Spring 2005

Effect of Automation Management Strategies and Sensory Modalities as Applied to a Baggage Screening Task

Michelle Ann Leach

Embry-Riddle Aeronautical University - Daytona Beach

Follow this and additional works at: http://commons.erau.edu/db-theses

Part of the Management and Operations Commons

Scholarly Commons Citation

This thesis is brought to you for free and open access by Embry-Riddle Aeronautical University – Daytona Beach at ERAU Scholarly Commons. It has been accepted for inclusion in the Theses - Daytona Beach collection by an authorized administrator of ERAU Scholarly Commons. For more information, please contact commons@erau.edu.
Effect of Automation Management Strategies and Sensory Modalities as Applied to a

Baggage Screening Task

by

Michelle Ann Leach

B.A., Flagler College, April 2003

A Thesis Submitted to the

Department of Human Factors & Systems

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Human Factors and Systems

Embry-Riddle Aeronautical University

Daytona Beach, Florida

Spring 2005
INFORMATION TO USERS

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleed-through, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

UMI®

UMI Microform EP32038
Copyright 2011 by ProQuest LLC
All rights reserved. This microform edition is protected against unauthorized copying under Title 17, United States Code.

ProQuest LLC
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106-1346
Effect of Automation Management Strategies and Sensory Modalities as Applied to a Baggage Screening Task

by

Michelle Ann Leach

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

Thesis Committee

Shawn Doherty, Ph.D., Chair

Dahai Liu, Ph.D., Member

Hong Liu, Ph.D., Member

MS Human Factors & Systems Program Coordinator

Department Chair, Department of Human Factors & Systems

Associate Chancellor of Academic Affairs
Abstract

Automation management strategies can assist the operator in coordinating activity in automated systems. Baggage screening is a domain in which automation and alarms can be studied in terms of signal detection theory. Baggage screening is vital to national security and should be completed in a time efficient manner without compromising accuracy. In the present study, the automation management strategies of management by consent (MBC) and management by exception (MBE) were crossed with alarm modalities of a visual (flashing) or an auditory alert which served as redundant cues in a baggage screening task. A control base line condition existed in which participants received each automation strategy without an added alarm modality. Results failed to support multiple resource theory because significance was only found for modality in the comparison of overall reaction time and reaction time of automation false alarms. Yet significance was found between the automation management strategies. The time restraint that is inherent in a management by exception (MBE) strategy causes people to respond more quickly but less accurately than when compared to a management by consent (MBC) situation, even if participants are not as confident in their choice.
Table of Contents

Introduction .................................................................................................................. 1

Statement of Problem ................................................................................................. 2

Review of Related Literature ..................................................................................... 3

Automation Management ......................................................................................... 3

Alarms ....................................................................................................................... 8

Signal Detection Theory ......................................................................................... 10

Airport Baggage Screening ..................................................................................... 12

Hypotheses ............................................................................................................... 15

Methods .................................................................................................................... 18

Participants ........................................................................................................... 18

Apparatus ............................................................................................................... 19

Displays .................................................................................................................. 19

Design ..................................................................................................................... 21

Procedure ............................................................................................................. 23

Results .................................................................................................................... 25

Discussion ............................................................................................................. 32

Conclusion ............................................................................................................. 40

References ............................................................................................................. 42

Appendix 1: Management by Consent (MBC) Prompt ............................................. 44

Appendix 2: Management by Exception (MBE) Prompt .......................................... 46

Appendix 3: Consent Form ..................................................................................... 49

Appendix 4: Demographic Questionnaire ................................................................. 50

Appendix 5: Follow-up Questionnaire ................................................................... 51
Introduction

Advances in technology tend to increase the utilization of automation.

Automation involves the use of processes automatically executed or controlled by machines (Billings, 1997). Kearsley (1985, p.61) offers a simplistic definition of automation: automation replaces “human functions with machine functions.” Human (operator) error is foreseeable because human errors are inevitable, however, automation and humans can act as a check on each other and hopefully anticipate errors before they occur.

As automation continues to expand in its capabilities and uses, humans should remain involved in the loop of these systems. A human being “in the loop” means that humans are involved and aware of the processes of the automated system and receive feedback from the system. When people are not actively in the loop such as in complex systems, results could be fatal. Take the example of the complex systems involved at a nuclear power plant. When dangerous conditions arise in a nuclear power plant, automated systems should activate in order to resolve a problem, but if the automation does not function properly when the problem arises, the human operator(s) will need to take immediate action. Assuming the human operator would recognize the situation and take the appropriate action, the operator would then complete the steps manually that automation failed to enact. This example illustrates the need for the operator to be in the loop, in order to be able to correct for automation errors.

Under these emergency circumstances, response time would be crucial in alerting the human operator in order to prevent a disaster. Unfortunately, when detecting problems in monitoring automated systems, human response is slow (Endsley, 1996).
However, if an alarm is paired with automation such as in the prior example, the alarm could alert the operator to the automated task. In human-in-the-loop systems, alarms are often paired with automation to capture the operator's attention and keep them in the loop. Alarms can alert the operator to changes in automation allowing the human operator to respond promptly to monitoring of the specific task while encouraging them to remain attentive to the system.

Statement of Problem

In order to effectively utilize automation, humans should actively be involved in the process of automation, especially during the design phase of automation to ensure the appropriate interface is developed. The human operator and automation can work together in monitoring the task assigned to automation and act as a check on each other. If humans can be actively involved during the process of automation, total system performance should improve without sacrificing reaction time. Alerts can serve as redundant cues in combination with automation to help decrease reaction time and keep humans in the loop of automated systems. All these points taken together suggest that one automation design goal should be to find an optimal interface in which humans monitor automation in conjunction with alerts to gain insight into what combination provides the best reaction time. Obtaining such data, in the context of scientific research, will assist to improve the interface between people and automation.
Review of Related Literature

*Automation Management*

One place to start in finding the optimum interface design is to investigate various methods of interaction of operators with the automation. One key concept in addressing the interaction is to look at automation management strategies. Management strategies are techniques in which both humans and machines share control of a task (Olson & Sarter, 2001). For example, tasks are automated from the simplistic to the technologically advanced. On the simplistic end, a watch automates the process of keeping time. On the more complex end of the spectrum, an aircraft has multiple complex systems. To prevent overloading and overwhelming the pilot, automation management strategies come into play. For example, in some systems, the pilot does not need to think about simpler subsystems and components because such systems are fully automated, while other systems require human input.

As the previous examples illustrate, automation management strategies provide different degrees of operator involvement. Research in automation management strategies is one way to investigate keeping operators in the loop with automation. Automation management strategies can assist the operator in coordinating activity in automated systems. Unfortunately, there is not a lot of data available to determine the effectiveness of automation management strategies and which tasks would be better suited to each management strategy. Designers make decisions about automation management strategies regardless of whether data exists are not (Olson & Sarter, 2000). If more data were present, however, designers could utilize this information to develop technology that would be better suited to our needs and thus more efficient. In order to
take a closer look at automation management strategies one must first understand the various levels of automation. Table 1 explains the levels of automation according to Sheridan’s hierarchy.

