The Effects of Expertise and Information Location on Change Blindness Detection within an Aviation Domain

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THE EFFECTS OF EXPERTISE AND INFORMATION LOCATION ON CHANGE

BLINDNESS DETECTION WITHIN AN AVIATION DOMAIN

by

Dinorah Zárate

B.A., Flagler College, December 2002

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THE EFFECTS OF EXPERTISE AND INFORMATION LOCATION ON CHANGE
BLINDNESS DETECTION WITHIN AN AVIATION DOMAIN

by

Dinorah Zarate

This thesis was prepared under the direction of the candidate's thesis committee chair, Shawn Doherty, Ph.D., Department of Human Factors & Systems, and has been approved by the members of the thesis committee. This thesis was submitted to the department of Human Factors & Systems and has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Human Factors & Systems.

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Abstract

Change blindness is a phenomenon where the viewer fails to detect change in an object or scene during a visual disturbance. During a flight, a pilot samples multiple displays for information about the task at hand. It is imperative that the changes in the displays are being correctly viewed by pilots to ensure a safe flight. However, it is unknown how much change blindness affects pilots or if pilot expertise plays a role in change detection.

A change blindness experiment was performed with twenty four participants divided into two groups based on expertise. Expert pilots were defined as instructor pilots with an average of 952 flight hours and novice pilots were student pilots with an average of 80 flight hours. There were a total of 24 images that were presented to participants during a flicker paradigm that was used to induce change blindness and assess change detection within cockpit instruments by the pilots. Images were static depictions of the primary cockpit displays.

Results showed that there were no significant differences between expert pilots and novice pilots when detecting change in displays. The results did show that there was significant difference in location display. It was found that the ADI was the most commonly viewed display with other instruments slower in terms of detection. No difference was found for accuracy in all cases. Results indicate that future research is still needed in change blindness and aviation domain.
# Table of Contents

Abstract .............................................................................................................................. iii
Table of Contents ............................................................................................................... iv
List of Tables ...................................................................................................................... v
List of Figures .................................................................................................................... vi
Introduction ......................................................................................................................... 1
    Change Detection ............................................................................................................ 1
    Change Blindness .......................................................................................................... 2
    Theories ........................................................................................................................... 4
Aviation Displays ............................................................................................................... 6
    Attitude Directional Indicator (ADI) ............................................................................ 6
    Airspeed Indicator (ASI) ............................................................................................. 7
    Heading Indicator (HI) ................................................................................................ 7
    Altimeter (ALT) .......................................................................................................... 7
    Vertical Speed Indicator (VSI) ..................................................................................... 7
    Turn Coordinator (TC) ................................................................................................ 8
Scan Patterns ................................................................................................................... 8
    Basic-T Scan ............................................................................................................... 9
    Circular Scan .............................................................................................................. 9
    Vertical Scan ............................................................................................................. 10
    Inverted-V Scan ......................................................................................................... 11
Expert vs. Novice Differences ...................................................................................... 12
Hypotheses .................................................................................................................... 14
Methods ............................................................................................................................. 15
    Participants ................................................................................................................ 15
    Apparatus and Displays ............................................................................................ 15
    Design ....................................................................................................................... 17
    Procedure .................................................................................................................. 18
Results ............................................................................................................................. 19
Discussion ........................................................................................................................ 25
    Limitations .................................................................................................................. 26
    Future Research .......................................................................................................... 27
Conclusion ........................................................................................................................ 24
References ...................................................................................................................... 30
Appendix A: Demographic Information ......................................................................... 33
Appendix B: Consent Form ............................................................................................. 34
Appendix C: Debriefing Form ......................................................................................... 35
List of Tables

Table 1. Reaction Time..........................................................................................19
Table 2. Overtime Trials......................................................................................19
Table 3. Inaccuracy trials...................................................................................20
Table 4. Pairwise Comparisons.........................................................................23
List of Figures

Figure 1. Example of flicker paradigm ................................................................. 4
Figure 2. The six basic aircraft instruments ......................................................... 6
Figure 3. The Basic-T scan .................................................................................. 9
Figure 4. The circular scan .................................................................................. 10
Figure 5. The vertical scan .................................................................................. 10
Figure 6. The inverted-V scan ............................................................................ 11
Figure 7a. Standard instrumentation .................................................................. 16
Figure 7b. Displacement change of the ASI arrow .............................................. 16
Figure 8a. Standard instrumentation .................................................................. 17
Figure 8b. Bolding of #160 in the ASI display .................................................... 17
Figure 9. Expertise and location interaction ......................................................... 21
Figure 10. Average Expertise Means on Location .............................................. 22
Introduction

Failure to detect a change in our immediate surroundings may not seem like it would have serious consequences. However, when the failure to detect change results in events such as a deadly plane crash, the importance to detect change is vital. According to Jones and Endsley (1996) 76% of pilot errors are due to failure by the pilot to correctly perceive information when data is unavailable or difficult to discriminate or detect. Research by Haines (1991) demonstrated that air pilots in a simulator can be completely unaware of the presence of another aircraft in the middle of the runway when landing. Our ability to interact successfully with our environment depends greatly on our ability to visually notice and be aware of objects and events within the environment. As the world around changes from one moment to the next, we must depend on our capacity to detect the change in order to interact successfully within the environment.

