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Abstract

Text messaging has been the cause of numerous vehicle accidents, and studies have been done in simulated driving tests to support this. The use of iPads in the cockpit has increased since the technology has been introduced and the proposed research seeks to investigate whether an iPad causes distraction for pilots. This study explored the differences in two different forms of communication – verbal and texting. Primary errors were in altitude deviations during text communication. Text messaging in the cockpit is not necessarily a distraction for pilots, but takes away from the scan of instruments resulting in errors.
Exploratory Study in Pilot Communications: Verbal versus Texting Communication

Distractions in the cockpit can sidetrack a pilot and can lead to disastrous mistakes. All pilots are vulnerable to error, even if they think they are not. Pilots may seem amazed when an error occurs and may respond with: “…I have flown this airplane for 10 years and never set this (pressurization control) wrong. I am unsure how it happened except that possibly I was interrupted during my preflight check…” Distractions can also be affected by different levels of automation and the demands that airlines, fleets and routes have (Loukopoulos, 2001).

Drews, et al. (2009) identify in their research the impact text messaging has on simulated driving performance. The two objectives of their research were to establish the impact of text messaging in simulated driving on 1) driving performance and 2) safety. The researchers developed estimates of the impact of text messaging during simulated driving on accident rates. The study involved 40 participants who were each given two tasks to complete: a single driving test and a dual task of driving and texting. In the dual task, participants were given instructions to obey all traffic laws and to exchange text messages with the intent to plan an activity. A pace car was programmed to brake 42 times during the simulation and the participant reaction times were measured.

The study found that participants were 0.2 seconds slower to respond to the brake onset when driving and text messaging, compared to the single task of the driving-only condition. On average, text messaging drivers increased their following distance further than the drivers with the single task condition. Moreover, text messaging was found to impair both forward and lateral vehicle control. A total of seven collisions occurred, six of them during the dual task condition. Only one accident occurred during the single task. It was observed that text messaging drivers
significantly increased the distance between themselves and the lead car. This is a common practice among drivers who text and think it reduces their chance of an accident, but results from the study, including six collisions, appear to discount the minimal chance of an accident.

Drews, et al. (2009) also found that subject reaction time depended on the text being sent or received. Braking times were increased when participants were reading the text messages, versus sending the text. The authors anticipate future studies to investigate whether reading text messages produces greater impairments in test subjects. Text messaging while driving has a negative effect on drivers’ ability to maintain a central lane position. When participants went from a single-task to the dual-task, they changed their text messaging behavior by shortening the length of their replies and typing at a slower speed. Texting shorter messages did not mitigate the effects of text messaging while driving (Cheung, 2010).

In a driving simulator experiment led by Tsimhoni, et all (2004), it was investigated whether entering addresses into a navigation system had a difference in driving performance. Participants drove on roads with a visual while entering addresses. There were three address entry methods explored: word-based speech recognition, character-based speech recognition, and typing on a touch-screen keyboard. The shortest task time was word-based at 15.3 seconds. The next was character-based at 41 seconds and then touch-screen keyboard at 86 seconds (Tsimhoni, 2004).

NASA Ames Research Center has done a study on accidents and why crews are vulnerable to different kinds of errors (Aviation Safety Reporting System, 1998). Researchers found 21 different types of tasks that crews ignored while attending to another task from a total of 107 Aviation Safety Reporting System reports. Crews failed to monitor the actions of the pilot
flying and failed to monitor the position of the aircraft 69% of the time. Thirty-four types of activities distracted the pilots and of those, 90% of the activities fell within 4 categories: (1) communication (discussion among crew or radios), (2) head-down work (programming FMS or reviewing approach plates), (3) searching for VMC traffic, or (4) responding to abnormal situations.

A study was done to examine the time to read electronic maps while driving. There were 20 participants, 10 young and 10 older. They were given a task to read one of the following: (1) identify the street being driven, (2) find the name of a cross street ahead and (3) locate a particular street. The results showed the response time for Task 1 on-street to be 1.8 seconds. Task 3 had the highest response time at 4.3 seconds (Brooks, et al., 1999).

