through Data Comm Demo.		

Time/Phase/Place	**Action**	**Who is Responsible?**	**Check or Comments**
	Provide notepad, pencil, flashlight, flight brochure, kneeboards, placard with call sign.		
	Ensure that the participant has seat belt on, windows closed, panel lights must be full bright, overhead lights must be off, and they do not change G-1000 time offset.		
	Open DATACOMM_Practice scenario in SAFTE-VAT and press play Make sure control loading is active		
	Note Time that flying practice session begins:_________		
	Fly practice session		
During the practice session	Experimenter will act as quality control • Observe SAFTE-VAT • Simulator • Participant • Answer any questions regarding touch screen display		

Time/Phase/Place	Action	Who is Responsible?	Check or Comments
	If malfunction occurs, use script for handling errors • Note time of malfunction • Note the "problem number", as listed on error-handling script		
	Ensure that runway approach lights and airport lights are on.		
After the practice session	After they land instruct participant to come to a stop on the runway using script titled "At the end of practice session in FTD" Note Time:______		
	Allow participant a 10 minute break; provide water if possible.		
	Collect note pad from cockpit, label with participant number. Replace with a new note pad. Note volumes: Headset_____, G-1000:_______		
Launch Flight Data/Video/Touch Screen Display Recorder	Select the data recorder from the GISt toolbar.		
	Flight Data recorder will be on standby. (Flight Data archiving will occur at end of session #1 and #2)		

Time/Phase/Place	Action	Who is Responsible?	Check or Comments
	Video recorder will be set up prior to participant arriving at FTD. (Recording will begin at the start of session #1 and end at the end of session #2)		
	Touch screen display recording is automatic upon closing .bat file. (Archiving data will take place at the end of session #1 and session #2)		
	Ensure cockpit is set up to specifications stated before.		
Participant Returns to FTD	Instruct participant to attach the touch screen to their knee. Note: Left/Right		
	Conduct "**In the FTD, experimental session 1 briefing**"		
	Note Time that flying experimental session 1 begins:________		
	Upon requesting takeoff clearance: • Press the record button on the 3 video recorders to start recording. • Start flight data recording by pressing record. • Make sure that control loading is active		

Time/Phase/Place	Action	Who is Responsible?	Check or Comments
	Participant flies session 1		
During the session 1	Experimenter will act as quality control • Observe SAFTE-VAT • Simulator • Participant		
	If malfunction occurs, use script for handling errors • Note time of malfunction • Note the "problem number", as listed on error-handling script		
	Ensure that runway approach lights and airport lights are on.		
After session 1	After they land, instruct participant to come to a stop on the runway using script titled "At the end of experimental session 1 in FTD". Note Time:______		
	Pause video camera upon complete stop of the aircraft.		
	Stop flight data recorder upon complete stop of the aircraft		
	Collect note pad from cockpit, label with participant number and scenario number and decipher notes. Replace with a new note pad.		

Time/Phase/Place	**Action**	**Who is Responsible?**	**Check or Comments**
	Note Final Volume Level: Headset: G-1000:		
	Take participant to briefing room. Use script to describe post-scenario questionnaire. Make sure hard copy of TSD is offered.		
	Allow participant to complete questionnaire		
After post-scenario survey 1	Provide participant a 10-minute break; if possible provide water.		
	Brief participant on session #2 by reading "**In FTD, experimental session 2 briefing**"		
Archiving the Flight Data	Save raw data file using participant identifier as "YYMMDDhhmm_PXX_DATA COMM_XX". Ensure hhmm is same as video tape label. The data file will be stored on the GISt PC.		
	Export file in .csv format from GISt PC to secondary external hard drive. (Completed after experiment)		
	Double check that data has been archived. (Completed after experiment)		

Time/Phase/Place	Action	Who is Responsible?	Check or Comments
Archiving Touch Screen Display	Close out .bat file		
	Click and hold start		
	Select explore		
	Select Local Disk (C:)		
	Select folder titled “SynSpeechApp”		
	Select file based on date and time stamp in accordance with participant scheduled time slot.		
	Save data file to Flash Drive as “YYMMDDhhmm_PXX_DATA COMM_XX.csv”. Ensure hhmm is same as video tape label.		
	Ensure file has .csv extension		
	Ensure cockpit is set up to specifications stated before.		
Start of Session #2	Instruct participant to prepare for flight in the FTD and attach the touch screen display to their knee. Note: Left/Right		
	Open the SAFETE-VAT for session 2 • **Double check that the correct file is opened for counterbalancing**		

Time/Phase/Place	Action	Who is Responsible?	Check or Comments
	Note Time that flying experimental session 2 begins:________		
	Upon requesting takeoff clearance: • Press the record button on the 3 video recorders to start recording. • Start flight data recording by pressing record. • Make sure that control loading is active.		
	Participant flies session 2		
During the session 2	Experimenter will act as quality control • Observe SAFTE-VAT • Simulator • Participant		
	Ensure that runway approach lights and airport lights are on.		
	If malfunction occurs, use script for handling errors • Note time of malfunction • Note the “problem number”, as listed on error-handling script		

Time/Phase/Place	**Action**	**Who is Responsible?**	**Check or Comments**
After session 2	After they land instruct participant to come to a stop on the runway using script titled "At the end of experimental session 2 in FTD". Note Time: _______		
	Stop recording for video and flight data.		
	Note Final Volume Level: Headset: G-1000:		
Participant Completes Survey	Take participant to briefing room		
	Use script to describe post-session questionnaire. Make sure hard copy of TSD is offered.		
	Allow participant to complete post session survey.		
	Allow participant to complete post experiment survey		
	Following all surveys, use script to ask if participant has any final comments. Write down any comments on briefing script, and transpose at end of checklist.		
	Thank participant, provide compensation, get receipt, record compensation		

Time/Phase/Place	Action	Who is Responsible?	Check or Comments
Archiving Touch Screen Display Log	Close out .bat file		
	Click and hold start		
	Select explore		
	Select Local Disk (C:)		
	Select folder titled "SynSpeechApp"		
	Select file based on date and time stamp		
	Save data file to Flash Drive as "YYMMDDhhmm_PXX_DATA COMM_XX.csv". Ensure hhmm is same as video tape label.		
	Ensure file has .csv extension		
Archiving the Flight Data	Save raw data file using participant identifier as "YYMMDDhhmm_PXX_DATA COMM_XX". Ensure hhmm is same as video tape label. The data file will be stored on the GISt PC.		
	Export file in .csv format from GISt PC to secondary external hard drive. (Completed after experiment)		
	Double check that data has been archived. (Completed after experiment)		

Time/Phase/Place	Action	Who is Responsible?	Check or Comments
	Document final volume level. Headset: G-1000:		
Completion of Experiment	Close SAFTE-VAT lesson planner		
	Close out of ATC Voice application.		
	Turn off projectors		
	Note the HOBBS time on the clipboard		
	Click restart GISt on the toolbar		
	Recharge external speaker		

Abnormalities

Final Comments

What was the difference between the two scenarios? O.V. Text only vs. Text+Speech

Did you ever consider rejecting the holding clearance because the aircraft ahead of you was given the same holding instructions?