Change Detection

Research has shown that people have a difficult time detecting some changes in an image or scene when the change occurs at the same time as a visual disturbance (Turatto, Bettella, & Umiltá, 2003). Due to the inability to detect changes during a visual disturbance any change to the visual world during those disturbances gets lost and thus we end up with a sparse and incomplete visual depiction of our surrounding (Rensink, O’Regan, & Clark, 2000). As a result, all that can be carried across scenes are a few details of a few items. Therefore, we end up with a sparse and incomplete visual depiction of our surroundings.

Change refers to a transformation or modification of something over time (Rensink, 2002) whereas change detection refers to the difference between detected and
undetected changes (Pessoa & Ungerleider, 2004). An example of change can be seen in
the weather and the way it changes from one season to another or the difference in
temperature from one weekend to the next. Change detection occurs so frequently that it
becomes commonplace until something occurs to signal a change that was missed. A
stoplight, for example, is a commonly viewed device and detecting the change in color is
important in guiding driver actions while driving. Change detection in a stoplight alerts
drivers when to stop, slow down and when to go. Without change detection driving
would be chaotic and dangerous. Yet change detection doesn’t always happen, producing
conditions in which important real-life events are missed; a phenomenon known as
change blindness.

**Change Blindness**

Change detection refers to the visual processes involved in first noticing a change
(Rensink, 2002). The ability to detect changes in an ever-changing environment is
beneficial and may even be critical for survival. Change blindness is the inability to
detect change in an image or scene under specified conditions. Change blindness most
notably occurs when the change happens at the same time as a visual disturbance. A
visual disturbance is a disruption of the visual scene. It can be anything such as a saccade,
flicker, blink or other such disruption and once the change has been detected outside the
disturbance it is later very apparent (Simons & Levin, 1997). Change blindness
undermines the assumption that the visual system constructs a complete and integrated
representation of the visual world across glimpses (Henderson & Hollingworth, 2003).
Human vision is active and intricate and our eye movements are an inherent part of looking at the world. Observers typically move their eyes three times per second in rapid saccadic movements (Henderson & Hollingworth, 2003). A saccade is a rapid, jerky eye movement which allows the gaze to shift from one object to the next. Eyes range over visual information in saccades. Once the eye has completed the eye movement, the eye hovers and fixates for about 0.2 seconds at one location while neural impulses are passed from the retina to higher centers in the brain (Kundell & La Follette, 1972) that are needed to program the next saccade. During fixations the saccades are smaller and involve minute displacement of the gaze. Gazes are usually unconscious and are guided by attention. Change to a specific area of a scene will go undetected if the change occurs during a saccade (Sekuler & Blake, 2002).

A flicker paradigm is a research paradigm used to investigate the effects of change blindness. The flicker paradigm consists of an original image A repeatedly alternating with a modified image A’, with brief blank fields placed between successive images (Rensink et al., 2000). The blank fields produce a change all over the image, which serves to mask the change as it happens. The observer freely views the flickering display until the change is noticed. The flicker paradigm offers the best opportunity possible for the observer to construct a representation favorable to perceiving changes in a scene because the changes are available repeatedly for long stretches of time (Rensink, O’Regan & Clark, 1997). However, in spite of the extended viewing that this paradigm provides, observers still experience difficulty detecting large changes within a scene even when they know they will occur. While assumptions have been made in attempt to explain such phenomenon it is certain that attention is a key factor.
Theories. The majority of research on change blindness supports the premise that focused attention is needed to detect change (Rensink, 2000b). This is because once focused attention allocated to the area of interest, change can then be perceived. Usually, change is accompanied by a motion signal which attracts attention to the location of change making it easy to see. Though, when the signal appears at the same time as other visual movements it produces a blur on the retina that causes the signal to be missed, inducing change blindness because of the lack of focused attention on the change (Simons & Ambinder, 2005). Attention is needed to fuse together features into representation of objects, which allow the observer to detect change (Rensink, 2000c; Simons & Ambinder, 2005).

Several theories have been developed in an attempt to explain the phenomenon of change blindness. Two explanations in particular are the theory of Central or Marginal Interest and the theory of Coherence. The theory of Central or Marginal Interest states
that objects of central interest in the field of view are detected more rapidly than changes of marginal interest (Rensink et al., 1997). In order to identify what elements are Central or Marginal Interest aspects of a picture or scene, a group of five judges are asked to give a short description of each picture before the experiment. Central Interest aspects are usually aspects that tend to be related to the theme of a picture and are mentioned by at least three out of five of the judges. Marginal Interest aspects refer to objects in a scene that are not mentioned by any of the judges (O’Regan, Deubel, Clark, & Rensink, 2000). According to research relating to the theory of Central or Marginal Interest, observers saw changes within a scene 60% of the time, with identification being higher and faster for those aspects considered of central interest (Rensink et al., 1997). Overall, observers took a long time to see changes regardless of category and even when directly fixating on the change locations. Therefore, the theory of Central or Marginal Interest cannot account for all failures in change blindness detection and as a result other theories have been developed. A common alternative theory that attempts to account for change blindness is the Coherence theory.

