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Human Vigilance Performance in an Advanced Security System Environment

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Abstract

In a post-9/11 world, airport security has become a national priority. In 2005 the Department of Homeland Security's (DHS) budget set aside \$5.2 billion for the Transportation Security Administration (TSA) and \$851 million to improve aviation security. The current study was carried out within the operations division of a regional airport in the Southeastern United States. The operations division was responsible for the airport's communication center, safety, security, oversight of general aviation, ground transportation, compliance with Federal Aviation Administration (FAA) and TSA regulations, and coordination of police and fire services. Vigilance and situational awareness behaviors were defined and measured in the communications center. The effects of an advanced technological intervention designed to improve vigilance and situational awareness of airport operations security staff was evaluated in this study.

Human Vigilance Performance in an Advanced Security System Environment

In a post-9/11 world, airport security has become a national priority. In 2005 the Department of Homeland Security's (DHS) budget set aside \$5.2 billion for the Transportation Security Administration (TSA) and \$851 million to improve aviation security (Department of Homeland Security, 2004). With so much money available, the number of interventions proposed to increase human behavior related to security and vigilance performance should be expected to grow. However, this is an area that the science of behavior analysis can not only contribute greatly to, but has already been investigating for many years.

The study of human vigilance performance is not a new occurrence. Frazier and Bitetto (1969) studied the ability of participants to remain vigilant while scanning complex images on a monitor. Participants were divided into two groups and the schedules of concurrent reinforcement contingencies were manipulated for each. Frazier and Bitetto found that use of variable interval schedules combined with performance feedback and minute changes in the specific task required could maintain vigilance performance over the length of their 1 hour sessions. However, a major drawback to the study was that the participants were college students; not trained security personnel. In addition, a simulated vigilance task was used that was very basic in design. The "complex" display used by the Frazier and Bitetto was limited in the number of stimuli it could present and presented dramatically fewer visual stimuli than can be presented on a modern computer monitor. The study only used one panel for presenting stimuli to participants, while modern security settings typically contain multiple monitors. Finally, the Frazier and Bitetto study lacked the multiple distracters present in a modern advanced security environment.

Rosenberger (1979) further investigated the variables contributing to human vigilance. Rosenberger's study investigated the fixations of the participants to stimuli. For this study, analog volt meters were used as the targeted stimuli. In an improvement over the Frazier and Bitetto study, Rosenberger used three volt meters. Also, early eye-tracking equipment was used to assess the location and duration of the participants' gaze. While not as sophisticated and demanding as a modern security environment, Rosenberger's study did add to the knowledge base of variables required to increase the selected attention of participants.

Closer to Homeland Security applications, Leung (1993) used a simulated air defense task to study human behavior. In Leung's study, an extension of an earlier experiment (Leung, 1989), participants were instructed to use two simulated radar screens on a personal computer to detect and destroy enemy aircraft. The schedules of reinforcement and presentation of target stimuli (enemy planes) were experimentally manipulated by the researchers. Participants in the study not only performed better with shorter, unsegmented schedules, but also stated a preference for such schedules. The results suggest that as the duration between the presentations of stimuli of interest becomes longer, the greater the decrease in vigilance performance should be expected.

More recently, Lichstein, Riedel, and Richman (2000) evaluated a more practical measure of vigilance. Lichstein et al. evaluated an updated version of the Mackworth Clock Test. The test, originally developed for British radar operators in the Royal Air Force during World War II, was computerized in Lichstein's study. The computerized version of the test replicated the results of the evaluations of the original test, conducted by Mackworth himself (1948). Participants in both the original and computerized study demonstrated a significant

decrease in vigilance over the span of one hour. Unfortunately, while both studies measured vigilance, neither made recommendations for increasing vigilance in the future.

Madden and Perone (1999) further researched the area of human vigilance. Madden and Perone set up a vigilance task in a quiet room. Participants, all college students, were required to view a 14-inch computer monitor and looked for specified stimuli. During the study the schedule of reinforcement for the vigilance behavior was manipulated. The vigilance performance of the participants was then correlated to the schedules of reinforcement. Madden and Perone's finding suggested that personal differences, more than differences in behavior contingencies, was the major factor in the variability of vigilance behavior. As a result, the authors concluded human vigilance should be studied on an individual basis. Single-subject methodology would be best suited for such studies conducted in the future.