In your scenario with synthetic speech, were you able to respond to the tsd message before the synthetic speech was done talking?

Appendix H

Additional Survey Data

Usability of Computer-Generated Speech

Pilots were asked to rate the usability of the computer-generated speech following the text+speech condition. Pilots were asked to indicate their level of agreement with five statements:

1. It is easy for me to determine whether the computer-generated speech is male or female.
2. I can easily tell the difference between the computer-generated speech and a human voice.
3. The loudness of the computer-generated speech is sufficient.
4. The speaking rate of the computer-generated speech is appropriate.
5. It was easy for me to understand the computer-generated speech.

Agreement was indicated by selecting one of five response choices with anchors "Strongly Agree" and "Strongly Disagree." These response choices were assigned numerical values in order to calculate the average ratings, which are shown in Figure 43 below. The overall mean, across all five questions, was 4.48 (*SD* = .70).

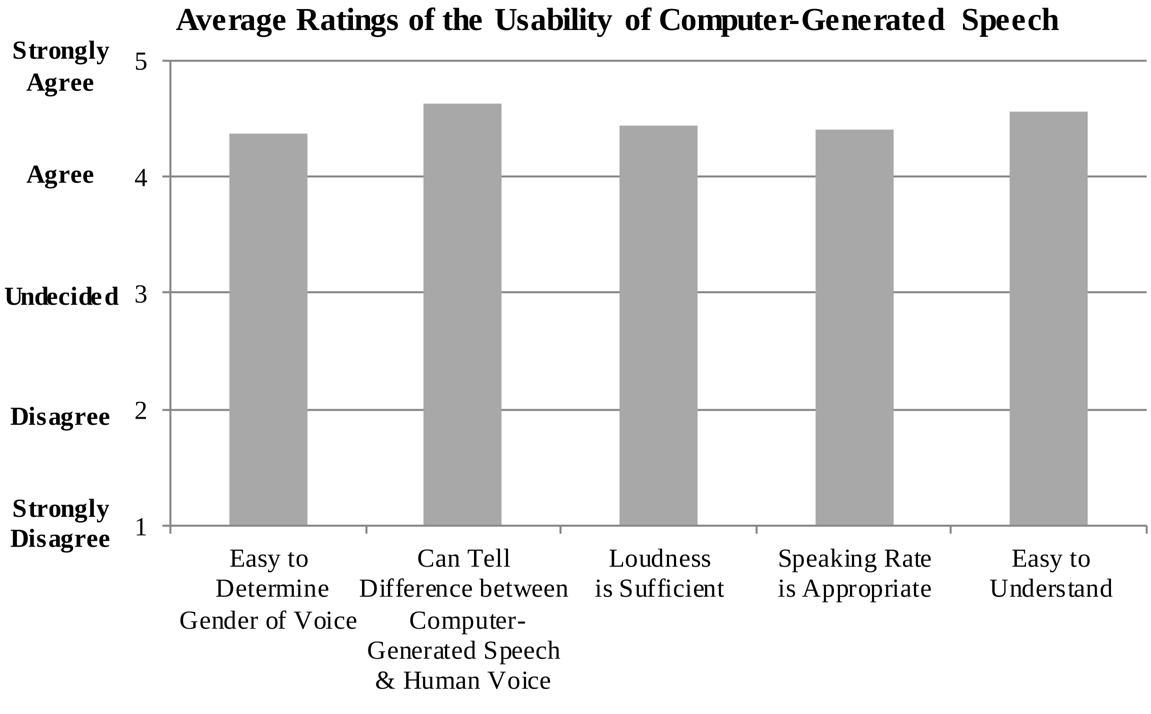

Figure 49. Average usability ratings of the computer-generated speech in the text+speech condition.

Pilots also offered some suggestions regarding the usability of the synthetic speech (note, comments are unedited; see Table 13 for unabridged comments):

- “Rate of speech can be better. It seems a little bit faster would make everything smoother”
- “The voice was easy to understand but it seemed was somewhat patchy, or broken in some spots”
- “I think the voice to me sounded very computer like but I feel that there are some people that have a monotone voice such as that and in a high workload environment may get confused.”
- “There should be an option to control the loudness of the voice.”
- “With max volume, and airplane volume, the computer voice was just about audible... i'd have it louder if i could. Speaking rate: i personally would prefer faster speaking COMMs, but this is a preference.”
- “I felt the computer-generated speech was a little too soft. Whenever I heard the computer-generated speech, I immediatly stoped listening and just looked at the computer screen.”
- “The rate the voice gave instructions could be speed up. I found myself wanting to hit wilco before she had finished.”

Usability of the Touch-Screen Display

Pilots were asked to rate the usability of the touch-screen display following both the text-only and the text+speech conditions. Pilots were asked to indicate their level of agreement with several statements under the following categories:

1. Colors
2. Layout
3. Responsiveness
4. Size

Agreement was indicated by selecting one of five response choices with anchors “Strongly Agree” and “Strongly Disagree.” These response choices were assigned numerical values in order to calculate the average ratings, which are shown in the Figure 44 below broken down by category. Overall (across Data Comm conditions and usability categories), the average usability rating was 4.36 (*SD* = .70), which falls between “Agree” and “Strongly Agree” (that the touch-screen display usability is acceptable). There was no difference in ratings following the text-only condition (*M* = 4.38, *SD* = .68) vs. the text+speech condition (*M* = 4.34, *SD* = .72).