The Coherence theory emphasizes the connection between focused attention and visual perception. Coherence theory explains how focused attention can form a stable, coherent representation of objects over time and space referred as spatiotemporal representation (Rensink, 2000a). The spatial coherence of two neighboring mental structures means that they form part of the same object extended over space. The temporal coherence of two consecutive structures means that they form part of the same object extended over time (Rensink et al., 2000). The spatiotemporal aspect of the Coherence theory explains the utilization of the flicker paradigm in the investigation of
change blindness. Since attention is needed to detect change, coherent mental structures are only stable as long as attention is directed towards them. The theory of Central or Marginal interest and the Coherence theory indicate how attention might be allocated in an applied environment such as scanning an aviation instrument display.

**Aviation Displays**

The traditional instrument panel within an airplane cockpit is occupied with many different displays and gauges that may seem complex and confusing to the average person. However, when the panels are analyzed on even the largest airplane, the instruments can be narrowed down to most important and manageable displays, which are the flight instruments. There are six primary flight instruments in a traditional aircraft which provide vital flight information that are essential for flight.

![Figure 2. The six basic aircraft instruments.](image)

**Attitude Directional Indicator (ADI).** The ADI display is the only instrument that gives a direct and immediate picture of pitch and bank attitude to the pilot and it is
designed to indicate the aircraft’s position relative to the horizon. The information displayed in the ADI instrument reflects the “inside-out” perspective, which is composed of a moving artificial horizon and a fixed airplane. The “inside-out” perspective matches the pilot’s frame of reference, however when the pilot banks the airplane to the left, the horizon in the display moves to the right. Simulating what they are seeing outside the cockpit. The importance of the ADI display comes from the information of both pitch and roll that are necessary to carry out changes in lateral and vertical variations. The importance of this information to pilots is the reason the ADI instrument is the considered the chief focus on the panel by pilots.

**Airspeed Indicator (ASI).** The ASI display provides information referred to as indicated airspeed that provides the speed of the aircraft as it moves through the air.

**Heading Indicator (HI).** The HI display shows aircraft travel as it moves along a magnetic heading, which is specified once it is aligned with a magnetic compass. The HI display contains a circular compass card marked with a complete compass rose of 360° that rotates around a fixed model airplane. The airplane is located in the center of the display with its nose pointed toward the top edge of the instrument.

**Altimeter (ALT).** The ALT display is the most important instrument for vertical navigation. The altimeter relates the static pressure at the level of the airplane to a height in the standard atmosphere. By measuring the changes in atmospheric pressure, the ALT display provides the pilot with information about the altitude (in feet) of the aircraft above sea level.

**Vertical Speed Indicator (VSI).** The VSI display provides information regarding the rate of change of altitude as an airplane climbs or descends by measuring the rate of
change in the atmospheric pressure. The VSI display is also a useful instrument when trying to achieve a precise level flight.

**Turn Coordinator (TC).** The TC display provides information regarding the direction, roll rate and rate of turn of the aircraft. The TC representation is a set of wings pivoted in the center of the instrument, the wings move in relation to the direction of bank. The bank is specified by the extent to which the wings pivot relative to the central point of rotation.

Together, these six instruments provide the necessary information for pilots to fly the aircraft. Therefore, it is important that the information from these instruments are sampled sufficiently to maintain flight. This sampling can be obtained through visual scanning of the instruments.

**Scan Patterns**

Detecting change is particularly important for pilots when in the cockpit. Piloting an aircraft depends mainly on the pilot’s ability to detect change when scanning the instrument panel and reacting appropriately depending on the information that is displayed. Pilots are taught to scan displays when flying solely by instruments (instrument flight) and to develop certain patterns in order to read and combine information effectively. Information from displays is, at times, constantly changing. Scanning of instruments is important in that, due to the amount of information and attention needed, it is not a simple task to maintain flight parameters at fixed values. There are four scanning patterns that are most commonly taught for scanning these instruments which include the basic-T scan, the circular scan, vertical scan, and the
inverted-V scan. The basic-T scan pattern is widespread and most frequently used (ASA, 2002).

**Basic-T Scan.** The basic-T scan is suitable for straight and level flight and centered on the attitude directional indicator (ADI). The scan begins in the center with the ADI and moves out and back following the basic-T pattern on the panel to the relevant performance instruments, always coming back to the ADI. Hence, ADI→Altimeter→ADI→Airspeed→ADI→Heading→ADI. The relevant instruments include the heading indicator (HI) to confirm heading and correct shallow turns on the ADI; the altimeter to confirm altitude and correct changes to the ADI; and the airspeed indicator (ASI) to confirm airspeed and correct power changes. This scan pattern will be the one the study will focus on due to the frequency of use and importance of instruments by pilots.

![Figure 3. The basic-T scan](image.png)

**Circular Scan.** The circular scan pattern is formed by scanning all six instruments in a circular motion. The scan starts from the top instruments moving to the
bottom left across to the right and back up where it started. The circular scan is considered a more relaxed pattern in contrast to others that may require a faster scan.