Vigilance and Aviation Security

In an age of heightened security due to increased threats of terrorism it is expected that everyone, from the general public to organizations in the private sector to government agencies, each do their part to ensure safety. However, the natural contingencies may not be arranged correctly for that to happen. In the analysis conducted by Heal and Kunreuther (2005), the study showed that individual airlines and private companies within the aviation industry are less likely to invest capital in security than in the past. This was due to a number of factors, including the potential problems remaining competitive with other companies that may not be contributing an equal share to security. Therefore, due to the natural contingencies acting on the behaviors of the private sector, it is important that government agencies be able to optimize their security performance.

Fiore, Scielzo, & Jentsch (2004) conducted their research with the goal of ultimately improving the performance of TSA employees. Fiore et al. studied college students using a simulated X-ray baggage screening task. The goal of the research was to determine optimal training methodologies by measuring the participants' detection rates with a variety of types of X-ray images displayed. The results of the study showed a relationship between spatial aptitude and the effectiveness of the training. However, as important as training may be, the authors stated a need for future research in the vigilance of security personnel, especially in natural settings.

The natural setting for aviation security personnel in the 21st century will increasingly become filled with advanced technology. Therefore, any studies on human vigilance in relation to security should be studied in conjunction with technology. Fiore, Rubinstein, and Jentsch (2004) stated that human-centered approaches to studying security should focus on how technology could increase the performance of security personnel. Fiore et al. saw technology as a tool, not a replacement, for the security personnel to utilize for performance improvement. Such an approach, however, will require a combination of both basic and applied research to better understand the variables influencing human responding in advanced technology security setting.

The present study was designed to evaluate the behavioral effects of a sophisticated technological intervention package designed to increase the situational awareness of security personnel. In contrast to the selected studies of vigilance and selected attention previously reviewed for this research, the current study was conducted as Applied Behavior Analysis research. One of the dimensions that separates Applied Behavior Analysis from the rest of the behavioral field is that it addresses practical, socially significant problems in their natural setting instead of theoretical issues that only seek to add to the basic knowledge base of the underlying

science (Baer, Wolf, Risely, 1968). Also, part of the ethical guidelines for a behavior analyst is the review of the effectiveness of alternative interventions designed to change any of the dimensions of a behavior (Behavior Analyst Certification Board, 2004). While this review can be done as a means of empirically revealing the ineffectiveness of interventions (Tomasi, 2006), it can also be used for more supportive purposes. For effective interventions, the independent review of an intervention by researchers trained in the study of the science of behavior can provide data-based, scientific verification. Such an independent evaluation can also assist in the on-going research and development of an intervention as a means of making it more efficient, effective, and ethical. The goal of this research was to meet these constructive purposes.

Method

Setting & Participants

The study took place at a small, regional airport. The airport was situated within the city limits of mid-sized city in the Southeastern United States. The site included a main terminal that catered to commercial aviation service, general aviation resources that catered to both private and government aircraft, and commercial air freight cargo services. In addition the airport housed various resources to support its aviation activities. The primary location for the research endeavors done on-site for this study was in the airport's Communications Center (Com Center). The Com Center at this airport was located in a windowless room within the main terminal building. The Com Center served as the central hub of all communication, security, and operational activities at the airport. The Com Center contained an array of equipment that included, but was not limited to, banks of closed circuit video monitors, telephones, equipment for monitoring and transmitting over a variety of radio frequencies, and computer terminals for

interacting with the airport's various systems. The airport in this study generally closed to the public after the last of the day flight arrived, yet the Com Center remained staffed 24 hours per day.

Participants in this study were employees of the airport's Operations Division. There were 16 participants; 14 male and 2 female. All participants were over the age of 18 and signed an Informed Consent form, approved by the Human Subjects Committee of Florida State University's Interdisciplinary Review Board, prior to the start of research. While the backgrounds of the individual participants varied slightly, the majority of participants had either previous experience in the military or in the airline industry. Participants operating the system in Com Center were all city employees and typically worked 40 hours per week. The majority of work in the Com Center was done alone.

Dependent Variables

The dependent measures for this study were phone activity, radio activity, public address system announcements, activities log entries, system alarms, manual camera movements, on-task engagement, and situational awareness. Engagement in off-task behaviors, selection of television programming, and use of automated camera sweeps were also recorded and analyzed during the study.