Dismukes, Young and Sumwalt (1998) noted that attempts to reduce vulnerability to interruptions and distractions in the cockpit, should take into account the following:

- Recognize that conversations are a powerful distracter.
- Recognize that head-down tasks reduce one’s ability to monitor the other pilot and the status of the aircraft.
- Minimize conflicts by schedule/rescheduling activities during critical moments in flight or taxi.
- When two tasks need done at the same time, do not spend all your time on either tasks.
- Treat interruptions as red flags.
- Assign pilot tasks, especially in abnormal situation (Dismukes, Young & Sumwalt, 1998).
Donoghue (2002) states that when there is a shared understanding between two or more people, communication is taking place. There are five stages to make this communication process successful between the pilot and air traffic control (ATC): (1) Message transmission, (2) Reception, (3) Comprehension, (4) Acknowledgement and (5) Execution. Any messages sent by ATC to pilots, must be read back to ATC before execution. Communication is a critical aspect of aviation. The National Airspace System is becoming more and more congested, and communication between ATC and the pilot(s) in the cockpit must be increasingly effective. To help with the communication problems in the National Airspace System, data-link has been developed. This type of technology enables ATC to communicate with the flight deck by up-linking text messages to the flight management computer (FMC) on the aircraft. Messages appear on the control display unit (CDU) in the cockpit and are then read by the pilots. Currently, data-link is being used during transoceanic flights, for which there are not a large number of tasks being done by the pilot. It is used in conjunction with the radio and is not anticipated to replace radio until further approval for domestic use, as evaluated by the Federal Aviation Administration (FAA).

Data-link has raised concerns whether pilots process information differently in speech versus text formats. Information from instruments, displays, and other flight crew, radio traffic, navigation, planning, and visual scanning of the environment is continuously being evaluated by pilots. The memory system has three major functions: information (encoding), storage, and the retrieval of information. The three types of memory are: sensory memory, working memory, and long-term memory. Early studies showed that individuals are unable to recall unrehearsed information in working memory after 20 seconds (Risser, 2004).
Datalink has been suggested to be a way to reduce radio congestion and may reduce read back and hear back errors. There has not been research that is clear to whether datalink will impact pilot procedures and pilot-ATC communications during surface operations. There have been enroute studies that have revealed that pilots are slower to respond to datalink than voice commands. A study of 18 crews, participated in an Advanced Concept Flight Simulator (ACFS). A datalink interface was added to the ACFS display of the B777. The message that arrived was annunciated by an aural alert (chime) and a visual alert on the upper Engine Instrument Crew Alert System (EICAS). Both pilots were able to see the text displayed and had an option to ‘Accept’ or ‘Reject’ if not able to comply (Hooey, et al., 2000).

The results indicated, that in the current operations, there was no difference except in one area. The number of radio transmissions were reduced very little when datalink was deployed. In the revolutionary approach, there were many advantages over current operations including: increased taxi efficiency, reduced radio transmissions, and reduced duration of radio use. It also indicated possible problem areas to make sure safety was not endangered. There was a negative impact on ATC-pilot communications when ATC gave instructions via datalink only. The report mentioned further investigation is needed to understand why this had a negative impact (Hooey, 2000).

Today, the exchange of information between pilots and controllers is most often carried out by radio. Voice messages carry clearances, advisories and warning information. There have been problems with having to rely on aural information transfer because of congestion on radio frequencies. This can cause messages to be missed or blocked by other transmissions, which then requires that the message be repeated. Kerns (1991) conducted a study of voice and data-link exchange between ATC and the cockpit, and found that crew response time from a pilot’s
perspective, differentiating between task times for voice compared to data-link communication, is not great. He found that data-link saved time and could reduce some of the workload for the pilot by replacing voice communication through off-loading routine communications to the data link. The average response times were determined to be about 10 seconds. Kerns listed three types of data-link applications:

- Non-control information messages – this is for informational use only. It includes weather-related observations and forecasts, reports on the status of facilities and equipment, and routine position reports.
- Strategic messages – concern the overall mission of the flight. This includes messages that are more time-critical, such as establishing the initial ATC clearance and revision to the initial clearance.
- Tactical messages – affect operating behavior and can be time-critical. Included in this category are: horizontal, vertical, or speed/time/delay instructions; procedure-based instructions; communications instructions; and traffic and urgent advisories (Kerns, 1991).