**Figure 4.** The circular scan

**Vertical Scan.** The vertical scan begins with the ADI and moves down to the HI and back again. This scan is meant to be used when performing other tasks while flying at a constant heading and to ensure everything is normal as the other four displays are unnecessary for the cruise phase of flight. It is mainly used for maintenance and standard operations.

**Figure 5.** The vertical scan
**Inverted-V Scan.** The inverted-V scan is another scan pattern that is centered on the ADI. The scan begins with the ADI, moves to the turn coordinator (TC) back to the ADI, then the scan moves to the vertical speed indicator (VSI) and back again. It used any time there is a concern of instrument failure in order to maintain awareness of vertical velocity.

![Inverted-V Scan](image)

*Figure 6. The inverted-V scan*

While these scan patterns attempt to be taught by instructors, the actual scan pattern by pilots occurs as a function of experience with the instruments and individual scanning strategies developed by the pilots as training progresses (Bellenkes, Wickens, Kramer, 1997). Training scan patterns is extremely difficult, and despite of training, there doesn’t appear to be a consistent scan amongst pilots. Overall scan training lacks standardization (Bellenkes, 1999). However, regardless of scan pattern, the main goal of pilots is to not allow the scan to break down. If the scan pattern breaks down it means the instruments aren’t being sampled for information in an optimal manner for correct aircraft management. In order to keep the scan from breaking down, pilots avoid fixation on any one instrument and keep their eyes moving continually returning to the ADI since
it is the master instrument and most frequently referred to during most stages of flight (ASA, 2004). Differences in expertise may affect the degree to which the scan pattern breaks down.

**Expert vs. Novice Differences**

The words expert and expertise are often used in everyday conversation. An expert is considered to be a person who has special knowledge or skill within a specified area. Expertise is a state where an individual is said to possess a level of knowledge or experience beyond that of a novice, who is a beginner or inexperienced. Past research has noted that expertise is domain specific and cannot usually be transferred from one domain to another (Glaser & Chi, 1988). Experts also tend to be faster than novices at performing skills within their domain and tend to hold greater short-term and long-term memory for domain specific material. This can impact scan patterns for pilots.

The differences in scan patterns between experts and novices have been studied in various areas including radiology images, driving, and pilots. The ability to read radiology images comes from not only having the knowledge of radiology and anatomy, but also developing an effective scan pattern. According to a study by Kundell and La Follette (1972), there’s a definite evolution of fixation pattern that develops in medical school. It begins during freshman year and improves dramatically during junior year when they have more experience and knowledge. When radiologists examine radiological images they are mainly searching for abnormalities. There are consistent initial search strategies that are found in trained viewers. A trained radiologist’s scan pattern tends to fixate on edges and excludes broad uniform areas of the images. They also tend to be
more efficient by requiring fewer fixations to sample different areas of the images. In contrast, novice radiologists choose to begin inspection in the center of the image and their strategy consist of a series of short jumps within the same area and are therefore less efficient.

Driving research has revealed similar information about the differences between expert and novice drivers. When scanning their instruments, novice drivers have a tendency to narrow their vision to the speedometer, at the cost of scanning other instruments or mirrors (Mourant & Rockwell, 1970). Mourant and Rockwell (1972) found that novice drivers lacked sufficient visual scanning coverage of a neighborhood visual scene. Compared to the novice drivers, expert drivers looked farther down the road and gained more lane information from their peripheral vision. Still another finding in the same study was the concept that experts were better at dividing their attention among various information sources during visual scans. In general, novice drivers do not have search and scan patterns that are adequate for the detection of circumstances requiring emergency action.

In the realm of aviation, expert pilots and novice pilots differ in their ability to effectively scan and read each instrument display. Bellenkes and his colleagues (1997) found that when it came to scanning, experts tend to visit instruments more frequently, while novices tended to dwell longer on each instrument. Expert pilots’ scan pattern is more flexible in that it is more relaxed and is dictated by the changing state of the aircraft, while novice pilots tend to have a more rigid and predictable scan pattern across the instruments than do expert pilots. (Spady & Harris, 1983). Concerning extraction of information, it was found that expert pilots can notice deviant readings more rapidly than
novices increasing their ability to effectively gather information during flight (DeMaio, Parkinson, & Crosby, 1978). This conclusion supports the hypothesis that expert pilots should be able to detect changes within instrument displays more rapidly than novice pilots. Overall, research shows that expert pilots have a more automatic skill in extracting information and a more refined mental model than do novice pilots.