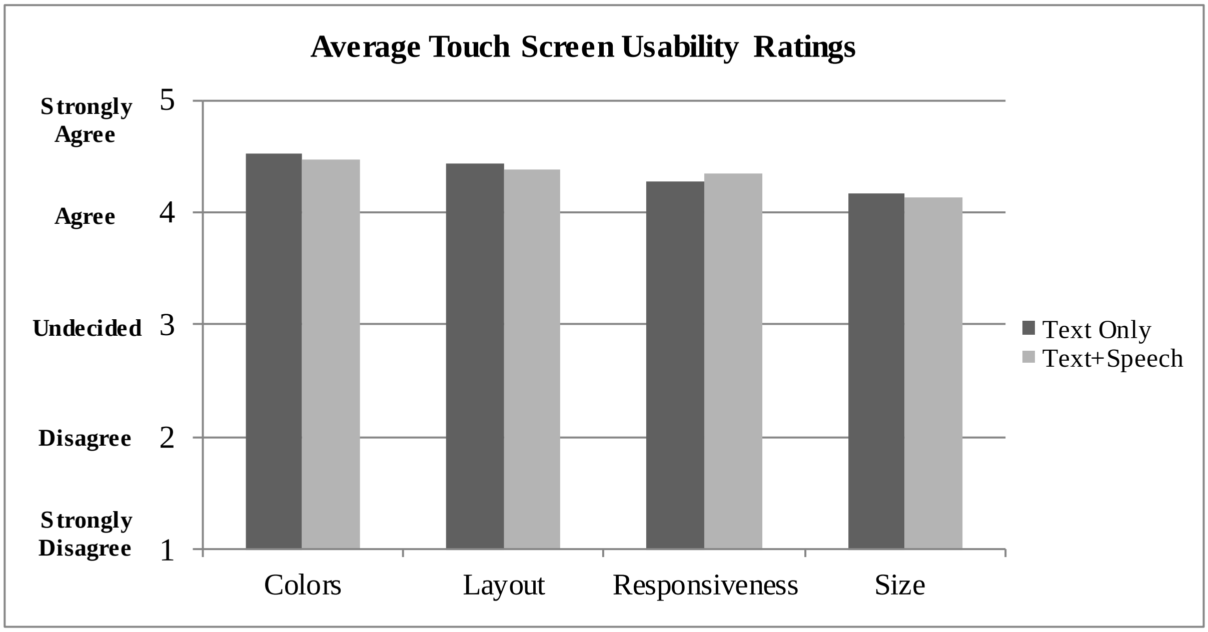

Figure 50. Average touch screen usability ratings by Data Comm condition.

The pilots were asked to rate several specific features within each of the above usability categories. For a list of means and standard deviations (in parentheses) by item, see Table 4.

Table 4. Mean ratings to usability questions by Data Comm condition.

Question		Text Only	Text+Speech
Colors	I find the background color of the ATC box supports easy reading	4.56 (.56)	4.53 (.57)
	I find the background color of the Log box supports easy reading	4.56 (.56)	4.53 (.57)
	I find the background color of the Pilot Response box supports easy reading	4.56 (.56)	4.50 (.57)
	I find the color of the Send button effective	4.19 (.74)	4.26 (.77)
	I find the color of the UNABLE/STANDBY/NEGATIVE response buttons effective	4.59 (.50)	4.44 (.72)
	I find the color of the WILCO/ROGER/AFFIRMATIVE response buttons effective	4.69 (.47)	4.59 (.67)
Layout	I like that the ATC box is at the top of the touch screen	4.59 (.56)	4.47 (.62)
	I like that the response buttons are at the bottom of the touch screen	4.42 (.67)	4.34 (.65)
	I like that the Log box is between the ATC and Pilot Response boxes	4.22 (.87)	4.28 (.68)

Question		Text Only	Text+Speech
	I like that the Pilot Response box is above the response buttons	4.50 (.51)	4.44 (.56)
	I like the location of the Send button	4.41 (.56)	4.34 (.70)
Responsiveness	The sensitivity of the response buttons is effective	4.28 (.73)	4.34 (.65)
Size	The response buttons are the right size	4.25 (.62)	4.28 (.58)
	The size of the text in the ATC box supports easy reading	4.19 (.83)	4.19 (.83)
	The size of the text on the response buttons supports easy reading	4.25 (.67)	4.13 (.98)
	The size of the text in the Log box supports easy reading	4.09 (.86)	4.09 (.86)
	The size of the text in the Pilot Response box supports easy reading	4.09 (.82)	4.00 (.92)

Open-Ended Responses

Throughout each survey, participants were able to indicate their comments regarding workload, usability of the touch-screen display, usability of the synthetic speech, and ability to learn/use the system. Participants' open-ended responses to each section of the post-scenario and post-experiment surveys are provided in the tables below. All responses, in their original form, are included. The breadth and often repetition of responses provides an indication of pilots' impressions throughout the experiment.

Post Scenario Open-Ended Responses

Tables 5-13 contain responses to the post-scenarios surveys (i.e., text only vs. text + speech) by question type.

Table 5. Suggestions regarding ATC communications workload.

Suggestions regarding ATC communications workload.	
Text Only	**Text + Speech**
• didnt like the text only....once again it requires me to put my head down during critical phases of flight and read and understand a message. easier to just read something back • Without the synthetic voice the communications were much more dificult. One factor was the ammount of heads-down time to read the clearances. The other was the fact that hearin the clearance helps	• trying to fly the airplane while looking down, easier to be looking at instruments and simply talk. Also to may commands to be dealing with....my eyes should be looking at the instruments and not a screen in my lap. • Although I do not disagree with the statement about departure control I do believe it is more dificult to respond through the CPDLC system in single-pilot

Suggestions regarding ATC communications workload.	
the pilot to remember what to do. I found my workload was much harder and that I forgot more items when there was no synthetic speech. • When the CPDLC had voice as well, it made it much easier. I had more heads down time when I had to read each line. • having to read al the controle insructions made for to much heads down time. • It was easier to receive long instructions such as holding and ILS by communicating via touchscreen instead of by voice. This reduced workload by avoiding having to write down the instructions and reading them back correctly. • Departure said to disregard instructions from the system that were not yet recieved, which was a litle confusing • At first, communicationg with TRACON (Departure Control), was difficult. Having to look down at my lap consistently for instructions was disorientating. I had a hard time of deciding whether to respond to the instruction first or start my maneuver. It eventually became easier and kind of felt just like to talking to departure. It was really nice having the instruction already written down so I could refer to it after the fact. However, in actual conditions head movement needs to be minimal. Kneeboard location and reading while in actual conditions might pose a threat to safety.	IMC. By takaing one's eyes away from the PFD to look down at the touch-screen display it disturbs the pilots scan. I found myself geting off altitude/heading and forgetting items (for example, I forgot to start my timer outbound on the hold over OMN). By talking over the radio it requires little movement and no need to look away from the PFD. This being said, I did like the fact that a written transcript of the ATC instructions was time-stamped and available for viewing. • Got confused when I was on CPDLC, then dept told me on voice to ignore an instruction that hadn't been sent yet on CPDLC. • Having the automated computer voice on on Departure Control was much better than just the Datalink text.

Table 6. Open-ended response to scan pattern question.

Scan Pattern - If you did look at other, please indicate what it was.	
Text Only	**Text + Speech**
• the approach plate. Also, i just looked around the sim aimlessly at some points throughout the testing. • approach plates, checklist, items to complete in the checklist - fuel control, mixture, etc • Approach plates • Approach charts, checklist and aircraft CB's, flaps, (not flight instruments but still within the cockpit) • checklist, notepad • Navigation Instruments and Secondary Instruments such as the MFD • Approach plates and checklist. • MFD and Approach chart • kneeboard, checklist • Checklist • approch plate • Approach plates, written notes about hold and other clearances • Approach plate, checklist • approach plates, and checklist • Checklists, Approach Plate, • Approach plates, flight controls, kneeboard • approach plate • Checklist and approach plates • aircraft engine controls • Charts • approach plate • Checklist and IAP • Checklist • Approach Plate	• approach plate, also looking aimlessly around the sim at the equipment. • approach plates, checklists, items to be completed in checklists • approach plate • checklist, notepad • MFD and Approach chart • Approach Plate and checklist. • MFD and Approach chart • kneeboard, checklist • Checklists • approach plate/ proctors • approch plate • Approach plates, notes on holding other clearance info • Checklists/Approach Plate • approach plate and checklist • approach plates, checklists • Looking at approach charts • Checklist and writtings on the note pad • approach plate, notes • Approach plates, kneeboard, flight controls • Dongs Intersection on approach plate • Checklist & Apporach Plates • engine related items • Kneeboard and approach plates • approach plate • Approach plates • Checklist and IAP • Checklist • Approach Plate

Table 7. Suggestions regarding the size of the touch screen.