Table 1

*A Scale of Degrees of Automation*

1. The computer offers no assistance; the human must do it all.
2. The computer suggests alternative ways to do the task.
3. The computer selects one way to do the task and
4. executes that suggestion if the human approves, or
5. allows the human a restricted time to veto before automatic execution, or
6. executes automatically, then necessarily informs the human, or
7. executes automatically, then informs the human only if asked.
8. The computer selects the method, executes the task, and ignores the human (Sheridan, 2002, p.62).

The automation management strategies of management by consent (MBC) (level 4 in the above table) and management by exception (MBE) (level 5 in the above table) are implemented most frequently in the aviation domain (Olson & Sarter, 2000). A management by consent (MBC) automation strategy offers choices to the operator of actions to perform. The human operator has the option to consent to the suggested option or reject the option to prevent the task. If the operator rejects the option, they then must select an alternate option for automation to complete a task (Olson & Sarter, 2001). A familiar example of MBC is deleting a file in a Windows environment. You press the delete button to rid yourself of the file and a dialog box appears prompting you to make a
selection to confirm that you do indeed want to delete the file and selecting delete was not a mistake. Olson & Sarter (2000) state required frequent interactions with automated systems under a management by consent (MBC) approach may increase pilots' awareness and control over automation behavior. Operators are forced to make a selection of either consenting to the automation or rejecting the solution provided by automation. In contrast, a management by exception (MBE) automation strategy does not force the operator to select an option before continuing the process of automation.

In a management by exception (MBE) automation management strategy, automation acts without consent of the operator; the automation determines the appropriate action. When management by exception (MBE) is utilized in a situation, automation takes the initiative to complete the task without input from the human operator. The operator can veto or override the action within a specific timeframe if he/she disagrees with the automation (Olson & Sarter, 2001). The system informs the controller or operator about a plan of action. This automation strategy is essentially an autonomous operation, but the controller has the ability to interrupt the process of automation by reverting to a lower level of automation to regain more control (Billings, 1997). Management by exception (MBE) involves fewer required interactions between the human operator and automation but at the risk the operator’s awareness of the system’s activities will be decreased (Olson & Sarter, 2000). The fear with management by exception (MBE) is that a human operator will not actively monitor the automation when this strategy is employed because input is only required to override automation.

A classic example of MBE is a virus protection program on a computer. These software programs have automatic times at which it decides to scan your computer for
viruses. A dialog box appears alerting the operator that their computer is about to be scanned for viruses. The operator must act quickly if they do not want such scans to occur because the dialog box only appears briefly; if they do not want the automatic scanning to continue they have to click the appropriate button to stop the process. However, if they want the virus scanning to continue, there is no need to do anything.

Research on these two automation management strategies (MBC and MBE) has been conducted primarily by Olson & Sarter (2000, 2001). A study was conducted by Olson and Sarter (2000), on preference for the use of management by consent (MBC) and management by exception (MBE) automation strategies. Their survey, administered to airline pilots, questioned pilots in order to gain insight into preferences concerning management by consent (MBC) and management by exception (MBE) management strategies. Pilots surveyed were given various scenarios and situational variables and asked which option of automation they would choose. Pilots indicated perceived control of automated systems was an important factor. Pilots were also asked to write comments explaining the reasons for such preferences. Pilots' responses that control is important to them support Billings human-centered design principle which states "operators should have ultimate control over automated systems" (Olson & Sarter, 2000). Because perceived control is an important factor to them, pilots preferred management by consent (MBC) overall. Management by consent (MBC) requires operator involvement unlike management by exception (MBE) which can function if the operator chooses not to respond in the designated time limit. If operators are more comfortable with a management by consent (MBC) strategy, operators may respond more accurately to this type of automation. However, for certain circumstances, such as when time pressure and
task complexity increased or when low task criticality was involved, pilots preferred management by exception (MBE) (Olson & Sarter, 2000).

In an additional study conducted by Olson & Sarter (2001), results indicated management by consent (MBC) does not guarantee effective control of automation. In this study, management by consent (MBC) was utilized across a variety of time pressure levels and conflict types. Results indicated that high time pressure did not affect the detection of impossible conflicts in an air traffic control task. Conflict detection was significantly influenced by several factors including conflict type and time pressure. When automated systems completed more tasks than pilots’ expected, expectations of pilots’ were satisfied (Sarter, 2001). Expectations were purely subjective. Based on these findings, human operators should evaluate the action automation decides and consider what effects completing the specific tasks will have on other parts of the larger system.

Even though research suggests human operators should evaluate the processes of automation, under time pressure constraints human decision makers tend to sample less information and switch to less effective strategies regardless of the domain (Olson & Sarter, 2001). In other words, operators are not as actively involved in monitoring tasks completed by automation. The most critical tasks perceived by the operator are dealt with first. In this type of situation, a strategy of management by exception (MBE) might be better suited to the operator because the operator is not required to consent to every decision but rather can play a more passive role and intervene when a conflict in judgment occurs between the automation and operator.
Unfortunately, automation management strategy research is lacking. The design community does not yet know how to effectively utilize these management strategies. Olson & Sarter (2000) suggest automation related research should pursue information on the practicality and efficiency of automation management strategies as applied to various domains. Once designers understand more about automation management strategies and their impact on reaction time as well as their impact in various tasks, the design community can make use of these findings to create a better interface between humans and automation.

Alarms

In an effort to decrease reaction time to an event, alarms are often used in conjunction with automation. This is most common, of course, when automation is monitoring tasks that could result in dangerous circumstances; in this case, when something goes wrong, alarms are used to notify human operators. Situations exist in which text alone may not be enough to alert the operator to a problem. Redundant cues or additional alarms (either auditory or additional visual alarms) could draw more attention to text prompts raised by automation.

Visual and auditory alarms are the most common alarms used. By utilizing alarms which access different sensory pathways than those already used in a task, reaction time can be decreased. Multiple resource theory states each of the sensory channels or pathways processes information differently. Therefore, it is best to “avoid competition” within the channels and make use of other channels (Ho, Nikolic, & Sarter, 2001, p 14). For example, in the domain of air traffic control, the visual channel is heavily taxed because air traffic controllers monitor aircraft on a computer screen and
process all of this information to determine where aircraft should go, where aircraft will be, and if aircraft are on the correct route. Therefore, if an alarm were needed in an air traffic control environment, according to multiple resource theory, an auditory alarm would be more effective than a visual alarm because the visual channel would have more information to process than the auditory channel. Ho, Nickolic, & Sarter (2001) completed a study which involved utilizing the visual, auditory, and tactile modalities in an air traffic control interruption task.

Upon completion of their experiment, Ho, et al. (2001) found participants rated the visual interruption task the most difficult task to perform in an air traffic control task. This rating probably arose because the air traffic control environment already requires the use of the visual system; this outcome supports multiple resource theory. The interruption tasks using the auditory and tactile channels were not rated as difficult as the visual interruption tasks because the auditory and tactile channels were not being utilized in the primary air traffic control task. When the interruption task was performed in isolation, performance across modalities did not differ significantly. However, performance degraded when the visual interruption task was performed while participants were engaged in a demanding air traffic control task. Quite the opposite occurred in the other modalities. No significant findings were found when comparing performance in auditory and tactile interruption tasks.