**Hypotheses**

Since there is limited amount of research dealing with change blindness and aviation combined, it’s difficult to establish what the data may reveal. Though, based on the theory of Central or Marginal interest and on the Coherence theory, it can be assumed that changes made to the ADI display will be detected more often than other locations since this display is considered to be of central interest by both theories and within the aviation when considering the basic T-scan. Furthermore, based on expert vs. novice research differences in scanning, the following hypotheses are expected:

1. Expert pilots will be faster and more accurate in detecting image changes than novice pilots.
2. Reaction time will be fastest and accuracy will be highest when detecting changes in the ADI display than in other locations.
3. Expert pilots will accurately detect more changes and have faster reaction times in the ADI display than novice pilots.
Methods

Participants

Participants in this study were instructor pilots and students at Embry-Riddle Aeronautical University in Daytona Beach, Florida. Participants were required have 20/20 vision or 20/20 corrected vision as determined by self-report. A total of 24 participants were used; 12 participants were instructor pilots who were considered expert pilots, and were all male. The other 12 participants were student pilots and were considered the novice pilots, 4 of which were female and 8 of which were male. All expert pilots were between the ages of 20-25, with an average of 23 years of age. Novice pilots were between the ages of 18-31, with an average of 22 years of age. Expert pilots had a range of 245-2500 flight hours, with an average of 952 flight hours. Novice pilots had a range of 46-80 flight hours, with an average of 70 flight hours. There were no specific flight hour requirements for expert pilots as long they met the university’s instructor pilot requirements. The flight hour requirement for novice pilots was 40-80 hours. These characteristics were confirmed in the form of a questionnaire (appendix A) administered to participants before the experiment began.

Apparatus and Displays

To examine change blindness by pilots in aviation displays the flicker paradigm was used in order to induce the visual disturbances. In this paradigm an original image repeatedly alternates with a modified image, with blank images in between successive images. Each blank image lasts for 80ms and the original and modified images last for 240ms. JAVA software was used to show the images for the flicker paradigm in the
experiment. The program ran on a Compaq Presario Laptop with 512 MB of RAM with a screen resolution of 1024 by 768 pixels. There were a total of 24 color images used. All images were of the six primary flight instruments used by pilots. The type of changes used for the modified images were displacement change and bolding effects for each of the six instruments. Position changes were selected as stimuli because prior research (O’Regan et al., 2000; Rensink et al., 1997; Rensink, 2000a; Rensink, 2000b; Rensink, 2000c; Rensink et al., 2000; Turatto et al., 2003) has indicated that these types of changes can be detected in a wide variety of scenes. Standard instrumentation is shown in figure 7a and figure 8a while altered changes are depicted in figure 7b (displacement) and figure 8b (bolding).

*Figure 7a. Standard instrumentation.*

*Figure 7b. Displacement change of the ASI arrow.*
Design

This experiment was a 6 x 2 mixed, fully factorial design. Two independent variables were manipulated. The first independent variable was the location of the change within the six primary flight instruments and was a within subjects variable. The second independent variable was pilot expertise and was a between subjects variable. For pilot expertise, participants were assigned to either the expert pilot group or novice pilot group. Participants viewed a total of 24 color images; four changed images per display location presented in random order. The four changed images were composed of two bold changes and two displacement changes.

The dependent measures for the study were the participant’s reaction time to the detection of the change within each flight instrument and their accuracy of the change detection. Accuracy was measured by asking for a description of the change and verifying the change after the trials. This measurement resulted in two incorrect accuracy measures: incorrect responses in cases when participants incorrectly identified what was
changing in the displays and failures to respond in cases in which the participant did not respond within one minute of trial initiation.

**Procedure**
A statement of consent form (appendix B) was read and signed by all participants. Participants were informed on the process of the experiment with a training session immediately preceding the experimental trials. The training session involved a total of three images. The images used for training contained similar type of changes as presented in the experiment, such as displacement change and bolding of items but utilizing different instrument cockpit display scenes. The same training and images were provided for the expert pilot group and for the novice pilot group. If there are any questions on behalf of participants, they were answered before the experimental trials began.

During the training sessions and experimental trails participants were asked to sit in the chair provided, placed about 50 centimeters from the monitor, in accordance to research performed by Turatto and his colleagues (2003) in the area of change blindness. Whenever they were ready to begin they left clicked the mouse to initiate the experiment. Each trial used the flicker paradigm that consisted of a blank image that lasted 80ms, followed by an unaltered image for 240ms, then again a blank image for 80ms, followed by modified image for 240ms. The entire cycle repeated for one minute or until the participant indicated that the change had been noticed by left clicking the mouse, which stopped the trial. At this time the experimenter asked for a detailed description of the change to confirm accuracy and then continued on with the rest of the trials. If the description of the change is incorrect, it was recorded as an incorrect detection of change and the experiment proceeded with the rest of the trials. Feedback was not provided
during the experiment. If after one minute the participant did not notice the change, the
eperiment moved on to the next image, recording it as a failure to detect change. After
he experimental trial each participant was given a debriefing form (appendix C).

**Results**

Data from the study were reviewed for performance extremes. Results from
image #17 were not used due to a software malfunction. Data from all other images were
reanalyzed for the three dependent variables without image #17. Reaction time data
includes trials in which participants responded correctly to the change in the image.
Overtime and inaccurate trials from the reaction time data were taken out and analyzed
separately. The following tables display the descriptive information for expertise and
location. Table 1 shows the reaction time data (in seconds), table 2 contains the number
of times a participant exceeded 60 seconds for a trial and table 3 contains the number of
cases that a participant incorrectly identified the change in the scene.