Suggestions regarding the SIZE of the touch screen.	
Text Only	**Text + Speech**
• I would like the text in the response buttons to be a bit larger in font. • It gets cluttered with all of the messages after a couple have been sent. I recommended as a suggestion that you have the most recent message color coded as opposed to the others so that it can be more easily referenced when necessary. • Its hard to read the message when it's flashing, but it's easy to tap the screen to make it stop. The text is a little small. • I think the size is fine, but it may make more sense to make the log window taller and the ATC box shorter, keeping the font the same size. It's easy to ready, but you dn't need that much space for most ATC instructions and I'd have liked to see more history in the log. • After a while, I just pushed towards the green buttons, not caring which was pushed, as long as a positive response was attained • the responce buttons could be just a bit larger. Still ok at this size, but they are close together and make for an easy mistake • Text was a bit too small. If larger text then it would be easier to read, as well as less responses shown would make it easier to understand which comunication was just recieved and which was an older response. • Log is difficult to scroll up and down. • I fournd myself having to spend extra time scanning the text to make sense of the	• The font of the response buttons could be a little bit larger. • I would make the response text bigger so it is easier to read • larger font. • Longer clearances are hard to read, especially in the pilot response box. Since WILCO is most comonly used, I think it could be a little larger than the rest of the keys so the pilot doesn't accidently hit something else, especially in turbulence. It would be handy if the last ATC instruction and/or pilot response was larger than the the previous text. • Same comments as on the last run about making the log box bigger, ATC box smaller, all caps labels on the buttons versus making them upper and lower case. • Response buttons could be a bit larger • try making older responces a different color • A bit too small for easy reading. There is too many ATC, and log responses listed on the screen. Maybe bigger font, and less comunication would be easier to read, and understand. • Needs slightly larger text. Moving head to look down is disorientating and takes time to look for the information. The touch screen button text is hard to read because the white does not show up well on the green background. The Magenta background is better, but a darker color would help.

Suggestions regarding the SIZE of the touch screen.	
instruction. It might have been the contrast of white and black, but the txt could have been larger or the valuable parts of the information highlighted. As a pilot I only care to see/hear HDG and Altitude asignments. When I listen to ATC over the radio my mind automatically highlights and reserves important information like altitude and HDG for readback and memory storage. Extra wording is a hassle, especially with text. If it is a holding instruction I just want to see cardinal direction, radial/CRS/BRG, and altitude. Eliminate a lot of the extra wording, such as words like of and the. In my mind a holding instruction should be organized like this: E OMN 090 2,000. Short concise and easy to interpret and would have had to spend less time trying to read the somewhat small font. Aircraft control during critical phases was made difficult by the reading - like trying to respond during a level off or about to turn to intercept final.	• The reading size was good for me, however I can see the font size not beeing large enough for older people.

Table 8. Suggestions regarding the responsiveness of the touch screen.

Suggestions regarding the RESPONSIVENESS of the touch screen.	
Text Only	**Text + Speech**
• There were two times when workload was a little higher - I was being vectored on the approach I think - and I guess I didn't hit the buttons quite hard enough to send the Wilco response. It increased workload further when I had to read back the prompt from ATC to respond and go and push the buttons again. I think it needs to be a little more sensitive. • I don't "strongly" agree because of different	• I was surprised at how easy it was to tap the buttons and have the command be recieved • Again, when workload increased being vectored onto the approach, first couple attempts to acknowledge an instruction weren't hard enough for the screen to register so I had to do it over again. Should make it more sensitive. • Only 1 time did I touch a response and it

Suggestions regarding the RESPONSIVENESS of the touch screen.	
occasions I tapped on the send button but it wasn't sent. Once I started noticing that I also began double checking to make sure the message was sent which increased slightly the workload. • Thought I pushed the send button at one point then realized later that it did not transmit through. Could be human or machine error. • sensitivity could be better. Occasionally I had to hit the screen multiple time for it to register • I had some trouble when multi tasking and trying to click. Press could be easier to press buttons	was not picked up • For the most part it was ok, but I did hit a response but it was not sent. I didn't press it hard enough. perhaps a audible tone alerting you if there is a responce in the log, but not sent.

Table 9. Suggestions regarding the layout of the touch screen.

Suggestions regarding the LAYOUT of the touch screen.	
Text Only	**Text + Speech**
• Text size could be increased in the log • I believe it would be easier to read the ATC instructions first, have the response buttons just below that box, and lastly read the response log. This would match the chronological order in which the message was processed. • Previous survey responses still hold, but I have become more familiar with the placement, so it doesn't bother me as much • Like Mentioned before, I would rather have the Log and ATC text windows switched • There were times i instictively looked at the very bottom for the COMM log... possibly moving the response box and send box to the middle of the screen, and leave the COMM log at the bottom may avoid this.	• I definately like where the ATC and LOG Boxes are, I think the send box could be relocated to a better spot perhaps left justified with the rest of the windows. or perhaps have the pilot reponse box be a command button to send, • Same comments as last session • I'd prefer to see the Log box at the end because it reflects the chronological order in which the message was processed. First ATC gives instructions, then the pilot answers and lastly the message is displayed as accepted and answered. • I think the send box should be at the bottom right and there should be some division between the responses that are new/old/I made. Having the most recent ATC relay on top of the middle screen

Suggestions regarding the LAYOUT of the touch screen.	
	took a little getting used to • In my opinion, I would like the ATC and Log display boxes switched. This will allow the pilot to 100 percent understand the most resent communications and intructions

Table 10. Suggestions regarding the colors of the touch screen.

Suggestions regarding the COLORS of the touch screen.	
Text Only	**Text + Speech**
• Initially the send button was hard to locate, however once I got used to where it was located it was easy to use/send messages • Not disagreeing but I had to refer back to the boxes 3 or 4 times just because I could not remember or didnt fully understand the instuctions • On the send button, the color's good but the font is a little smaller than on the response buttons. Why? I think it'd be eaasier to read if it were the same size. On the response buttons, the words are in all caps. I've noticed that it's easier to read something written in a combination of upper- and lower-case letters than if it's written in all caps. I had to look twice a few times to verify I'd read the button correctly before I picked my response. • The white on black is a very good contrast to have when working with the screen • The send button could be a brighter color or outlined to make it stand out better. Overall it was not hard to use. • Send button kind of blends in, could have used something to make it stand out. As said in an earlier response I'm not sure if it was text size or the contrast of white on	• For the unable/ standby/ negative responses I thought there would be a red box, but I think the pink works just as well. • Same as last time • In various lighting conditions, the black background may be too harsh • The touch screen buttons need a darker background to make the text stand out, or make the text larger. I memorized which buttons were where, but had I needed the unable or affirmative button more often - it could have taken some time to make sure I was pressing the right one.

black, but reading it could have been easier. I do like how the background is black for night operations to reduce light flooding.	