The combination of voice and data-link communications outperforms each one individually. Comparing the two media, voice communication is fast and flexible, and data-link communication is precise and concise. The reason for introduction of data-link communication is to reduce radio congestion at busy airports, decrease miscommunications between controllers and pilots, and a future goal is to shift the responsibility of maintaining safe separation between aircraft from controllers to pilots (Baldwin, 2003).
Donoghue states that when there is a shared understanding between two or more people communication is taking place. There are five stages to make this communication process successful between the pilot and air traffic control (ATC):

- Message transmission
- Reception
- Comprehension
- Acknowledgement
- Execution (Donoghue, 2002)

Any messages sent by ATC to pilots, must be read back to ATC before execution.

Communication is a critical aspect of aviation. The National Airspace System is becoming more and more congested so communication between ATC and the pilot(s) in the cockpit must be increasingly effective. To help with the communication problems in the National Airspace System, data-link has been developed. This type of technology enables ATC to communicate with the flight deck by up-linking text messages to the FMC on the aircraft. Messages appear on the CDU in the cockpit and are then read by the pilots. (Donoghue, 2002).

The researcher has look at the current literature about text messaging and driving, and wants to do a similar study, but using pilots flying and texting. This exploratory study will use an iPad to text, and investigate if it is a distraction to pilots while flying. The researcher hopes to record the types of errors, if any, pilots make while texting and flying. With the iPad being used more frequently in general and commercial aviation, it is important to do research, so there are fewer errors.
Method

Participants

For this study there was a sample size of 10 Purdue University flight students. It was not based on age, ethnicity or gender, but on level of flight certification. FAA Instrument-rated, private pilots were the minimum certification requirements for this study. To recruit students, a brief explanation was given in a classroom and sheets of paper were passed around for volunteers to write their contact information and times of availability. Participation was voluntary.

Apparatus

Purdue University-owned Cirrus simulators, for single pilot operations, were flown by the participants for this study. The iPad was chosen because new applications have become available for pilots that are very useful for everyday tasks and the iPad is increasingly found in the flight deck of general aviation and commercial aircraft. There are now apps for weather, approach charts, checklists, and flight manuals. Each participant used the iPad in another form - communications. An iPad was provided to the participant to use to retrieve and respond to information given from air traffic control. After the simulation was complete, the participant was given a short survey asking their preference using radios to communicate to ATC versus using text to relay the same information on the iPad.

Procedure

There were 10 instrument-rated students who participated in this exploratory study. Each participant was given time to type messages on the iPad, if needed, before the experiment begun and to practice using the device. Each participant was given instructions to not use the autopilot during the study and told there would be two different approaches. Five participants started using verbal communication and five started using the iPad to text. The participant received the text on
an iPad from a cell phone and replied back on the iPad. Then the form of communication was
switched for the second approach. Weather was set to marginal visual flight rules (MVFR) and
clouds were low stratus. A pre-determined script was used for each participant and altitude,
speed, heading and their response were recorded.