From the findings of this experiment, one could conclude a visual alarm is not the best route to gain the operator's attention in an already visually demanding task but rather another sensory modality should be employed such as an auditory alarm. This alarm implies that if in the normal use of automation management strategies a dialog box is
used to gain the operator's attention, an auditory alert would most likely be a more
efficient redundant cue than flashing regardless of the type of automation management
strategy employed.

*Signal Detection Theory*

Alarms are used to gain the attention of an operator and can be used to alert the
operator to whether an event (signal) is present or not. Automation management
strategies can be used in conjunction with alarms to detect whether a signal is present or
absent in an attempt to capture the operator's attention more quickly. Under these
conditions, the role of the operator is to decide whether automation is correct or incorrect
in its assumptions on detection of signals.

The basis for determining the presence of a signal is based on signal detection
theory. According to signal detection theory (SDT), a person detects whether a signal is
present or not; “a person sets a criterion level ... whenever the level of sensory activity
exceeds that criterion, the person will say there is a signal present. When the activity
level is below the criterion, the person will say there is no signal (Sanders & McCormick,
1993, p.64).” The interaction of the person and automation results in a diagnosis of the
event. A person determines a specific criterion that can match or mismatch with the
automation.

The premise behind signal detection theory is noise. Noise (not only auditory
noise but the presence of other stimuli that are non-informative to the task at hand) can
interfere with detecting the signal (Sanders & McCormick, 1993); noise can be visual or
auditory. An example of visual noise would be icons on a Windows desktop computer
screen. If an individual saves everything to the desktop rather than saving computer files
into designated folders, then their computer screen probably looks cluttered; this would be an example of visual noise (in a Windows environment). In contrast, auditory noise is associated with the traditional sense of the term noise. Auditory noise is often referred to as an alarm; a common example of an auditory alarm is a fire alarm.

As pertaining to signal detection theory, the operator and automation are either correct in their decision or inaccurate resulting in four possible outcomes. Sanders & McCormick (1993) describe these four possibilities as hit, false alarm, miss, and correct rejection. A hit and a correct rejection are accurate responses to the conditions the operator experiences. A false alarm and miss are inaccurate responses to the conditions the operator experiences (Sanders & McCormick, 1993).

In the context of automation management strategies coupled with sensory modalities of flashing or an auditory alarm, the human operator is detecting the presence of flashing or an auditory alarm (in a baggage screening task as applied to this thesis). Once the cue is detected (whether the redundant visual cue of flashing or an auditory alert), the human operator must decide if the automation is correct or inaccurate. If the operator agrees with the automation and the automation is correct about signal detection, a hit has occurred by the human operator. If the operator agrees with the automation about detection of a signal when automation is incorrect then a false alarm has occurred on the part of the operator. If the automation is incorrect, and the operator notices this and disagrees with automation then a correct rejection occurs on part of the operator. A miss would occur if automation failed to find a signal and the operator also failed to find the signal or in the event that automation found a threat, there was an actual threat present and the operator failed to identify the threat and disagreed with automation.
The sensory modalities of either a visual or an auditory alert would alter the reaction time in the automation strategies. The sensory modality would in effect act as a redundant cue in combination with automation management strategies urging participants to make a selection and thus assist in improving reaction time. In terms of signal detection theory, sensory modalities combined with automation strategies should increase the number of hits and correct rejections (by the human operator) because participants would be more active in the implementation of automation and its decisions.

*Airport Baggage Screening*

One domain for investigating automation management strategies and alarms in terms of signal detection theory is the arena of baggage screening. With increased levels of homeland security, the process of baggage screening is becoming a more serious task. Even though security measures have become more stringent, anxious passengers expect baggage screening to be an efficient process not delaying them from their flight. Travelers need to get through this process in a reasonable time frame while at the same time the thoroughness of which the screeners are scanning the “X-rays” of your baggage contents must not be comprised. Automation can assist in this task to increase efficiency of work and safety of the skies to help assist the human operator. Automation can scan your baggage contents and alert you when a suspicious object or shape appears.

Automated technology currently exists in baggage screening to assist in the process of monitoring for potential threats. New scanning devices such as the Computer Tomography X-ray (CTX) scanner are designed to reduce time spent during the baggage screening process while making inspection more thorough. This device and others have the technology to distinguish explosives from other objects (Elliot, 2002). Unfortunately,
baggage scanning often results in a high number of false alarms. For instance, the C-4 explosive has the same density as sugar and the density of Christmas puddings (Venter, 1998) thus creating a common false alarm. Automation can assist in tasks such as baggage screening but there are times in this task when human intervention is necessary such as to further investigate potential threats. In addition, human interaction with automation while monitoring baggage screening can reduce the number of false alarms and misses and assist to create an increased number of hits and correct rejections.

In order to reduce the number of false alarms and misses in baggage screening, humans should remain in the loop through the proper use of automation management strategies. However, management strategies alone might not be enough to capture the operator’s attention because environmental work conditions at security checkpoints in airports involve numerous distractions including noise (Parasuraman, Mouloua, Molloy, & Hilburn, 1996). Redundant cues might prove beneficial in an automated baggage screening task. Automation management strategies in conjunction with auditory or flashing can perhaps keep the baggage screener more alert in the monotonous task of screening. A visual alert of a dialog box might not be enough to grasp the screeners’ attention. A flashing dialog box is much more likely to be noticed. Or an auditory alert might be more appropriate if most of the time the operator is not actively scanning the computer screen. An auditory alert could alert the operator to return his or her focus to the computer screen, but the alarm must be loud enough to be recognized as an alarm and not as noise common to airport terminals. An operator might be distracted with all the activity surrounding him or her (especially if the baggage screening occurs within the context of an airport). The operator might only occasionally view the computer screen
(displaying the images of baggage contents) to determine if automation has found a problem.

These alerts when used with automation strategies could gain the attention of the human operator. Not only does the operator need to be aware of what tasks are being automated but ideally operators should be able to effectively monitor without the use of automation. If both automation and the human operator are actively involved, then each can act as a check on the other. However, unfortunately, awareness is difficult to maintain in such a monotonous task as baggage screening. For instance, analysis of operator’s performance in a signal detection task demonstrated a high miss rate as well as declined performance during the first half hour or so of watch (Wickens, 1992). Baggage screeners have difficulty maintaining awareness or attention to the task at hand over their shift of work. Baggage screeners must monitor X-rays of baggage over long hours and many bags may pass through the screener’s watch before a threat (signal) is detected. Threats of knives, guns, explosives, and other weapons are not necessarily present everyday. Baggage screeners can train for such scenarios but in reality threats are not routine. These threats (signals) are often sporadic and irregular (Wickens, 1992).