<table>
<thead>
<tr>
<th>Table 1. Reaction Time</th>
<th>ASI</th>
<th>ADI</th>
<th>ALT</th>
<th>TC</th>
<th>HI</th>
<th>VSI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Novice Pilots</td>
<td>15.31</td>
<td>7.88</td>
<td>10.95</td>
<td>6.95</td>
<td>19.56</td>
<td>9.32</td>
</tr>
<tr>
<td>Expert Pilots</td>
<td>18.23</td>
<td>9.95</td>
<td>11.82</td>
<td>5.75</td>
<td>17.95</td>
<td>7.36</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2. Overtime Trials</th>
<th>ASI</th>
<th>ADI</th>
<th>ALT</th>
<th>TC</th>
<th>HI</th>
<th>VSI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Novice Pilots</td>
<td>1.41</td>
<td>0.90</td>
<td>0.58</td>
<td>0.79</td>
<td>1.83</td>
<td>0.83</td>
</tr>
<tr>
<td>Expert Pilots</td>
<td>1.54</td>
<td>0.88</td>
<td>0.58</td>
<td>0.66</td>
<td>1.33</td>
<td>1.15</td>
</tr>
</tbody>
</table>
A 6 x 2 mixed factorial ANOVA was performed on the reaction time data. One of the requirements of ANOVA is that sphericity be met. The test for sphericity was significant, \( p = .005 \), indicating that assumption was not met and therefore the Geisser-Greenhouse correction was used in the ANOVA analysis. Once the correction was made there was a main effect of location, \( F (3.359, 73.887) = 3.982, p = .009 \), which signifies that there is a difference between the six displays. The power was high for the location effect at \( .847 \). The main effect of expertise was not significant, \( F (1, 22) = .039, p = .846, \) power = .054. There was also no significance of interaction, \( F (3.359, 73.887) = 1.478, p = .224, \) power = .399. The graphical depiction of stated information can be viewed in Figure 9.
Due to the main effect of location being significant, a Bonferroni post hoc test was performed to determine where the difference between conditions occurred. The comparisons on location are depicted in figure 10.
All possible pairwise comparisons for the location independent variable were made. The results indicated that the location of the ADI display demonstrated the most differences. There was a significant difference between ADI and ASI displays ($p=.036$), between ADI and ALT displays ($p=.004$), between ADI and HI displays ($p=.031$), and between ADI and VSI displays ($p=.000$) indicating that most of the main effects of location were due to the ADI display. The results also indicated significant differences between other displays such as between the ALT display and TC display ($p = .019$) as well as between the TC display and VSI display with ($p = .004$). The following table demonstrates all pairwise comparisons made, including those not significant.
### Table 4. Pairwise Comparisons

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean Difference</th>
<th>SE</th>
<th>p</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASI ADI</td>
<td>5.38</td>
<td>2.40</td>
<td>.036</td>
<td>0.38</td>
<td>10.37</td>
</tr>
<tr>
<td>ALT</td>
<td>-1.98</td>
<td>2.24</td>
<td>.385</td>
<td>-6.63</td>
<td>2.65</td>
</tr>
<tr>
<td>TC</td>
<td>3.49</td>
<td>2.07</td>
<td>.106</td>
<td>-0.81</td>
<td>7.80</td>
</tr>
<tr>
<td>HI</td>
<td>1.16</td>
<td>2.88</td>
<td>.609</td>
<td>-4.82</td>
<td>7.15</td>
</tr>
<tr>
<td>VSI</td>
<td>-2.62</td>
<td>1.39</td>
<td>.073</td>
<td>-5.52</td>
<td>0.26</td>
</tr>
<tr>
<td>ADI ALT</td>
<td>-7.36</td>
<td>2.32</td>
<td>.004</td>
<td>-12.19</td>
<td>-2.54</td>
</tr>
<tr>
<td>TC</td>
<td>-1.88</td>
<td>1.4</td>
<td>.221</td>
<td>-4.98</td>
<td>1.21</td>
</tr>
<tr>
<td>HI</td>
<td>-4.21</td>
<td>1.8</td>
<td>.031</td>
<td>-7.99</td>
<td>-0.43</td>
</tr>
<tr>
<td>VSI</td>
<td>-8.01</td>
<td>1.95</td>
<td>.000</td>
<td>-12.06</td>
<td>-3.95</td>
</tr>
<tr>
<td>ALT TC</td>
<td>5.48</td>
<td>2.17</td>
<td>.019</td>
<td>0.98</td>
<td>9.98</td>
</tr>
<tr>
<td>HI</td>
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<td>2.55</td>
<td>.232</td>
<td>-2.143</td>
<td>8.44</td>
</tr>
<tr>
<td>VSI</td>
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<td>2.62</td>
<td>.809</td>
<td>-6.09</td>
<td>4.80</td>
</tr>
<tr>
<td>TC HI</td>
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<td>2.19</td>
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<td>-6.87</td>
<td>2.21</td>
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<tr>
<td>VSI</td>
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<td>1.93</td>
<td>.004</td>
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<td>-2.11</td>
</tr>
<tr>
<td>HI VSI</td>
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<td>2.48</td>
<td>.141</td>
<td>-8.94</td>
<td>1.35</td>
</tr>
</tbody>
</table>