Table 11. Suggestions regarding the ease of using the system.

Suggestions regarding the ease of using the System.	
Text Only	**Text + Speech**
• The system was simple in both the effort necessary to input and receive messages, and also in the concern of sterile cockpit during important procedures and management skills. It takes away from having to write atc commands down, and quite possibly incorrectly recording them. It is simple and effective, and a joy to have in the cockpit. one more suggestion would be to increase the scroll button for the log so that it is not difficult to use your finger to scroll down previous messages in the log box. • I do not think it would take long for the average pilot to be able to use this system effectively in flight. Having the instructions available at all times to view is helpful. Again, the only thing I would be concerned with is the constant looking down and making responses using your hands rather than just reading back instructions directly to ATC. Also, the bulk of the system takes up space in the cockpit that is used for kneeboards, charts, and approach plates. That could be an issue seeing how the cockpit is already a tight space. • Once again, the system is very easy to use when its the only thing to focus on. For me	• Implementing the voice was beneficial because I was able to listen and do the instructions (adjust headin bug, altitude, nav radios, etc). However, one thing I would suggest would be to implement a tone or chime that would alert the pilot if he or she has not responded to a command. At one point I thought that I had responded to a command but did not push the pilot command button adequately to send my response. Overall this is a great system, it declutters atc communications, and at the same time provides a more sterile cockpit and an ease of recording atc commands to the pilot. It is simple and easy to use. • The system seemed pretty straight forward for the most part. I believe a pilot being familiar with the differences between the readbacks is of high importance since I did readback roger rather than wilco once. It would be helpful if a response back to incorrect response to ATC was sent so the pilot could correct the error. The system overall seems easy to get familiar with if pilots don't look down too long at the device and lose sight of flying the aircraft. • I disagree with A because its easy to learn the set up but it requires a new kind of

Suggestions regarding the ease of using the System.	
looking at the approach plates is looking down to long. For the text only version it required me to have my head down even longer to reciece a message. I would like a system that gave lengthy clearances so I didnt have to write it down, but for every little instruction I thought it was a little overboard. I feel like a quick instruction requires more work do send a text back and forth than to actually just say it. • The system was not awkward to use. I do not believe the average pilot would need to learn a lot of things before they could effectively use the system. • It was very user-friendly and very easy to use • I think that the system is easy to use although it requires a lot more concentration than talking directly to the controller. • It felt akward to have so much heads down time just to reply to a clearance • System was farily intuitive on its own. With a short briefing (less than 1 min), all functions were adequately explained, and I felt comfortable and confident using the system. • The system is very easy use! In no way did it feel awkward to use other then you were not talking over a mic to the controller. There should be nothing to learn to be able to go from "todays" voice comm to the cpdlc except for maybe learning troubleshooting if the system shuts down or freezes while in flight. • I think the majority of people would be able to use this system quickly. I did not find the system awkward to use It came to me very naturally I think	flying to control the airplane...its another distraction in the cockpit B. I would not want to use this system unless there were serious training criteria and if there were less buttons to press(eyes need to be more focused on instruments) C. I didnt need to learn alot about how to use the system, i just need to learn how to fly while using it • very easy to use • I believe that the system was easy to use and that it would not take much training to get used to the system. • System intuitive with no previous instruction. With short briefing (less than 1 min), I fully understood how to work the system and had no problems in flight. Voice prompts synced with text only further enhanced usability during flight. I felt comfortable and confident in using the system within a few minutes. • After flying with the ystem for a 3rd time it felt almost second nature just as easy if not more easy to communicate with ATC. The only thing I would like to do before going flying with device is learn the system malfunction and how to troubleshoot it the device shutdown or froze. Also learn the ATC procedures if that where to happen in flight. • The only detractor I see with stating that most people will learn to use the system quickly is that there are very many older people who may have trouble or people that have trouble with vision etc. I found the system awkward to use only because of all the cable and makeup of the kneeboard. If there was just the electronic device for me to mount or hold I think it would be much less of an awkward arrangement. I

Suggestions regarding the ease of using the System.	
• It didn't feel awkward to use the equipment nor did I feel the need to have prior to training to understand it. • Nothing other than a brief instruction to use the system was needed • Easy to use and see. At times, looking down distracted my flying but not drastically. • It is very easy to learn • This system is very intuitive and after only 3 flights with it, I would actually perfer to use to over the current ATC verbal system. It allows the pilot to focus his attention on the setup of the avonics in the holds and ILS approaches and is a reference to confirm the altitude instructions • The system was easy to use, and felt like a normal knee board. • I would like to note that as a CFII in the local DAB area the scenerio i flew today i have done countless times. i knew what clearance was coming, even which headings to expect at times. this significantly minimized the amount of time i looked at the CPDLC touch screen box. I was also able to fly approaches i have flown countless times- again, minimizing my time spent looking at the log box and spending more time flying. Due to the fact that it was IMC, i could not look out for other traffic. To really gauge the effectiveness of this device, the experiment should be conducted in a scenerio in an unfamiliar area, with approaches and instructions the pilot has not seen before. My understanding is this device is being researched to be implemented in actual aircraft. without a two man crew, or, someone like myself extemely familiar	felt I could just pick up the device and go. If it had just been handed to me without any instructions I feel I could have interpolated what each button on the device was for. • The system was easy to use and did not seem to require additional training to be understood. • It was not difficult to use, but it created a higher workload. Division of attention and creating a list of priority is required • Easy to use and learn. • This was an extremely helpfull and efficent way for the pilot to interact with ATC. The only issues I would have with the device is human error which I mistakenly did. I stopped the ATC button from blicking, yet did not replay to the message. This caused me to recieve the Vectors for the ILS 7L approach late and I needed to be promoted by ATC to correct the sistuation. Additionally, it is possible that older pilot generations will not be able to interface quickly and properly with the device, yet this should not discourge is developement as it is a very useful tool when used correctly • I felt as if the system was easy to use and did not require much instruction prior to use. • I again would like to point out that i have flown this given scenerio countless times as a CFII based in DAB. These are second nature flight maneuvers in an aircraft i fly six days a week. The real question is whether i newly-minted instrument pilot, flying his first IMC approach into an unfamiliar airport, single pilot, in a new type aircraft, could handle this. as a CFII, i