The redundant cues of visual and auditory alerts when used in conjunction with automation management strategies could assist in maintaining attention by providing redundant cues. If attention is maintained then the human operator is more likely to succeed in monitoring the automation and have an increased number of hits and correct rejections, as well as be able to detect the occurrence of false alarms and misses in the automation. With both automation and the human operator actively engaged working together on a task it is much less likely that errors will occur.
If a problem arises in baggage screening, it should be dealt with accordingly to ensure the safety of all individuals involved. To obtain a better understanding of automation management strategies and the impact of redundant alarms on reaction time, continued research is essential. This thesis provides a framework to determine which automation strategies used in combination with either an auditory or redundant visual alert (flashing) produces the quickest reaction time. The results of this study can be utilized in future baggage screening tasks by implementing the management strategy and alert combination which baggage screeners respond to most quickly to assist in moving air travelers quickly through airport checkpoints without compromising security. It is also hoped that this research will inspire more research in the domain of automation management strategies and reaction time.

Hypotheses

Previous research comparing automation management strategies and sensory modalities was not found; therefore, results of these combinations in this experiment were unknown, but no interaction was expected. With regard to automation management strategies, research is quite limited comparing management by consent (MBC) and management by exception (MBE) styles. However, it was expected that, overall, management by exception (MBE) would result in a faster reaction time in the present experiment compared to management by consent (MBC) because of the time limitations inherent in management by exception (MBE). However, one must be cautious because the context of management by exception (MBE) constrains reaction time. In those instances in which participants were told to let the automation time out when they agreed with the statement provided by automation, reaction time was automatically set to a maximum time limit. Conversely, reaction time was artificially suppressed in those instances in which
participants did not have sufficient time to respond to the automation or felt pressured to make a response. Therefore, participants may have responded faster in management by exception (MBE) conditions because of the fear that automation would time out if they failed to make a selection.

Due to the baggage screening environment being full of distractions, it was hypothesized that alerts would have a beneficial effect on reaction time. In addition, all conditions involving alerts (whether flashing or auditory) were predicted to provide faster reaction times than the control conditions involving no alerts because redundant cues were provided to help assist in maintaining attention of the operator. On the basis of multiple resource theory, it was predicted that conditions involving auditory alerts would provide faster reaction times than those conditions involving flashing due to the non-redundant information presented between the visual and auditory channels. Furthermore, the alarm would be annoying to the participant and they would want to respond as quickly as possible in order to stop the alarm. Flashing conditions were hypothesized to result in a worse reaction time than auditory conditions because the visual field would be overloaded, as participants would have to read the text in the dialog box in addition to searching for possible threats. Control conditions for both management strategies would result in the worst reaction times because redundant cues would not be provided to urge the participant to respond quickly. This was hypothesized because the control baseline condition lacked redundant cues which would provide a sense of urgency for the participant to respond. Figure 1 provides a visual representation of the hypotheses of relative outcomes between the conditions for reaction time (lower values indicate better reaction times and higher values indicate worse reaction times).
Accuracy responses were hypothesized to be better in conditions involving management by consent (MBC) because participants would not feel the time constraints involved with management by exception (MBE). Without having to worry about time pressure, participants in management by consent (MBC) would take their time to ensure that they were correct in their response. In terms of accuracy for modality, extra alarms would startle the participant into hurrying and making a selection even if they were not confident in their decision resulting in a low accuracy. Flashing conditions were hypothesized to result in a worse accuracy over auditory conditions because tasks involving flashing were the most visually demanding. Figure 2 provides a graphical representation of the hypotheses for accuracy.
Hypotheses of Mean Accuracy Performance

Methods

Participants

Participants in this study were students enrolled in courses in the Human Factors Department at Embry-Riddle Aeronautical University in Daytona Beach, Florida. Participants had 20/20, 20/20 corrected vision, or better, and no known hearing problems. In addition, all participants were between the ages of 18-30. These characteristics were asked in the form of a questionnaire administered to participants before the experiment began. A total of 60 participants were used; 30 participants experienced management by consent (MBC) and another 30 participants experienced management by exception (MBE). Of the 30 participants who experienced management by consent (MBC), 22 were male and 8 were female. Of the 30 participants who experienced management by exception (MBE), 19 were male and 11 were
female. Participation for this experiment was voluntary. Participants were compensated for their participation by receiving extra credit in their Human Factors or Psychology courses.

**Apparatus**

Participants monitored scenarios in a computer software program specifically created for the needs of this experiment. A baggage screening task was simulated using Java programming language in JCreator software. This program collected reaction time data of participants in addition to recording accuracy of responses. The program was run on a Dell Optiplex, Pentium(R) 4 with 512 MB of RAM. The monitor was a Dell Trintron and the screen resolution was set to 1024 by 768 pixels.

**Displays**

For the experiment, screenshots of actual X-rays of baggage were viewed by participants. These X-ray images were obtained from the technical marketing manager of L3 Security and Detection Systems, a company that specializes in intelligence and surveillance products including baggage security screening systems (Hurd, 2004). These screenshots contained items common in luggage as well as dangerous objects not permitted (i.e. knives, guns, explosives), which were mixed together for viewing by the participants. Participants were informed that automation would provide a text message in a dialog box of an action automation thought was necessary. When the X-ray image of the baggage appeared, automation simultaneously displayed a dialog box on the screen alerting the human operator. Dialog boxes did not obstruct the view of the X-ray image of the baggage. Participants were informed that automation would either state, “Alert! Threat Found! Search Baggage.” or “No Threat Found! Pass Baggage.” in the dialog box. The background of the dialog box was white in control conditions, flashing red in
the flashing conditions, or white in the auditory conditions when instead an auditory alert sounded simultaneously with the appearance of the dialog box. One alert (whether visual or auditory) was present for each condition except in baseline control conditions. The alert did not cease until the participant selected an option in management by consent (MBC) conditions or ran out of time in the management by exception (MBE) conditions (after six seconds had passed). Figure 3 provides an example of an image used in the experiment and a sample dialog box for when the automation stated that a threat existed while Figure 4 provides an example of when automation stated no threat existed. Please note that both Figure 3 and Figure 4 are examples of management by consent (MBC) because an option to accept or reject automation’s response is provided.

Figure 3. Example of Management by Consent (MBC) Image with Threat Text
Design

This experiment was a 3 x 2 mixed repeated measures design. Two independent variables were manipulated. Management strategy was manipulated between subjects while alarm modality was a within subjects variable. Participants were assigned to either the management by consent (MBC) group or management by exception (MBE) group and experienced the sensory modalities within the automation management strategy to which they were exposed to. The automation management strategies of management by consent (MBC) or management by exception (MBE) were crossed with the sensory modalities of a visual (flashing) alert or an auditory alert which served as a redundant cue. A control base line condition existed in which participants received one automation strategy without an added sensory modality.
Participants viewed 20 scenarios of each of the conditions involving sensory modalities within each management by consent (MBC) and management by exception (MBE).

Participants were exposed to the three sensory modality conditions in one setting; all conditions and scenarios were randomized. Within each sensory modality condition, 10 of the images were images with threats and 10 were images with no threats. Within each of those, five of those images were combined with the threat text of, “Alert! Threat Found! Search Baggage.” and five of those images had the no threat text of, “No Threat Found! Pass Baggage.” Figure 5 provides a visual representation of the conditions used.