Results

This study explored the differences in two different forms of communication – verbal and
texting. Primary errors during text communication were altitude deviations. Differences in
altitude between the participants, comparing both flight scenarios, can be found in Table 1. There
were 10 participants total, but only 9 sets of data were used in the results because one was
discarded due to using autopilot during both flight scenarios. Altitude deviations in feet were
averaged during the flight. Speed (in knots) and heading (in degrees) were also averaged during
the flight. Comparing the two sets of data between text and verbal communication, altitude
showed the greatest deviations. Heading only differed by 1 or 2 degrees in each comparison.
<table>
<thead>
<tr>
<th>Text Communication</th>
<th>Verbal Communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude</td>
<td>Speed</td>
</tr>
<tr>
<td>Participant 1</td>
<td>43</td>
</tr>
<tr>
<td>Participant 2</td>
<td>34</td>
</tr>
<tr>
<td>Participant 3</td>
<td>57</td>
</tr>
<tr>
<td>Participant 4</td>
<td>38</td>
</tr>
<tr>
<td>Participant 5</td>
<td>45</td>
</tr>
<tr>
<td>Participant 6</td>
<td>41</td>
</tr>
<tr>
<td>Participant 7</td>
<td>103</td>
</tr>
<tr>
<td>Participant 8</td>
<td>125</td>
</tr>
<tr>
<td>Participant 9</td>
<td>60</td>
</tr>
<tr>
<td>Averages</td>
<td>60.7</td>
</tr>
</tbody>
</table>

Table 1: Data from each study; altitude and heading are the deviations from the given flight clearances

The post-experiment survey (see Appendix) was given at the end of the flight. Table 2, shows the responses of each participant. The question, “Do you feel safe if one texts while driving?” had a range from 1 to 10 for each participant to choose. “1” meaning you do not feel safe and “10” means you feel very safe. There was no difference in flight performance between those participants who own an iPad and those that did not. Seven participants preferred not to use text in the cockpit, but 5 of those said in a multi-crewmember environment they would have no problem using text to communicate. The participants who said text should be used in a cockpit with multi-crewmembers were labeled as “MAYBE” in Table 2. The only “YES” in Table 2 said
text should be used as a form of communication, but that it would require different procedures than radio calls. One had no preference, but said it would be good to look into and that was labeled as “NOT SURE”.

<table>
<thead>
<tr>
<th></th>
<th>How often do you text per day? (in times)</th>
<th>Do you text while driving?</th>
<th>Do you feel safe if one texts while driving?</th>
<th>Do you own an iPad?</th>
<th>If no, are you familiar operating an iPad?</th>
<th>Should text be used in the cockpit?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant 1</td>
<td>&gt;160</td>
<td>NO</td>
<td>1</td>
<td>YES</td>
<td>-</td>
<td>MAYBE</td>
</tr>
<tr>
<td>Participant 2</td>
<td>80</td>
<td>YES</td>
<td>6</td>
<td>NO</td>
<td>YES</td>
<td>NOT SURE</td>
</tr>
<tr>
<td>Participant 3</td>
<td>20</td>
<td>NO</td>
<td>3-4</td>
<td>YES</td>
<td>-</td>
<td>NO</td>
</tr>
<tr>
<td>Participant 4</td>
<td>40</td>
<td>NO</td>
<td>2</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Participant 5</td>
<td>60-70</td>
<td>YES</td>
<td>7</td>
<td>NO</td>
<td>NO</td>
<td>MAYBE</td>
</tr>
<tr>
<td>Participant 6</td>
<td>80</td>
<td>NO</td>
<td>2</td>
<td>YES</td>
<td>-</td>
<td>MAYBE</td>
</tr>
<tr>
<td>Participant 7</td>
<td>&gt;160</td>
<td>YES</td>
<td>7</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Participant 8</td>
<td>80</td>
<td>NO</td>
<td>2</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Participant 9</td>
<td>20</td>
<td>NO</td>
<td>3</td>
<td>NO</td>
<td>YES</td>
<td>MAYBE</td>
</tr>
<tr>
<td>Participant 10</td>
<td>20</td>
<td>YES</td>
<td>5</td>
<td>NO</td>
<td>YES</td>
<td>MAYBE</td>
</tr>
<tr>
<td>Averages</td>
<td>71</td>
<td>NO</td>
<td>4</td>
<td>NO</td>
<td>YES</td>
<td>MAYBE</td>
</tr>
</tbody>
</table>