Suggestions regarding the ease of using the System.	
with the area/instructions/approaches/aircraft, this is just another distraction that will create another hazard for pilots. As an instructor, i would not feel comfortable knowing there may be a pilot flying his first IMC approach ever, into an unfamiliar airport, in a brand new type aircraft, single pilot, already over stressed. while that is a worse case scenerio, thats what should be tested. not someone who can fly these approaches eyes closed in an aircraft that he teaches in six days a week. • Unclear if ATC wanted me to ignore the cpdlc momentarily or just for that single message • A. I feel older pilots would have a trouble trying to learn on the new technology, also I feel student pilots could be easily distracted by whats in the box apposed to what is outside the airplane. For me it took the first 4-5 minutes using it to pick up the system. B.Little bit large but reasonable C. Took most of the first flight to feel confident using the machine • The system was cumbersome but not awkward. A better mounting location would be preferable. There is not too much to learn regarding function of the system. What I would want to learn about is the what if scenarios if CPLDC and voice disagree or other scenarios. • It is still awkward to use this system because it takes time to read the message and takes time away from focusing on the instruments. While talking over the radio, we can easily not take our eyes off the controls and instruments while still responding to ATC.	am concerned this device creates just another distraction in the cockpit. I would not feel comfortable with other inexperienced pilots using this device while flying IMC or VMC in an unfamiliar area. • Not awkward just cumbersome. The background information and disagreement procedures I would need to cover but not the function of the system. • The system was very user friendly and easy to pick up. • Computer generated voice made it infinitely easier, since that is what I'm used to from ATC. However, the head movement to look down was a problem again. • The system is pretty straight foward. I can see some problems with people not knowing when to speek if they have an unusual problem but should be ok with proper instruction. • I found the system easy to use but image it would be a difficult transition in the real world application.

Suggestions regarding the ease of using the System.	
• The system is easy to use. I often found myself looking at the log to double check the instructions which is something you can not do with voice communications. This was helpful as a pilot to ensure no mistakes are being made. • Awkward at first and can get in the way of using checklists. Would be MUCH better if it were panel mounted and the head could be up and eyes in the direction of flight instruments. • I can see how it might be confusing when the controller asks you to disregard an upcoming message. However, it was really easy to learn and should not be a problem. This system is really good for easing communication congestion and I love that it alerts you when a new message appears. • I would not want to fly with this system in GA airplanes	

Table 12. Comments regarding use of the log window during flight.

Briefly describe how you used the log window during flight.	
Text Only	**Text + Speech**
• I used the log window to remind of the instructions that were previously given. For example, I used it mostly for remote memory items such as headings. • scanned previous commands from atc to verify radar vectors for the ILS 7L • Reviewing instructions and readbacks • clearances etc • I used it to review past communications or to see current ones. • To verify clearence information if I was not sure of them • To review clearances and altitudes.	• just to reference rote headings. but other than that no. • to verify atc commands • To confirm my answers and to confirm instructions • it was a way for me to not write down clearances etc. • Used to review communications. Very helpful feature. • To refer to clearances. • I used it to confirm clearances. • I used to double check previous clearances and make sure that I my response was

Briefly describe how you used the log window during flight.	
• It made it easy to review previous instructions to ensure accuracy • Used to verify altitude assignments and clearances after they were acknowledged as a form of "double-checking" • Just want to double check the holding procedures I was issued for the OMN VOR. • Just to check over and make sure I had done everything correctly. On one occasion I noticed that I had neglected to send one reply and the log window helped me determine that. • to refrence prior control instructions • To remind myself what the clearances were and to verify I was flying as cleared • At some points of high workload it was easier than voice communication to tap on the message received, see if it required immediate action, and fit it in the list of priorities at hand if it was not. It also served as a useful tool in double checking received information without having to call ATC again to confirm. • Verify instructions • to verify holding instructions • I reaffirmed the clearences given by ATC. For example cleared for the approach, and certain headings. just a double check made me feel more confident in my flying • Used to remember holding instructions, and other ATC directions • I used to verify the previous ATC instructions • To recheck atc instructions • I used it to verify holding instructions, altitude and heading assignments. • to check what ATC was telling me	appropriate • veify clearances • To double check a clearence Issued • For the OMN VOR Hold I referred back to it to see if ATC had specified what type of turn or side to conduct the hold on, among other less outstanding times. • I used it as a quick refrence to controle instructions • To check what my last clearances were and make sure I was flying them • To comply with instructions, to double check any doubts I may have had, to increase situational awareness by planning for future instructions such as "climb to 3000' " at the OMN VOR. • Holding instructions, altitude reminders • just to verify a few times.. probably used it twice at most • reafirm holding altitudes and clearences • Recall ATC instructions • I used it to verify my heading and altitude changes as well as holding and ILS intercpet instructions • i used the log window to verify instructions. • To reference holding instructions, altitude/heading assignments • confirming an altitude • To double check actions, speech w/ text helped reduce ammount of time looking at the screen greatly. • reference memory • To see previous instructions and verify that what I remembered was in fact correct • Used it to double check previous instructions • headings and altitudes

Briefly describe how you used the log window during flight.	
• to confirm an altitude/heading • Just to see what the responses looked like. • After responding to clearence, I would do approatie action then double check my actions in the Log window. • Referencing the numbers on the screen to confirm my thought and memory. • To verify that the information I remembered was correct. • review previous instructions • Making sure i was turning to correct headings and climbing or descending to correct alt. • Used it verify my holding instructions, altitudes, and HDGs. • Made sure that I had the right heading and altitude. • check clearances	• Verify I was following the instructions (correct HDG etc.) • Made sure I was flying the right headings and altitude. Also for the spelling of the intersection. • To confirm headings or altitudes

Table 13. Suggestions regarding the computer-generated speech.

Suggestions regarding the computer-generated speech.
Text + Speech
• Rate of speech can be better. It seems a little bit faster would make everything smoother • The voice was easy to understand but it seemed was somewhat patchy, or broken in some spots. "maintain 1600 until established.......on the localizer.....cleared ILS 7...L" • I think the voice to me sounded very computer like but I feel that there are some people that have a monotone voice such as that and in a high workload environment may get confused. • There should be an option to control the loudness of the voice. • With max volume, and airplane volume, the computer voice was just about audible... i'd have it louder if i could. Speaking rate: i personally would prefer faster speaking COMMs, but this is a preference. • I felt the computer-generated speech was a little too soft. Whenever I heard the computer-generated speech, I immediatly stoped listening and just looked at the computer screen.

Suggestions regarding the computer-generated speech.
• The rate the voice gave instructions could be speed up. I found myself wanting to hit wilco before she had finished.

Post Experiment Open-Ended Responses

Responses in Tables 14-21 pertain to the post-experiment survey.

Table 14. Comments regarding the helpfulness of the text display.