Phone activity included the use of all land-line phones in the Com Center. In-coming and out-going calls were both included in phone activity. Usage of personal cellular phones were not included in phone activity.

Radio activity was a measure of interactions over the various radio frequencies monitored in the Com Center. Due to the one-way nature of radio calls, radio activity was not measured in terms of the frequency of individual instances of keying the microphone. Such a measure could

have been biased by a number of variables, including the individual speaking patterns of the participants, as well as those of individuals calling the Com Center. Instead, each discrete conversation between an individual and the participant in the Com Center was scored as single instance of radio activity.

Public address announcements were a measure of the frequency of announcements made by the participants over the public address system. This was only applied to announcements made by the participants during observation sessions, and did not apply to pre-recorded, pre-programmed announcements.

The activities log was a daily record of significant events that occurred. Entries into the activities log were made by the participant working in the Com Center.

System alarms referred to audio alarms automatically triggered by the airport's existing security system. Each alarm required a specific chain of behaviors in order to appropriately respond to the triggering event and to deactivate the alarm. A frequency count of system alarms was used for measurement, as 100% of alarms elicited a response from the participants. The latency of all responses to system alarms was within parameters set by airport management.

The primary dependent measures in this study were manual manipulation of cameras on-task engagement, and situational awareness. Manual camera movement was defined as a change in the viewpoint displayed on any of the monitors in the Com Center as a result of responses emitted by the participant. A camera could be moved manually in a number of ways. The most common method was by entering in the number assigned to a specific camera into a keypad on the desk in the Com Center. The viewpoint displayed on a monitor could also be manually changed by using a joystick attached to the camera keypad. Fluid movement of a camera, as a result of use of the joystick, was scored as a single response until the camera was still for 2

seconds or more. If the participant resumed movement after a pause of at least 2 seconds the behavior was scored as a new response.

Manual manipulation of the cameras differed from most of the other responses targeted. This response was considered a free operant behavior (Baer & Fowler, 1984). A participant could engage in this free operant behavior at any time; antecedent stimuli (Cooper, Heron, & Heward, 2006) were not needed to signal when responding should occur. Other behaviors, such as responding to a system alarm, first require a discriminative stimulus, or S^D (Malott & Trojan-Suarez, 2003), to be emitted before the engagement in the specific chain of behaviors could be reinforced. Free operant behaviors require only a minimal amount of time for the completion of individual instances of the response. Since manual camera movement was a free operant behavior, it was an important measure of the vigilance of the participants, especially in the absence of security-related stimuli.

On-task engagement was a grouped measure of all work related responses. The behaviors listed above, as well as the remote updating the displays of arrivals and departures through the main terminal building, signing out of operations equipment, use of the access control system, work-related discussions with colleagues, surveillance of the monitors, completion of checklists, completion of online training, and adjustment of the lighting controls were all defined as on-task. The checking of email was defined as on-task if and only if it was on the account assigned to airport employees by management.

The detection of potential and actual security violations was an important aspect of the participants' role in the Com Center. In order to assess this, situational awareness was selected as the third primary dependent variable. Situational awareness was operationally defined as assessing the status of an environment across more than one dimension over time and responding

to stimuli within the environment according to set operational protocols. It was assessed as the percent of events that elicited an appropriate response out of the total number of events per observation session. An appropriate response was defined as the chain of behaviors required to investigate an event following the established operational protocol until resolution. For this target, perimeter intrusion, avoidance of the TSA security checkpoint, loitering in a secure area, unattended vehicle, unattended object, vehicle tailgating, failure of a vehicle to stop at a secure checkpoint, human tailgating, and entering a secure area through the exit lane were the violation classes of events that could elicit an appropriate response.

Procedure

Direct observation sessions were conducted in the airport's Com Center. Based on the results on pilot work conducted by the research team, a 3 hour observation session was determined to be optimal for effectively sampling behavior in the Com Center. To sample the differences in performance during peak and off-peak hours of operation, observation sessions were held twice per day. Sessions ran 09:30 - 12:30 and 23:30 - 02:30 on Sunday, Monday, Tuesday, Wednesday, and Friday. Similar to the observers in Olson and Austin's (2001) study of the safety performance of lone workers, observers in the present study sat behind and to the right of participants working in the Com Center. The position of the observers offered a view of all monitors and the behaviors of the participants.