<table>
<thead>
<tr>
<th>Sensory Modality</th>
<th>MBC Management by Consent</th>
<th>MBE Management by Exception</th>
<th>Number of Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flashing</td>
<td>10 Threat Images</td>
<td>10 Threat Images</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>5 Threat Text</td>
<td>5 Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 No Threat Text</td>
<td>5 No Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 No Threat Images</td>
<td>10 No Threat Images</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Threat Text</td>
<td>5 Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 No Threat Text</td>
<td>5 No Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 Threat Images</td>
<td>10 Threat Images</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>5 Threat Text</td>
<td>5 Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 No Threat Text</td>
<td>5 No Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 No Threat Images</td>
<td>10 No Threat Images</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Threat Text</td>
<td>5 Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 No Threat Text</td>
<td>5 No Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 Threat Images</td>
<td>10 Threat Images</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>5 Threat Text</td>
<td>5 Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 No Threat Text</td>
<td>5 No Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 No Threat Images</td>
<td>10 No Threat Images</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Threat Text</td>
<td>5 Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 No Threat Text</td>
<td>5 No Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 Threat Images</td>
<td>10 Threat Images</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Threat Text</td>
<td>5 Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 No Threat Text</td>
<td>5 No Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 No Threat Images</td>
<td>10 No Threat Images</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Threat Text</td>
<td>5 Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 No Threat Text</td>
<td>5 No Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 Threat Images</td>
<td>10 Threat Images</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>5 Threat Text</td>
<td>5 Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 No Threat Text</td>
<td>5 No Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 No Threat Images</td>
<td>10 No Threat Images</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Threat Text</td>
<td>5 Threat Text</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 No Threat Text</td>
<td>5 No Threat Text</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 5. Experiment Design*
The dependent measures for the study were the participant's reaction time to each scenario presented in addition to their accuracy of response to that scenario. Accuracy measures were recorded in order to eliminate the possibility of participants responding quickly without regard to accuracy. As Figure 5 indicates, within each sensory modality, half of the time the automation was correct and half of the time the automation was incorrect. The false alarm rate was therefore held constant across all conditions at 50 percent in order to reduce possible confounds due to participant's potentially responding without assessing the scenario presented. Therefore, out of 20 scenarios for each condition, 10 of the scenarios were false alarms by automation.

Procedure

Participants were briefed on the process of the conditions with a training session immediately preceding experimental trials. The training session involved two scenarios of each of the sensory modality conditions for either management by consent (MBC) or management by exception (MBE) for a total of six images per training session. The same training was provided to participants within the management by consent (MBC) or management by exception (MBE) conditions and provided participants exposure to the baggage screening task and experimental conditions. Any questions were clarified before experimental trials began.

The only difference in procedure between the management strategy groups were the way in which participants were instructed to respond. Participants were told they needed to decide if they should accept or reject the automation's response to the situation presented in the display. In management by consent (MBC), participants always responded both for agreement or disagreement with automation's action. In management
by consent (MBC), if participants agreed with automation’s response, they were instructed to press the left arrow key on the keyboard which was indicated by an “A” sticker to represent Accept. In management by exception (MBE), if participants agreed with automation’s response they were instructed to let the automation time out. A pilot study was utilized to provide the timing used in management by exception (MBE) at six seconds. After six seconds, if a response was not made, automation timed out and moved onto the next scenario. In both management by consent (MBC) and management by exception (MBE), if participants rejected the action provided by automation, they were instructed to press the right arrow button on the keyboard which was indicated by an “R” sticker to represent Reject. In all conditions, participants’ responses did not influence the next scenario viewed as all scenarios were randomized. The computer software created for this experiment recorded response time to scenarios automatically in addition to accuracy. The internal clock measuring reaction time started counting once the dialog box appeared on the computer screen. The clock stopped and recorded the reaction time for each scenario at the first sign of depression of the selected key. For those circumstances when automation timed out, a reaction time of six seconds was recorded.
Results

Various repeated-measures Mixed Analysis of Variance (ANOVA) tests were used to analyze data with the assistance of a SPSS statistical package. Six comparisons were made. These comparisons are listed below; all comparisons were made using a Mixed ANOVA design analysis. A \( p \) value of .05 was used to determine significance for all analyses.

- Overall Reaction Time within sensory modalities
- Overall Accuracy within sensory modalities
- Reaction Time of False Alarms within sensory modalities
- Accuracy of False Alarms within sensory modalities
- Reaction Time of Misses within sensory modalities
- Accuracy of Misses within sensory modalities

The comparisons of overall reaction time and the comparisons of overall accuracy were examined to provide global information regarding treatment effects. Additional comparisons of reaction time and accuracy of automation false alarms and automation misses were examined to address the issue of restriction of range in response due to the management strategy. These subsequent analyses were required to address equal comparisons. Conditions under which management by consent (MBC) and management by exception (MBE) can be directly compared are under automation false alarms and automation miss conditions for both reaction time and accuracy data. In these cases, in management by exception (MBE) conditions participants would need to respond with a manual response for action (“Reject”) in the same fashion as would be necessary for the management by consent (MBC) conditions rather than waiting for automation to proceed
to the following trial. The requirement of response in both management strategies allows for equal comparison between the two strategies but thereby only allows a subset of the overall data to be addressed.

After a repeated measures Mixed ANOVA was completed on the overall reaction time comparing sensory modalities between the strategies, significance was found between the automation management strategies of management by consent (MBC) and management by exception (MBE), $F(1, 58) = 61.627, p = .000$. Power for the between subjects test of strategy was observed at 1.000 with a partial eta squared of .515. This suggests that approximately 52% of the variance in this test was accounted for by the difference between the two management strategies. Significance was also found overall for the reaction time of the sensory modalities, $F(1.621, 116) = 3.740, p = .036$. For the tests of within subjects effects of modality, a power of .609 with a partial eta squared of .061 was observed. These results suggest that there is a difference between the sensory modalities. There was a medium power for modality (power is over .5) yet only 6% of the overall variance was accounted for by the differences in modality; therefore, the overall effect on modality was very small. The interaction of modality and strategy was not found to be significant, $F(1.621, 116) = 1.514, p = .227$. Figure 6 displays the overall means for reaction time.
A repeated measures Mixed ANOVA for overall accuracy comparing sensory modalities between the strategies revealed a main effect of automation management strategies, $F(1, 58) = 22.394, p = .000$. Power for the between subjects test of strategy was observed at .996 with a partial eta squared of .279. This means that approximately 28% of the variance was accounted for by automation management strategies, therefore, the overall effect on modality was small. No significance was found overall for the accuracy of the sensory modalities, $F(2, 116) = .931, p = .397$, or for the interaction of sensory modality and strategy, $F(2, 116) = .120, p = .887$. Figure 7 displays the overall means for accuracy. Better accuracy performance is toward the top of the figure, worse accuracy is located at the bottom of the figure.
In order to further investigate the main effect between automation strategies for reaction time, a repeated measures Mixed ANOVA was done comparing reaction time of response to automation false alarms across the sensory modalities between the strategies. The ANOVA test revealed significance for the main effect of automation management strategies of management by consent (MBC) and management by exception (MBE), $F(1, 58) = 52.840, p = .000$. Power for the between subjects test of strategy was observed at 1.000 with a partial eta squared of .477. Therefore, approximately 48% of the variance in the automation false alarm situations was accounted for by the automation management strategies, which is a medium effect. For the within subjects test for the modality, significance was found, $F(1.779, 116) = 4.338, p = .019$, with the power of .706 and partial eta squared of .070. Even though significance was discovered for modality, only 7% of variance was accounted for by modality, which is a small effect size and mimics the findings in the overall analysis. For the interaction of sensory modality and strategy,
no significance was found with $F(1.779, 116) = 1.905, p = .153$. Figure 8 depicts the mean reaction time of automation false alarms.