Additional comments to "The text display is helpful."
• It is helpful because you can reference your instructions from time to time if needed. In congested airspace, the text display would be the most helpful.
• The textual command is helpful because it allows further reference if necessary to verify a command
• All pilots loose track of instructions and it is nice to have them in front of you automatically rather than constantly writing them down.
• Can be a little bigger as to grab the attention of the pilot/user quicker
• I like the white on black display.
• Text display is a good tool to use for ATC clearances. It allows the student to verify what instructions have been issued and what they acknowleged. However, this could become a crutch for some students, and when they are in the real airplane without this device, their memory will be their only tool. Students should still be encouraged to write down clearances and NOT use the device as a replacement for written information or their memory.
• It is a great benifit because with todays atc system it realies on memory and writing down all clearences. With this you have the clearence to the sentence of what atc issued. This could help cut down on alot of mis communications between ATC and pilots.
• the log box in particular was handy. It allowed me to confern atc instructions with out having to ask they repet them.
• I frreqeuntly referred back to the log to remind myself what my clearance was.
• By using text display it is sufficient for the pilot to accept the information and comply with it, which avoids the step of reading back extensive instructions which not only take up the pilot's time but may increase workload.
• I am used to current procedures, this helps to look at instructions, but hurts because it adds to the workload
• its nice to have a record of atc instructions for pilot verification

Additional comments to "The text display is helpful."
• It allows the pilot the confidence that he is properly flying the right heading and altitude
• Having the atc instructions infront you you prevents me from having to write them down, therefore saving me time and possible miscommunication.
• you are able to check ATC instructions at anytime
• text display is helpful if it contained larger font, and less information shown at one time.
• Text was useful, could use a little bit of space between messages in Log box.
• Good backup since memory and comprehension of voice are limited.
• This is attempt #2, the first survey crashed. The text alone was very difficult since it involved taking my eyes from outside the airplane and instruments, down inside the airplane. While during instrument conditions this may not be all that bad, in VMC, I would rather look outside the airplane for safety.
• As a pilot the text helps to eliminate any misunderstanding with instructions.
• The message should flash in yellow when it hasn't been responded to within a min
• Nice having it automatically log the instructions to refer to during flight.
• It is a lot more effecient for pilots to have a copy of instructions on a computer display rather than trying to write everything down on a piece of paper while trying to fly the plane.
• I liked to display to check clearances

Table 15. Comments regarding the computer-generated speech and text display--helpful.

Additional comments to "The computer-generated speech in addition to the text display is helpful."
• This was the best part because the pilot doesn't have to take their eyes off the aircraft's attitude. If we were flying in turbulence or partial panel the last thing we would want to do it look away from our instruments.
• The speech allows the pilot to do the necessary actions to complete the command rather than having to divert his attention to look at the command on the screen.
• The speech is a good addition but having the display is even more helpful to interpret.
• Good and easy-to-understand synthetic voice.
• The computer-generated speech makes the sim experience more realistic. I would like to see this implemented to the sims in the near future. It is a "real-world" challenge to sift through the radio chatter for your callsign. Especially while flying IFR in a single-pilot environment, it makes the whole experience much more beneficial for the student. Similar sounding callsigns are a great idea to keep a sharp ear.
• This alerts the pilot that a clearence has been issued and that can read it on the screen the same time it is being read to them for double sitution awareness.
• I thought the text was helpful but not nearly as much as the voice was. I consider myself to be able to understand and comprehend the instructions much more accuratly and quickly

Additional comments to "The computer-generated speech in addition to the text display is helpful."
when they are spoken. Also, I think it detracts time away form flying the airplane when you have to use your hands to repond to something. • with out the computer generated speech reading long control instructions was a little cumbersom. • It's helpful when the voice does not contradict the text - ie it should read exactly what the text says • Audio is needed. It is much harder without it • Didn't even notice in the second scenario that there was no computer generated speech involved. • it just reaffirms the instructions and allows you to keep your eyes on the instruments • It should be constant or not at all though, not random • It is a useful addition to the system, yet is not a neccesity • having only text means more heads down time for the pilot. having the voice means the pilot can act while still looking at the flight instruments and then just verify his response via text • keeps your head up and not down • Every transmission should have computer-generated speech. • This helped minimize time looking down at the machine ten-fold. It was like hearing ATC talk normally. • Having the voice lets one focus on the instrument during critical phases of flight. The voice lets me fly the airplane and then stare down to confirm the text. • The speech made it a lot easier. • I am use to hearing my instructions and utilizing that sensory organ. Combined was a much more enjoyable experience and easier to comply with instructions in a timely fasion. • It is cool, but I'm not sure if it is effective because the pilot is still going to look down and read the text anyways.

Table 16. Comments regarding the computer-generated speech and text display--distracting

Additional comments to "The computer-generated speech in addition to the text display is distracting."
• It would be the same as ATC instructions so I do not see why it should be a distraction in the cockpit. • I think the combination of the two is helpful. • Both are useful. • Very Helpful! • I welcomed the computer generated speech and wish I could respond and have it transcribe my speech to make it easier. • see above • It can be distracting having both when the voice isn't talking as fast as I can read. When that happens I have to decide which to pay more attention to - my ears or my eyes - and that decision takes some mental energy that I could otherwise have been using to scan or control the plane or anything else. • The computer-generated speech makes the equipment easier to use because it decreases head down time. • I think it helped remember the instructions a little bit more but not much difference. Was not distracting to me while I was flying. • It allows the pilot to understand that a message from ATC is recieved and adds in situational awareness • I think with a system like this it is nice to also hear the voice. • for long clerances both work well • Having to read the text is more distracting and time consuming when my attention is need elsewhere throughout the cockpit. • Good addition to it. • helped to keep my attention to flying the plane • I'm not sure if it is effective because the pilot is still going to look down and read the text anyways.

Table 17. Comments regarding preference for text display only.

Additional comments to "I prefer the text display only, without the computer-generated speech."

Additional comments to “I prefer the text display only, without the computer-generated speech.”
• for reasons stated in the above comments • The speech is an addition but in my opinion not needed since the pilot is chimed upon instructions from ATC and it's right there on the tab. • Voice limits head down time to read the ATC instructions. • I think I can see the benefits of both, with one being more useful VFR and the other IFR. Same goes for high workload environment vs low workload environment where voice might be distracting. • The speech as-is does help, more for shorter clearances than longer ones. With some tweaking of the pronunciation and pacing on longer clearances it would probably be more useful then too. • The computer generated speech decreases the time spent scanning the display, thus allowing more attention to be dedicated to the instruments. • Either way was fine with me. I don't think it made much of a difference to me complying with instructions. • I like having both for increased situational awareness • THe computer-generated speech is an effective addition to the text display • more heads down time.... NOT GOOD. • Too much time looking down and not what's infront of you. • Like having both. • I like them coupled but would like to have the speech alittle faster

Table 18. Comments regarding preference for speech display only.