Direct observation data were recorded on uniform data sheets designed specifically for this study. A behavior code, outlined in a data collection protocol, was utilized for the recording of data on the data sheet to minimize disclosure of the specific behavioral targets to the participants and to further protect the confidentiality of participants. Data for phone activity, radio activity, public address announcements, activities log entries, system alarms, and manual

camera movements were each recorded as frequency counts in 10 minute intervals. A partial interval procedure (Bailey & Burch, 2002) was used for measuring on-task engagement. The partial interval procedure recorded engagement in 1 minute intervals, and stipulated that participants must be engaged in work-related duties for at least 31 seconds of each interval to be scored as on-task. Finally, data on the appropriate resolution of perimeter intrusion, avoidance of the security checkpoint, loitering in a secure area, unattended vehicle, unattended object, vehicle tailgating, vehicle stopping, human tailgating, and entering the exit lane were collected during observation sessions.

Videos of all events producing alarms were automatically digitally recorded and archived by the system. All videos that occurred during observation sessions were retrieved and reviewed by the research team. Scoring of archived videos by the research team was conducted in one of the airport's conference rooms, located next to the Com Center. The video of each alarm was projected on a screen located at the end of the conference table. Observers, seated at the table, viewed and independently scored each video clip. The scoring of the videos was then compared with the observation data and used to assess the situational awareness of each 3 hour observation session.

Assessment

The prediction of behavior is a key feature to the applied analysis of behavior. As Bailey and Burch (2006) stated, "Before we can do anything about changing a behavior we must first be able to predict it." In order to predict a behavior the function of that behavior must first be understood. To do this, a Functional Behavior Assessment (FBA) must be conducted. The Performance Diagnostic Checklist (Austin, 2000), or PDC, was the FBA methodology used as the primary behavioral diagnostic tool for this study. The PDC, based on Gilbert's Behavior

Engineering Model (Gilbert, T. 1978/1996), analyzes performance of key behaviors in terms of antecedents, knowledge and skills, equipment and processes, and consequences. The benefits of using the PDC are that it can pinpoint variables that are maintaining current performance, identify variables that are needed to improve performance, and highlight obstacles that are hindering performance. Information gathered from interviews of all participants, observations during the pilot phase of the study, and a review of materials provided by airport management were used to complete the PDC. This same information was also used to develop a process map (Rummler & Brache, 1995) to further examine the organizational variables that influenced individual performance.

Independent Variable

The intervention in this study was a series of hardware and software components combined into an advanced security package. The intervention package added an array of cutting-edge security sensors and systems to the existing security system. Data from the new sensors were communicated to the participants in the Com Center via a geospatial user interface. This interface gave the participants a real-time global view of the airport's security status. Participants could also access the features of the various subsystems of the intervention package through the geospatial user interface.

Implementation of the intervention package in regards to the participants operating the Com Center's systems was done in two phases. In the first phase the participants were trained to operate the advanced security system. A performance-based training procedure, based on the guidelines established by Brethower and Smalley (1998), was developed by the research team. Training was limited to skills required for successful daily operation and utilization of the intervention package. Skills required for administrative features and system maintenance were

not addressed in the training. Airport management selected one of the participants to be the department's trainer for the new system. The trainer received instruction from the research team on the effective implementation of the performance-based training procedure. The trainer then provided instruction on the use of the new system to the other participants using the performance-based training procedure. The research team observed the training of 7 of the participants to verify consistent and proper use of the training procedure. Technical adjustments were also made to the intervention package's components by the developers of the advanced security package at this time, in preparation for use by the Com Center operators. Following the completion of training and the final technical adjustments to the system the features of the advanced security system were activated for use by the participants working in the Com Center.

Experimental Design

Based on the review of the relevant literature, results of the assessments and the pilot work, a single-subject methodology was determined to be most appropriate for the study of the human behavior in this research. Variability is an important part of studying human behavior, and understanding the subtle environmental changes that ultimately produces that variability is very important. In single-subject research variability is not controlled or eliminated from the final analysis through statistical methods (Bailey & Burch, 2002). Therefore the use of procedures that utilize repeated measures are vital. A modified ABA Reversal Design was selected for this study to demonstrate a functional relationship between the dependent and independent variables. An ABA Reversal Design is the simplest single-subject research design to be able to demonstrate experimental control. Also, a reversal design allows participants/groups to serve as their own control group (Bailey & Burch, 2002).