The data on overtime and inaccuracy was analyzed using nonparametric tests. The overtime trials were defined as those in which participants failed to notice the change after 60 seconds. Inaccuracy trials were identified as cases in which participants reported incorrect changes in images. The Mann-Whitney test was used to examine overtime trials and Friedman test was used to analyze inaccuracy trials. The main effect for
overtime and expertise was not significant $U=60.500, p = .503$. The main effect for overtime trials and location was, also, not significant, $X^2(5) = 25.523, p = .000$. Main effect of inaccuracy and expertise was not found to be significant, $U=59.500, p = .265$. The main effect for inaccuracy and location was not significant $X^2(5) = 2.000, p = .849$. Overall, the results for both overtime and inaccuracy trials indicate that there were no difference in expertise or location.

**Discussion**

The purpose of the study was to assess the impact of pilot expertise and information location on change detection within aviation instrumentation. The first hypothesis tested sought to compare expert and novice pilots in overall detection of change and accuracy. The main effect of expertise was not significant. The second hypothesis tested, looked to compare the six different displays. The main effect of location of ADI display was significant, reaction time was fastest, as expected. The third, and final, hypothesis tested stated that expert pilots would have faster reaction times and higher accuracy when detecting changes in the ADI display. The interaction was not found to be significant.

The lack of significance in the expertise effect can be explained by the low power. Due to low power there is little confidence in the manipulation and therefore many factors could have played a role in the end performance outcome. Participants’ behavior and outcome had little to do with expertise. A control group for expertise was not used, which could have assessed whether there was an actual difference being tested between pilots. A control group of non-pilots, would be the baseline group to evaluate whether
the experiment is actually tapping into pilot knowledge, which is a variable that is being manipulated. For example, if both pilot groups’ performance had been equivalent to a non-pilot group it would suggest that pilots were not using any aviation knowledge during the task. Also, the task that was given during the experiment, to keep a straight and level flight, could also explain the lack of significance. A straight and level flight may not require pilots to tap into any specific mental model or specific scan pattern due to its simplistic nature, causing both groups to not measure differently in reaction time to detect the instrument changes. Instructor pilots, with an average of 952 flight hours were recruited to represent the expert pilots. While student pilots, with an average of 70 flight hours, were recruited as novice pilots. The wide range in flight hours disputes that these groups were equivalent, suggesting that the simplicity of the task is most likely the reason for failure to find a difference based on expertise. However, the fact these pilots were all trained at a similar location with similar methods might suggest that these groups are homogeneous and could contribute to the lack of difference for expertise.

The second hypothesis stating that reaction time will be fastest when detecting changes in the ADI display compared to other locations, was found significant. A subsequent Bonferroni post hoc test was performed. The results did not support the original T-scan concept as the pattern of results suggested pilots sampled the instruments based on the task, instead. The post hoc test did sustain the hypothesis that the ADI display was most prominent. Such results were expected since it is anticipated to be sampled most often in a basic T-scan as well as a straight and level flight task. The order and frequency in which the rest of the displays were being sampled were also revealed. It was found that the second display to be sampled most often was the turn coordinator.
(TC). This display would be sampled to ensure no drifting from a straight and level flight, as instructed in experiment. The heading indicator (HI) display, the third most sampled, is also important in the task given to keep from drifting off course. The airspeed indicator (ASI), altimeter (ALT) and vertical speed indicator (VSI) were the fourth, fifth and sixth most sampled displays, respectively. Changes in these displays may have been detected the slowest because they were sampled the least. The reasoning for this being that the information presented by these instruments is not expected to change much in a straight and level flight.

Each of the hypotheses suggested there would be effects in change detection accuracy between the conditions. This was not found. In all cases there were almost no instances of participants taking too long or identifying incorrect changes in the displays. Most participants found the change within the first 20 seconds. Those few that did not find the change within the first 20 seconds did not find the change within the 60 seconds allotted; having an extra 40 seconds did not make a difference for the change detection. This suggests that in nearly all cases the participants were both fast and accurate in detecting changes when they were found at all.

**Limitations**

The static depictions of the cockpit used for the change blindness paradigm in the experiment could be considered a drawback. The static depictions are just pictures of cockpit displays, where in an actual aircraft or flight simulator the information on displays is changing depending on the task. However, the instructions given for the task in this experiment were to keep a straight and level flight, which does not involve information to be constantly changing.
Scan patterns are used and developed when the information displayed is changing. It’s difficult to assess where attention was allocated and what type scan pattern was used, especially without a way to measure eye movements as with an eye tracker. Although, it was not within the scope of the study to use an eye tracker as a way to measure scan patterns, the fact that there was a difference in the display location suggests that a scan pattern was indeed used by the pilots to sample information from the displays in a systematic manner.