![Mean Reaction Time of Automation False Alarms](image)

**Figure 8.** Mean Reaction Time of Automation False Alarms

The accuracy performance in false alarm trials was analyzed using a repeated measures Mixed ANOVA. No significance was found between the automation management strategies, $F(1, 58) = 1.288, p = .261$ and a power of .200 and partial eta squared of .022. No significance was found overall for the accuracy for the within subjects test for the modality, $F(2, 116) = .238, p = .789$. For the interaction of sensory modality and strategy, no significance was found $F(2, 116) = 2.139, p = .122$. Therefore no effects were found in the accuracy data for the automation false alarm subset of the data. Figure 9 displays the overall mean accuracy for automation false alarms.
Another repeated measure Mixed ANOVA was completed on the reaction time of automation miss cases. Significance was found between the automation management strategies, $F(1, 58) = 57.351, p = .000$, with a power of 1.00 and partial eta squared of .497. This suggests that nearly 50% of the variance was accounted for within automation strategies. No significance was found overall for the reaction time for the within subjects test for the modality, $F(2, 116) = .716, p = .491$. For the interaction of sensory modality and strategy, no significance was found, $F(2, 116) = 1.488, p = .230$. Refer to Figure 10 for a graph displaying the mean reaction time of automation misses.
Figure 10. Mean Reaction Time of Automation Misses

The final repeated measures Mixed ANOVA was completed on accuracy of automation misses across the sensory modalities and between the strategies. Significance was found between the automation management strategies with, $F(1, 58) = 18.574$, $p = .000$, with a power of .989 and partial eta squared of .243. This suggests that 24% of the variance is accounted for by strategy, which is a small effect size. No significance was found overall for the accuracy for the within subjects test for the modality, $F(2, 116) = .913$, $p = .404$. For the interaction of sensory modality and strategy, no significance was found, $F(2, 116) = 2.378$, $p = .097$. Figure 10 graphically displays the accuracy of automation misses.
Discussion

Results show that in all but one analysis made (accuracy of false alarms), a significant difference exists between the automation management strategies of management by consent (MBC) and management by exception (MBE). Significance occurred for automation strategies for the overall analysis of reaction time and the overall analysis of accuracy. Significance for strategy was also found in the analyses of reaction time of automation misses, accuracy of automation misses, and the reaction time of automation false alarms. The finding of the management strategy was robust and typically had a fairly large effect size and high power. There was definitely a difference appearing between the two groups. Power in these instances was equal to or greater than .989. This extremely high power suggests that there is indeed a significant difference
between the types of automation management strategies of management by consent (MBC) and management by exception (MBE) and results are likely to be replicated.

Therefore, the hypothesis that differences exist in the reaction time between the management strategies was supported. Overall reaction time for management by exception (MBE) was lower than the reaction time for management by consent (MBC). This is most likely because participants felt pressured to respond in management by exception (MBE) because they wanted to “beat the clock” and avoid time outs if they rejected automation’s response. Additionally, reaction time was capped at six seconds in management by exception (MBE) conditions because if a response was not made within six seconds, the automation proceeded to the next image. Thus, participants may not have had enough time to respond to the image and if given an unlimited amount of time, their reaction time to the situation would have likely been longer. However, the amount of time is an inherent difference between the two automation management strategies.

Furthermore, the significance found in overall accuracy between the automation management strategies supports keeping humans in the loop and that humans should have ultimate control over automation because management by consent (MBC) resulted in a significantly higher mean accuracy than management by exception (MBE). A higher accuracy suggests the operator is kept in the loop because accuracy improves when automation stalls and the person must select an option before automation will continue. Consequently, this also supports the hypothesis that accuracy for management by consent (MBC) is higher than management by exception (MBE).

Since these two automation management strategies are significantly different, thought should be given to which type of automation management strategy is used with a
task. These results stated that a difference was evident and management by exception (MBE) results in a faster reaction time. On the other hand, management by consent (MBC) is the more accurate strategy in terms of automated baggage screening as shown by these results. This information should be taken into consideration when a task is automated because in some situations false alarms and misses by the human operator are more forgiving than others. For example, in baggage screening a false alarm by the operator wastes time but a miss by the operator could result in a potential disaster if a weapon passes security. In terms of baggage screening, accuracy would be more important but in other domains the severity of misses by the operator may be minimal and decreased reaction time may be valued.

In terms of sensory modalities, significance was only found in two analyses. Significance for modality was found in the analysis of overall reaction time and the analysis of reaction time of automation false alarms; in all other analyses, modality was not found to be significant. One should be cautious that even though significant results were found in two analyses, the effect size was very small. For the overall reaction time comparison, only 6% of variance was attributed to effect size. For the comparison of reaction time of false alarms, only 7% of variance was attributed to effect size. Therefore, even though the effect of modality was significant in these analyses, the application in reality may be minimal due to the extremely low effect size.

The manipulation of modality was found to be significant in overall reaction time suggesting that a small difference does exist between the modalities in terms of reaction time. These results support Ho, et al. (2001) who found significant differences when alarms were used in a demanding ATC interruption task. For the present study, most
effects were non-significant, and those that were had very small effect sizes. In those cases where significance was found, it may have been due to the difference in threat detection by the operator. In the case of automation false alarms, the automation suggests that nothing is there, and the operator has to determine if that is true or not. For automation misses, there is clearly something there, but the automation is suggesting otherwise. So the extra time that is required for the visual modality in the false alarm by automation is that the person has to “search” for whether something is present or not, aided by the visual alarm of flashing (same modality). The operator has to not only search for something that is not there while the visual alarm (another piece of visual information) further adds to the information the operator must process. In the misses by automation, that effect does not occur, because the presence of the obvious threat (missed by the automation) negates any need for additional information.

Additionally, the effect of modality found in overall reaction time and reaction time of false alarms but not seen in the miss data could be due to trust in automation. When a false alarm by automation occurred, the automation stated that a threat was present even though the image did not contain a threat. People rely on automation even when automation is incorrect because they have an “unwarranted trust in automation” (Parasuraman & Miller, 2004). Participants commented that the use of alarms whether visual or auditory made them more inclined to believe that an actual threat was present. This suggests the use of alarms in combination with people’s trust in automation may have resulted in a longer processing time and thus a longer reaction time when a threat was present.
Recall that those situations in which automation produced hits and correct rejections were not analyzed for the reaction time data or accuracy data between the automation management strategies because those data would not be valid comparisons. If the automation is correct in its response, the correct response would be for the person to accept automation’s action; however an action is only taken to reject automation’s response in the management by exception (MBE) management strategy. Therefore, for participants in the management by exception (MBE) group, if an individual agrees with automation’s response, they are instructed to do nothing and let the automation time out. Comparing reaction time then would not be a valid comparison in this instance because in management by consent (MBC) participants have an unlimited amount of time to respond and are required to make a response while in management by exception (MBE) their response time is artificially constrained to six seconds (the length of time before management by exception timed out in the experiment).