In keeping with the single-subject methodology of this study, visual analysis was the primary means of examining the data. According to Poling, Methot, and LeSage (1995), the three advantages to using visual analysis are that it is very robust in the types of data that can be analyzed, it allows the researcher to easily review the data after the addition of each datum point, and it is an effective process for determining the success of an intervention. Bailey and Burch (2002) further detailed the advantages of visual, or graphical, analysis. The visual analysis process evaluates data just as it was collected, without hiding trends in the data and creating difficulties in evaluating the social validity of results. The three primary components of conducting visual analysis are trend, variability, and level. Trend refers to the overall path of the data. This is sometimes illustrated by evaluating the slope of a line of best fit. “No trend” refers to data that displays a flat, or zero, slope. Variability refers to the degree to which data fluctuates in terms of values on the y-axis within a phase. Effective interventions should display the same amount, if not a reduction, in variability in the data when compared with baseline phases. Level refers to the range on the y-axis in which the majority of the data points are located. Quite often the descriptive statistics of mean and standard deviation are utilized to assist in description of the level of a data set.

Interobserver Agreement

To ensure the reliability of the observations conducted in this study, the interobserver agreement (IOA) was assessed. During observation sessions in the Com Center, observers sat next to each other and independently recorded the data. When scoring archived videos in the conference room, the video was projected onto a screen at the end of the room’s conference table. Observers were seated around the table and scored the video clips independently. IOA was assessed on 32.6% of observation sessions in the Com Center and 50.8% of video clips

reviewed in the conference room. A block-by-block methodology for calculating occurrence reliability (Bailey & Burch, 2002) was used to evaluate the IOA of the frequency measures in this research. IOA during the study was a mean of 98.5% for phone activity, 100% for radio activity, 100% for public address announcements, 95.5% for activities log entries, 97.7% for system alarms, and 91.2% of manual camera movements. The two measures used in the calculation of situational awareness were the number of events that elicited an appropriate response and total number of events that occurred, per observation session. IOA was 100% for both measures across the entire study.

Since on-task engagement was measured with a partial interval observation procedure instead of a frequency count a slightly different methodology was used for calculating reliability. IOA for on-task engagement was assessed in terms of both occurrence and nonoccurrence reliability (Bailey & Burch, 2002). For the occurrence reliability of on-task engagement, observers agreed on a mean of 91.5% of intervals. For the nonoccurrence reliability, observers agreed on a mean of 91.9% of intervals.

Results

A total of 593 man-hours of direct observation in the Com Center were required for the reliable collection of the data included in this evaluation. The initial baseline phase of the study lasted for 78 observation sessions. Baseline was followed by the training and technical modification phase, which lasted for 41 observation sessions. The implementation and use of the intervention package by the participants was the third phase of the study, and lasted for 15 observation sessions. Finally, the intervention package was withdrawn for the reversal to baseline for 18 observation sessions.

All of the ancillary targets were important to understanding the overall environment of the Com Center and the variables influencing the behaviors of the participants. While none of these targets were direct measures of vigilance or situational awareness, they did illustrate the existing demands placed on the participants within this type of security environment. The rates of phone activity, shown in Figure 1, radio activity, shown in Figure 2, and public address system announcements, shown in Figure 3, were all measures of the communication behaviors of the participants. In addition to those behaviors, the frequency of activities log entries, shown in Figure 4, further illustrates the demands placed on the participants. Finally, the rates of system alarms, shown in Figure 5, were another set of behaviors the participants needed to engage in to keep the daily operations of the airport functioning smoothly. During the visual analysis of the data for the ancillary targets no change in the frequency of the targets as a result of the changes in experimental condition were found.

The first behavior directly related to the vigilance and situational awareness of the participants was manual camera movements. The frequency of manual camera manipulations per observation session is illustrated in Figure 6. A mean of 126.3 (SD=55.0) camera movements during day observation shifts and a mean of 86.4 (SD=67.8) during night shifts were recorded during baseline. The night shift, which showed more variability than the day shift, had a downward trend across the phase. In contrast, the day shift showed little-to-no trending across the phase. However a sharp increase in variability was recorded in the data near the end of the baseline phase. During the training phase, the means were 116.7 (SD=49.5) during the day and 86.7 (SD=58.5) at night. A downward trend can be seen across the phase in the data for the day shift. The night shift showed little-to-no trend on a macro level across the phase, as a result of two conflicting micro trends that split the phase. Both day and night shifts showed data within