Table 2: Post-experiment survey results

**Discussion**

Exploring the differences in altitude shows texting does distract the pilot from flying the airplane while performing other tasks. Even with the differences in altitude and longer response times, text communication has some very useful benefits for pilots. The clearance is given electronically when using text and it can be referred back to at any time. The main error found
was a change in altitude, and this has to do with the focus taken away from the instruments to look at the iPad to text. In a multi-crewmember setting, this error is less likely to occur because one pilot is able to devote all of his or her attention to flying, while the other pilot texts back.

Phraseology was another problem because there was not one participant who responded back like another. An example of a text clearance given was: “Cleared to KLAF via direct RESAW direct, climb maintain 3,000, dep 123.85, squawk 4215, taxi 28.”

The following were responses during the study:

- “Accepted”
- “Clrd klaf resaw 3000 23.85 sqk 4215 taxi 28”
- “Roger that clearance ready for takeoff!”
- “CPR remain 3k 123.85 sq4215”
- “Cleared to Olaf via direct resaw direct climb 3000 sqwuak 4215, maintain 3000”

Figure 1, is an example of one participant’s response to the clearance. The researcher typed the text in the gray box from a cell phone, and the participant typed the text in the blue box from the iPad. Autocorrect had an effect on the responses as well. If text is to be incorporated into the cockpit, there will have to be procedures put in place, so the responses are the same across the board. Every person would need to have training on what is acceptable and not, and there needs to be standards for everyone to follow.
Recommendations and Conclusion

This paper was an exploratory study on the effects text messages, received and sent from an iPad, had on flying performance when responding to ATC instructions. The following are recommendations:

- Texting should not be the only form of communication between the pilot and ATC.
- Text should only be used in a multi-crew operation and/or with use of an autopilot.
- An application for the iPad should be created for ATC instructions. When a text clearance is received, there could be at least two options for the pilot to choose from, including “accept” or “reject”.
- Standards need to be established for phraseology when responding back via text.
- Simulator training using an iPad for text communication should be considered for all pilots.

For texting to be fully introduced in the cockpit there needs to be more research. In future studies, it would be interesting to look at the different flight experiences and determine how the response times and the changes in altitude differ. Although this study was limited to instrument-rated students, it would be worth investigating the effects of flight experience and time. Another variable to look at are those who use technology such as, texting on a cell phone or GPS usage, on a daily basis compared to pilots who do not. Most pilots have used some form of GPS, but the study might compare whether text communication makes a difference depending on the kind of technology one is used to using.

In conclusion, currently pilots and controllers communicate primarily by radio. Voice messages carry all clearances, advisories and warning information. Research has shown there
have been problems with having to rely on oral information transfer because of congestion on radio frequencies. This can cause messages to be missed or blocked by other transmissions, which then requires that the message be repeated. Currently, data link is being used in some limited settings. It was found that the errors differ when an iPad is used to respond rather than voice responses. The iPad was not particularly a distraction to the pilot in the cockpit, but it took more concentration to send the response to ATC, resulting in greater altitude deviations.
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Appendix

Post-experiment Survey

How often do you text per day?

NEVER  20 TIMES  40 TIMES  80 TIMES  >160 TIMES

On a regular basis, do you text while driving?  YES or NO

How safe do you feel if someone were to be texting while driving when you’re a passenger in a vehicle?

Not Safe   Very Safe

1  2  3  4  5  6  7  8  9  10

Do you own an iPad?  YES or NO

If no, are you familiar with how to operate an iPad?  YES or NO

Experiment (short answer; please be as detailed as possible)

Was it a challenge to go from radio calls to text or vice versa? Please explain.

Did you notice a change in flight performance? Please explain.

What types of errors do you think you made, if any?

Do you have a preference whether or not text should be used in the cockpit for communication? Why?