While reaction time data cannot be compared between these conditions due to the temporal constraints on action, comparisons of accuracy of the hit and correct rejection conditions could be performed. However, these analyses were not pursued because in the overall comparison of accuracy, sensory modality was not found to be significant. Therefore, one assumes that it would not be significant in a subgroup of the data (of only hits and correct rejections) especially after analyzing accuracy of automation misses and automation false alarms and not finding significance for modality in these comparisons as well.

The lack of significance for modalities across analyses in this study fails to support multiple resource theory. In the analyses comparing overall reaction time
between the automation strategies and reaction time of automation false alarms, significance was found, but in all other analyses (overall accuracy, accuracy of automation false alarms, reaction time of automation misses, and accuracy of automation misses) significance was not found. Due to significance only being found in one subsequent analysis (reaction time of automation false alarms) and the extremely small effect size, results do not provide conclusive evidence of multiple resource theory. Therefore, the hypotheses that overall conditions with an auditory alert would result in a faster reaction time compared to flashing and control conditions were not supported. Additionally, the hypotheses about accuracy of sensory modalities were not supported.

Results also indicated a consistent speed accuracy tradeoff existed in a good portion of the data. In much of the data, increases in reaction time (slower responses) were accompanied by increased accuracy or decreases in reaction time (faster responses) were accompanied by decreased accuracy. This was especially evident for those participants in the management by exception (MBE) conditions where they performed significantly worse in terms of accuracy than those participants exposed to management by consent (MBC). Participants in the management by exception (MBE) condition were asked after the completion of the experiment if they felt they had enough time to respond to the scenarios and all but three individuals felt they had enough time to respond. Some participants commented that it took them a few scenarios before they felt comfortable with the time limit. These responses from the participants indicate the time limit was not producing a speed accuracy tradeoff at the conscious level. The data does indicate a tradeoff occurs, but this could be due to the strategy on part of the participant (people feeling they do not have enough time, so they rush) but it could also just be that they perform worse because they simply have less time, which prevents the participants from being as accurate as
possible. However participants' responses suggest that they feel they have enough time while results indicate accuracy is worse than participants who experienced management by consent (MBC).

This study does provide some evidence regarding the combination of management strategy and alarm modality that was not previously seen in the literature. It may be that the modality used was not sufficient to achieve an interaction. One important conclusion to draw from this finding is that determining the appropriate amount of time necessary in management by exception (MBE) is dependent on the task and is an area which should be pursued in future studies to determine the amount of time that could best optimize accuracy and efficiency if management by exception (MBE) must be used. The issues of accuracy and time constraints are critical factors to the domain of baggage screening because numerous bags must go through security and mistakes can be fatal. Time is crucial not only because of inpatient passengers but because time is money and baggage must be processed in time to make its flight.

Possible limitations of this research could be the number of images used. More images may have produced different results. For example, overall reaction time could have decreased and accuracy could have increased if more images were used because participants could have become more familiar with the task and thus perform better. If more images were used, then modality may have been found to be significant under more analyses. However, if more images were utilized in a future study, vigilance issues would need to be addressed as vigilance is a problem in the actual task of baggage screening. Baggage screening is visual demanding and baggage screeners could become tired viewing baggage contents possibly becoming less likely to detect threats that are not immediately obvious. The similarity of the images could have been another possible limitation. Approximately 30 original images were taken and then those
original images were mirrored and transposed to produce different images. Participants caught onto the similarity of the images even at times thinking the images was identical to images previously seen. This could have resulted in a higher accuracy as compared to if all images were completely different. Additionally, an overall decreased reaction time could have resulted because when a repetitive or similar image appeared, participants could have recognized the image as a repeat and respond more quickly. Furthermore, some of the images were color images and some of the images were black and white. Even though all images were randomized there could be a difference in detecting threats in color versus non-color images. Some of the images were blatantly obvious and not obscured by other baggage contents. For example, most individuals are familiar with the shape of a hand gun and probably could easily identify such an object. In some of the images, the shape of a hand gun was evident and it appeared as if whoever packed the luggage just threw a hand gun inside the luggage with no attempt to conceal the contents of the baggage. Other threats were more a bit more difficult to detect and were partially obscured by baggage contents; therefore, difficulty of threat detection is a possible limitation to the present study. However, in a realistic baggage screening environment some threats are more difficult to detect than others. Results from this study indicate that when accuracy is of importance that management by consent (MBC) should be used. Management by exception (MBE) should be used with caution and care should be taken to determine the appropriate time limit. In domains where speed is only of concern and accuracy is not an issue then management by exception (MBE) would be a better automation strategy to employ.

Future directions of research should further pursue management by exception (MBE) and more specifically the time limit used in management by exception (MBE). More research on automation management strategies is necessary especially on determining the length of time
allotted before a time out occurs in management by exception (MBE) not only in baggage screening tasks, but any form of automation that utilizes a management by exception (MBE) strategy for managing the automation. Setting the time limit too long does not encourage people to speed up while setting the time limit too fast would result in people not physically having enough time to respond and likely increase error. In addition further research should also investigate the areas mentioned previously as limitations. Similarity of baggage, color versus non-color images, difficulty of threats, and a greater number of images viewed should further be researched.

In addition automation management strategies and alarms as applied to various domains could further be explored. While nothing was found in this domain, it may be either that an interaction failed to be found or an interaction may be of interest in another domain. Different alarms utilized across all modalities and different alarms within the auditory and visual channels could provide additional research opportunities. Special care should be taken when alarms are utilized in an automated task is signify only threats as to the baggage screening task simulated in this experiment, participants stated that the use of alarms made them more prone to believing a threat was present.

Conclusion

By pairing automation management strategies with sensory modalities, results indicated the different types of alarms used did not have a significant effect for reaction time and accuracy. However, results indicated significant differences exist between automation management strategies. Surprisingly, statistical analysis provided minimal support for multiple resource theory because significance was only found for modality in the comparison of overall reaction time and reaction time of automation false alarms.
The domain of automation management strategies is new and becoming increasingly more important. Limited research and application to various domains makes the topic an attractive research topic and identifies the need for continued research in the domain of automation management strategies.
References


Appendix 1: Management by Consent (MBC) Prompt

You are about to participate in an experiment that involves detection of threats in a baggage screening task. Automation will scan X-rays of baggage which will be displayed on the computer screen in front of you. A text statement will be provided in a dialog box and you will determine if you accept or reject automation’s response. Automation will either state “Alert! Threat Found! Search Baggage.” or “No Threat Found! Pass baggage.” Automation will not always be correct in its response.

Your responsibilities include first reading the text provided in the dialog box and then actively scanning the image to detect if a threat is present. You will then determine whether you wish to accept or reject automation’s response.

- If you ACCEPT the action provided by automation, press the left arrow key on the keyboard which is indicated by the A sticker.

- If you REJECT the action provided by automation, press the right arrow key on the keyboard which is indicated by the R sticker.