the same range of that previously recorded in baseline. When the intervention was implemented a mean of 136.0 (SD=44.5) camera movements were recorded per session during the day, and a mean of 126.7 (SD=73.9) at night. While this was an increase in mean for both day and night shifts, the data remained within the same range of the previous two phases. Contradicting trending was also found during the intervention phase; data during the day trended upward, while data at night trended downward. With the withdrawal of the intervention the mean frequency of camera movements was 157.3 (SD=66.5) during the day and 107.0 (SD=75.5) at night. With the exception of the 70th session during the day shift the data remained within the same bandwidth of the previous phases. Both day and night shifts also displayed a downward trend during the final baseline phase; the night shift being the more extreme of the two.

The second behavior related to the vigilance and situational awareness of the participants was on-task engagement. The percent of intervals spent engaging in on-task behaviors per observation session is illustrated in Figure 7. Throughout the initial baseline phase, participants were on-task a mean of 60.5 (SD=16.7) percent of observation sessions during day shifts and a mean of 38.5 (SD=18.5) percent of observation sessions during night shifts. Both shifts displayed considerable variability in the data during baseline, but maintained minimal trending. A slight downward trend was present in the data for the night shift for baseline. During the training phase, the means were 58.1 (SD=17.7) percent during the day and 33.3 (SD=11.5) percent at night. A downward trend can be seen across the phase in the data for both the day and night shifts. Both day and night shifts displayed data within the same range previously recorded during baseline. When the intervention was implemented a mean of 69.1 (SD=19.3) percent of sessions were recorded as on-task during the day, and a mean of 43.7 (SD=17.8) percent at night. Similar to manual camera movements, this was an increase in mean for both day and night shifts.

However the data again remained within the same range established by the previous phases. Also similar to the manual camera movements, contradicting trending was found for on-task engagement during the intervention phase; day shift data trended upward and night shift data trended downward. The withdrawal of the intervention resulted in a mean of 64.4 (SD=16.0) percent of sessions engaged during the day and 47.5 (SD=21.6) percent of session engaged at night. For the final phase both shifts remained within the same bandwidth of the previous phases and both displayed a downward trend

The most direct assessment of intervention package's impact on the vigilance and situational awareness was with the measure of the situational awareness of the participants. The percent of events that elicited an appropriate response per observation session are illustrated in Figure 8. During the initial baseline phase, participants were situationally aware a mean of 3.92 (SD=6.24) percent of observation sessions during day shifts and a mean of 1.96 (SD=5.83) percent of observation sessions during night shifts. Both day and night shifts displayed no trending. In addition, the data for both shifts remained within a bandwidth ranging from 0 to less than 34 percent during baseline. During the training phase, the means were 2.92 (SD=4.54) percent during the day and 0.00 (SD=0.00) percent at night. A slight downward trend was found for the day shift and there was a reduction in the range of that data. The night shift showed no trending during the training phase, and was completely stable. When the intervention was implemented a mean of 62.5 (SD=15.9) percent situationally aware per session was recorded for the day, and a mean of 80.2 (SD=21.8) percent at night. A slight upward trend was shown for both day and night shifts. Also, there was no overlap of bandwidths of the data for the intervention phase with the any of the other experimental conditions for both shifts. It should be noted, however, that the 63rd observation session for the day shift was omitted from the visual

analysis of the data and computation of descriptive statistics. This was done due to the presentation of extraneous circumstances that more closely simulated baseline conditions than intervention conditions. The participant during the 63rd day shift repeatedly stated a refusal to interact with the advanced security system to supervisors, peers, and the observers. In addition, the participant did not have his eye glasses in the Com Center; a necessity for that participant to be able to read text on the monitors. The distance of the monitor displaying the geospatial user interface from the participant amplified the problem. Even if the participant had been willing to use the system, he would have been physically unable to do so.

The withdrawal of the intervention resulted in a mean of 3.83 (SD=3.98) percent of sessions situationally aware during the day and 5.00 (SD=10.0) percent of sessions situationally aware at night. During the final phase both shifts remained within the same bandwidth of the previous baseline phases and both displayed a downward trend.