**Future Research**

In the future, an eye tracker would be a way to measure pilots’ eye movements and have a better idea of where they might visually focus. It would also facilitate to discern which scan pattern is being used and identify how well it matches with the pilots’ attention allocation. An eye tracker would also enhance knowledge to train and support the use of scan patterns.

Follow up studies in change blindness in the aviation domain could incorporate different changes. One such change could be dynamic depictions as opposed to static depictions used in this study. An example of a dynamic depiction could be changing the needle on the ASI to move from one speed to another. Another change could be the compass rose of the HI rotate while heading in a specific direction. Yet, another modification that could be made would be to make multiple changes in different instruments simultaneously. Changes to future research could also include pictures that are more detailed and display more complex information. Such changes could help understand what pilots actually see during flight. It could also help distinguish more differences in change detection between expert pilots and novice pilots or pilots and non-
pilots and what is necessary for pilots to tap into knowledge that makes them actual experts. Using the change blindness paradigm in other domains and in combination with an eye tracker would yield interesting results.

The use of a control group is advised for future research. The use of control group would allow verification that there is a difference between groups being tested. A control group would verify that pilots are actually using pilot knowledge and are treating the experiment task as an aviation task. The control group would also guarantee that the focus of the study is engaging the faculties of participants in the experiment.

A final direction for future studies could be applying change blindness studies in the area of glass cockpit displays. Research in glass displays is still necessary; there is limited research on this topic (Schnell, Kwon, Merchant & Etherington, 2004). It is still uncertain to what and where exactly pilots are focusing attention and are scanning. Without such knowledge it is difficult to train and support scan development.

**Conclusion**

The world around us is filled with objects, events and information necessary to interact with it successfully. Missing some of that information can be devastating, and depending on the circumstances, also dangerous. In the aviation realm, a pilot’s ability to detect changes within the instrument panel can be the difference between a successful flight and a horrible crash. This study investigated the influence of pilot expertise and change blindness detection in aviation.

Overall, the results of this study indicated that there was no statistically significant difference between expert and novice pilots when detecting change in cockpit
displays. However, there was a significant difference in display location. A Bonferroni post hoc test was performed that revealed that the ADI display was the most commonly sampled display. Although, the results did not show that the participants were using a T-scan pattern, they did use a scan pattern that coincided with the instructions to keep a straight and level flight.

Research in change blindness is available and research in aviation is abundant, however, there is still much to be discovered in these two fields combined. Future research could vastly improve the way cockpits are designed, the way pilots are trained and a way to improve the aviation realm.
References


Appendix A: Demographic Information

Participant Number (To be completed by researcher) ______________

*Please write your responses in the appropriate space.*

Name: ______________________

Age: _________________

Sex: M F

Student or Instructor Pilot? ______________________

Number of flight hours: ______

Number of instrument flight hours: ______

Do you meet the vision requirements set by the university in order to pilot a plane? _____

Do you have 20/20 or 20/20 corrected vision? ______

During flight training, were you taught a certain instrument scan pattern? ____________

If so, what type? ______________________

Do you believe you have a well developed instrument scan pattern? ____________

What class did you sign up to receive extra credit in for the completion of this experiment? Please include professor’s name.

________________________________________________________________________
Appendix B: Consent Form

Expertise and Change Blindness Detection

Conducted by Dinorah Zárate
Advisor: Shawn Doherty
Embry Riddle Aeronautical University
   Human Factors and Systems
   Daytona Beach, FL 32114-3977

The purpose of this experiment is to study the relationship between pilot expertise and information location on change blindness detection. The experiment consists of one session with 24 image trials. The experiment session will take about 45 minutes. During each trial you will be asked to look at two alternating images using the flicker paradigm and reporting any changes you may see between the images. You will also be asked to provide some general demographic information prior to the experiment trails. There are no known risks involved with the study. Your participation in this study is voluntary and there is no penalty for not participating. You have the right to withdraw from this study at any time.

Your identity and scores will be kept confidential. Your experiment information will be coded using a participant number. Once the study is completed, all personal information will be destroyed.

Thank you for your participation. If you have any questions, please ask during the experiment or contact me at (904) 806-2692.

Statement of Consent

I acknowledge that my participation in this study is completely voluntary and that I am free to withdraw at any time. I have been informed as to the general scientific purposes of this experiment and that I will, if designated by my professor, receive extra credit for my participation in this study. If I withdraw before the experiment is completed, I will not receive extra credit.

Participant’s name (please print): ________________________________

Signature of participant: ________________________________ Date: ______

Experimenter: ________________________________ Date: ______
Appendix C: Debriefing Form

Expertise and Change Blindness Detection

Conducted by Dinorah Zárate
Advisor: Shawn Doherty
Embry Riddle Aeronautical University
Human Factors and Systems
Daytona Beach, FL 32114-3977

The study that you just participated in is concerned with the effects of expertise on information location on change blindness detection within an aviation domain. The researcher is seeking evidence of the effects of pilot expertise on the ability to detect change. Research in the area of change blindness and aviation is limited. Research in this area is needed in order to understand how expert pilots and novice pilots differ in their ability to detect change when in the cockpit and to provide a basis for continued research in this area that will provide insight to the challenges faced by pilots.