Any time you detect a threat, baggage should be searched. In the instance where automation states that a threat is found, if you detect a threat and therefore you agree with automation’s response to search the baggage, select ACCEPT. If you disagree with automation because you do not detect a threat, you would REJECT automation’s action to search the baggage, and the baggage would pass on. In the instance where automation states that no threat is found and you agree with automation’s response to pass the baggage, you would select ACCEPT to allow the baggage to pass on and continue. However, if you detect a threat and therefore disagree with the action provided by
Appendix 1: MBC Prompt (continued)

automation you would select REJECT which would prevent the baggage from being passed on.

Potential threats include guns, knives, grenades, and explosives. Images will appear in black and white and in color. In color images, organic material should appear red and explosives will appear red. However, just because baggage contents are red does not imply that explosives exist.

A black screen will appear between images. Do not press any keys when this screen appears. During the training and the experiment, alarms will occur. These alarms are both visual and auditory alarms. Your response did not cause these alarms to occur; they are merely part of the experiment. You will first begin with a training session. The training session will familiarize you with the task you will complete during the actual experiment. During the training session you may ask me any questions, however, I can not tell you which option to select. After the training session is completed, you may ask questions before beginning the experiment. Once the experiment begins you can not ask me any further questions.

Remember...

You are ACCEPTING OR REJECTING automation’s response.

- If you agree and wish to ACCEPT automation’s action, press the left arrow key which is indicated by the A sticker on the keyboard

- If you disagree and wish to REJECT automation’s response, press the right arrow key, which is indicated by the R sticker on the keyboard.

Do you have any questions before the training session begins?
Appendix 2: Management by Exception (MBE) Prompt

You are about to participate in an experiment that involves detection of threats in a baggage screening task. Automation will scan X-rays of baggage which will be displayed on the computer screen in front of you. A text statement will be provided in a dialog box and you will determine if you accept or reject automation’s response.

Automation will either state: “Alert! Threat Found! Search Baggage.” or “No Threat Found! Pass baggage.” Automation will not always be correct in its response.

Your responsibilities include first reading the text provided in the dialog box and then actively scanning the image to detect if a threat is present. You will then determine whether you wish to accept or reject automation’s response.

- If you ACCEPT the action provided by automation, do NOT press any keys. After a set time period, automation will time out and move on to the next image.
- If you REJECT the action provided by automation, press the right arrow key on the keyboard which is indicated by the R sticker.

You only need to take action if you REJECT automation’s response.

Any time you detect a threat, baggage should be searched. In the instance where automation states that a threat is found, if you detect a threat and therefore you agree and ACCEPT automation’s response to search the baggage, do NOT press any keys. Automation will time out and move on to the next image after a set time period. If you disagree with automation because you do not detect a threat, you would REJECT automation’s action to search the baggage, and the baggage would pass on. In the instance where automation states that no threat is found and you agree with automation’s response to pass the baggage, allow the automation to time out.
Appendix 2: Management by Exception (MBE) Prompt (continued)

However, if you detect a threat and therefore disagree with the action provided by automation you would select *REJECT* which would prevent the baggage from being passed on.

Potential threats include guns, knives, grenades, and explosives. Images will appear in black and white and in color. In color images, organic material should appear red and explosives will appear red. However, just because baggage contents are red does not imply that explosives exist.

A black screen will appear between images. Do not press any keys when this screen appears. During the training and the experiment, alarms will occur. These alarms are both visual and auditory alarms. Your response did not cause these alarms to occur; they are merely part of the experiment. You will first begin with a training session. The training session will familiarize you with the task you will complete during the actual experiment. During the training session you may ask me any questions, however, I can not tell you which option to select. After the training session is completed, you may ask questions before beginning the experiment. Once the experiment begins you can not ask me any further questions.
Appendix 2: Management by Exception (MBE) Prompt (continued)

Remember...

You are ACCEPTING OR REJECTING automation’s response.

- If you agree and ACCEPT automation’s response, sit back and do nothing.

  Wait for the automation to time out.

- If you disagree and wish to REJECT automation’s response, press the right arrow key, which is indicated by the R sticker on the keyboard.

Do you have any questions before the training session begins?
Appendix 3: Consent Form

Automation Management Strategies and Sensory Modalities

Conducted by Michelle Leach
Advisor: Shawn Doherty
Embry Riddle Aeronautical University
Human Factors Research Laboratory
ERAU, Daytona Beach, FL 32114-3977

The purpose of this study is to determine how effective people are at judging threats in a baggage screening task with the aid of automation. The experiment consists of one session lasting approximately 15 minutes during which you will be asked to respond to a series of trials involving automation on the computer. You have the choice to accept or reject automation’s response.

Your scores will remain anonymous. There are no known risks associated with this experiment. You will be compensated for your participation with extra credit in the course previously designated. You may terminate your participation at any time. Your assistance will help us better understand how automation management strategies affect performance in baggage screening tasks.

Thank you for your participation. If you have any questions, please ask during the experiment or feel free to call me at (386) 226-7518.

Statement of Consent

I acknowledge that my participation on this experiment is entirely voluntary and that I am free to withdraw at any time. I have been informed as to the general scientific purposes of the experiment and that I will receive extra credit for completion of the study. If I withdraw from the experiment before its termination, I will not receive extra credit.

Participant’s name (please print): __________________________

Signature of participant: __________________________ Date: ________

Experimenter: __________________________ Date: ________
Appendix 4: Demographic Questionnaire

Participant Number (To be completed by researcher) ________________

Please write your responses in the appropriate space.

Name ________________________________

Male or Female? __________

How old are you? ____

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

Are you color blind? ______________________________________________

Do you have any known hearing problems? If so please state what they are. _______________________________________________________

Are you right or left handed? ______________________________________

Have you ever been a baggage screener? ______________________________

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

Once you complete the front of this sheet, please give to the experimenter.
Appendix 5: Follow-up Questionnaire

Participant Number (To be completed by researcher) ________________

For the below questions use a scale of 1 to 7 for your responses.

On a scale of 1 to 7, please rank the difficulty of the task, with 1 being extremely easy and with 7 being extremely difficult. ________

Rank on a scale of 1 to 7 how well you think you performed on the task considering the accuracy of your responses. Use a 1 to indicate you think you performed poorly on the task and use a 7 to indicate that you think you performed well on the task. ________

Rank on a scale of 1 to 7 how well you think you performed on the task considering your reaction time. Use a 1 to indicate you think you performed poorly on the task and use a 7 to indicate that you think you performed well on the task. ________

Overall, rank on a scale of 1 to 7 how well you think you performed on the task considering both the accuracy of your responses and your reaction time. Use a 1 to indicate you think you performed poorly on the task and use a 7 to indicate that you think you performed well on the task. ________

How similar did the images appear to you on a scale of 1 to 7 with 1 meaning images were not similar at all and with 7 meaning images looked identical and appeared repetitive? ____________________

MBE condition only

Did you have enough time to make a decision and respond to whether or not automation was correct in the action it decided to take concerning the baggage? ________________

Please state any thoughts on your performance or the experiment below.

Additional Comments ____________________________________________

______________________________________________________________

______________________________________________________________