Additional comments to “I would prefer the computer-generated speech only, without the text display.”
• They're both necessary. The speech is great beacuse you don't have to take your eyes off the flight instruments. • the text is necessary to check and verify the command and helpful for latter referece • It seems like the main advantage of this system is to loosen the workload on ATC and pilot as well as to always have the information available for review rather than writing instructions down. This would not be a good idea. • The text is much more appropriate than the CGS..if anything CGS should be accompanied by the text for better use • I like having the combination of the two. • The text provides something for the pilots to look back on if there is any confussion without cluttering the radio frequency to the controllers • I honestly liked both. they both have pros and cons, but I think the more ways the

Additional comments to "I would prefer the computer-generated speech only, without the text display."
information is presented the better prepared the pilot will be. • the comanation of both the text and speach work well to gether • The text is very useful as a memory aid. I'd definitely want to keep that. • The redundant system of text and speech decreases the chances of misinterpreting information. The two components work well together. • Both are helpful. Text was useful to review instructions that may have been forgotten • Without the text is like real ATC communications but how would you reply via the CPCDL without it sending you text and just speech? I think using this device you need to have the text no matter what, the speech would be the variable. • If you have just the speech it is just like talking to ATC directly. Whats the point? maybe get rid of accents, but not worth the upgrade costs • The Text display is the best innovation of this new system • I do not like the additional distraction of the text box. taking the few extra seconds to look down, read, choose response, and send, not counting if you have to tap multiple times, means more time an unusual attitude/worst case scenerio could happen. takes away from situational awareness • text helps with long clearances • The text would constitute as a backup. should be used in lue of the computer-generated speech. • Speech and text is the ideal condition. Reduces need for call back to atc for repeat instructions. • Having the text is a good backup function since voice can easily be forgotten. • Text is very helpful. • It's nice having the text log there to refer to. • It can be hard to hear, if I am going to listen to a voice, I'd rather just listen to the controller himself. • I would rather have a live person talking to me.

Table 19. Comments regarding preference for text+speech display (1).

Additional comments to "Compared to a live controller, I prefer to communicate with ATC using the text display AND the computer-generated speech."
• As the i was performing the tasks, i was thinking about all the congestion there is with readbacks out here in daytona's airspace. Also the number of times a controller has to repeat themselves; as well as the number of blocked transmissions beacuse everyone is trying to say something all at once. • it is simple, and there is a cut and dry standard to responses. A pilot does not have to worry

Additional comments to "Compared to a live controller, I prefer to communicate with ATC using the text display AND the computer-generated speech."
about how they respond to a command and what needs to be said. • It would take some time for me to get used to the concept. I think over time it could be effective if proper training is involved, but I've always been a fan of being able to talk to someone directly for instructions in flight. • I think that this system is very good for its current uses in oceanic communication although it is much less efficient during routine terminal ATC procedures. I think that it is still easier to talk to a controller than recive at text/speech message. • It helps to have a log of all the ATC instructions so there is no need to clarify later. Also it eliminates the "was that for us?" question between pilots. • There is no replacement for the live controller. Controllers speak faster than the computer and with different accents and sometimes use slang. The computer-generated speech is better than nothing, but still not a realistic simulation of real-world ATC. • No moodieness of the controllers if you read back something wrong. • Nothing beats the real thing. Just more personable. • Ease is about the same either way and at least no one can step on you when you acknowledge a texted clearance. • I think you still need the live controller for traffic avoidance to an extent. You might not get the text message in time in a mid air situation that requires immediate diviation. But the text is good because you will always have it there on your lap in case you forget the instructions so it will reduce radio communications with pilots having to ask for the instructions again because they didn't hear it the first time. • ATC can be asked if there is a question or situation, but the text info is a great tool. Highly recommended • I do not like the additional distraction of the text box. taking the few extra seconds to look down, read, choose response, and send, not counting if you have to tap multiple times, means more time an unusual attitude/worst case scenerio could happen. takes away from situational awareness. Communicating with audio and voice does not take away from the pilot's scan. • It helps the pilot focus on things in the cockpit. Having the device allowed me to focus on other things and not miss a radio call because I wasn't constanly scanning the radio. I was able to jump to attention when hearing the chime of the device. • A live controller can give communication is a much more dynamic tone. I would much rather have a live controller given the choice and if it was not a burden. • Still prefer to talk to a controller rather than using this system. • This really depends on the operation and phase of flight. Most of my flight operations a live controller is extremely helpful especially when it comes time ask them from PIREPs of aircraft ahead on the route or about radar information. TRACON controllers also do a really good job of taking requests and giving out various information. I would LOVE to have a real controller and text. As for routine instructions (HDS, altitudes, etc.) the systems seems

Additional comments to “Compared to a live controller, I prefer to communicate with ATC using the text display AND the computer-generated speech.”
effective. But when the situation becomes abnormal or you have special requests or trying to get some information, it seems impractical.

Table 20. Comments regarding preference for text only display.

Additional comments to “Compared to a live controller, I prefer to communicate with ATC using ONLY the text display WITHOUT the computer-generated speech.”
• Again, the speech helps to prevent diverting attention of the pilot to look at the screen before performing duties relaed to the atc command
• Again I'd have to get used to the method of communication, but I do not believe the computer-generated speech is needed at all.
• I liked both and felt between the 2nd and 3rd scenarios that I was 'missing' something, which turned out to be the speech element.
• see response to #4
• Both with and without worked for me. It still got the same message across.
• Although it can be done, and just as useful, the speech did help a little bit. Maybe have the speech available as an optional upgrade.
• The computer-generated speech device was an added bonus to the text display yet, I as a customer would not pay an additional price to have the voice.
• STRONGLY DISAGREE. I do not like the additional distraction of the text box. taking the few extra seconds to look down, read, choose response, and send, not counting if you have to tap multiple times, means more time an unusual attitude/worst case scenerio could happen. takes away from situational awareness.
• Horrible idea..
• The controller can add an element to which text by itself cannot. The text is nice since there is no garble or memory issues, but the controller interaction can be beneficial.
• This made things easier for me becuase I worried less about missing a call from the controller and I did not have to write as many things down on the notepad. I could focus on flying the plane more.

Table 21. Comments regarding preference for text+speech display (2).

Additional comments to “I prefer to communicate with ATC using the text display and the computer-generated speech, rather than the text display alone.”
• once again, I believe that text and speech go hand in hand and that it is required for check and verification.

Additional comments to “I prefer to communicate with ATC using the text display and the computer-generated speech, rather than the text display alone.”
• Text alone is fine for me. It's right there in front of me and available anytime I need to view past instructions. • Overall, if the system where offered with the voice display, the pilot would have increased Situational Awareness with the computer generated speech device • I do not like the additional distraction of the text box. taking the few extra seconds to look down, read, choose response, and send, not counting if you have to tap multiple times, means more time an unusual attitude/worst case scenerio could happen. takes away from situational awareness. • The same applies to ATC, if you're not listening to the machine and need repeated instructions then the entire point of this device is lost. • The combination of text display and speech went very well. I felt confident and confortable using the system.