Discussion

The results of the study show a clear improvement in situational awareness with the introduction of the intervention package during this study at the targeted airport. The large change in the level of the data, the non-overlap of the range of the data, and the nonoccurrence of trending problems between the intervention and nonintervention phases support the conclusion the intervention package had an effective, socially significant impact on the situational awareness of the participants in this study.

The intervention package did not show a clear, functional relationship with on-task engagement or manual camera use. For the evaluation of both targets the overall range and level of the data remained consistent across all four phases. Changes in trend were seen for on-task engagement and manual camera use during the study. However direct cause-effect relationships

between the changes in trend and the intervention package were not found in the analysis of the data. The changes in trend that were present were also insufficient to create a socially significant change in the level and variability of the data, whether dependent or independent of the intervention package.

The advanced security system evaluated in this study did not show a clear, functional relationship with any of the ancillary target behaviors. However for the intervention package to be an effective tool that does not overwhelm the operator, it should be expected that no significant changes in any of the ancillary targets would occur. Such changes, at a significant level, would risk transforming these standard behaviors of Com Center operators into distracters from the security environment. It is a strength of the intervention that it was able to increase situational awareness without changing the frequency of any of the ancillary target behaviors.

An interesting finding of this study was in the results of the training phase's impact on vigilance behaviors and situational awareness. The training phase had created no change in these behaviors. While a large and lasting change in performance due to training was not expected, the complete lack of any increase in performance was surprising to the authors. During all phases of the study participants had the ability to respond to events following set protocols. In addition, during training participants learned of all the behaviors targeted by the advanced security package. The targets included, but were not limited to, all of the targets used in the assessment of situational awareness. These results suggest that, at least in regards to performance in this study, training alone was not the answer to improving performance.

Without the existence of similar studies in academic, peer-reviewed sources for comparison of results the present research becomes a benchmark for future behavioral analyses of vigilance and situational awareness in advanced security settings. The use of repeated

measures over an extended period of time, especially during baseline conditions, will offer a helpful comparison for researchers conducting future studies in similar settings with similar behaviors. These future studies may include possible behavioral evaluations of potential revisions to the specific advanced security system studied in this research. However the evaluations of other intervention packages will find the results of this study equally important for comparison.

Recommendations for Future Study

Based on the findings of this study, several areas of future research are recommended. First, an extended systematic replication of this study is suggested. The relatively brief duration of the intervention phase leaves several scientific questions unanswered. Most prominent of these would be in regards to the longevity of the effects of this intervention package. It is possible that the effects of the intervention are a result of a novelty effect. A longer implementation of the intervention would be required to rule out this possibility. It is also recommended that if such a future evaluation were conducted, an ABAB Reversal Design (Bailey & Burch, 2002) be utilized in the evaluation. The addition of a replication of the invention condition would provide added strength to the design and results.

It is also recommended that future studies seek to not only improve the situational awareness of participants, but also address free operant behaviors. Since these behaviors are not dependent on the presentation of antecedent stimuli, they should be considered key to human vigilance. Improving these vigilance behaviors would result in specialists in the security field actively searching for threats instead of evaluating system generated stimuli, whether at a local or global view point, and responding accordingly. Combining an intervention such as the one

evaluated in this study that improves situational awareness with an intervention that improves free operant behaviors would successfully add additional layers of security to targeted settings.

Future studies of advanced security systems should evaluate the effects of false alarm rates on the users' performance. In security environments, vigilance behaviors, such as searching for a threat, are positively reinforced by the successful detection of a threat/violation. The schedule of reinforcement can be thinned from a continuous schedule to various intermittent schedules to support the maintenance of the behavior. However, exaggerated thinning, or spreading the instances of reinforcement too far apart, runs the risk of putting the vigilance behavior on extinction (Malott & Trojan-Suarez, 2003). This is further supported by the results of Methot and Huitema (1998), in which low-probability signals produced poor vigilance performance. False alarm rates were measured during the current study, but the intervention phase of the present study was too brief to sufficiently evaluate the effects of the rate of false positives. Future studies should not only investigate the rate of false positives (both false alerts generated by the system and legitimate alerts that are non-violations), but also the effects of various rates of false positives on user performance. In addition, various interventions for inserting system generated probes to supplement the natural reinforcement schedule should be evaluated.

Finally, a system of providing the user effective, performance-based feedback should be added to any security system. Deficiencies in effective feedback have been repeatedly linked to poor performance (Daniels & Daniels, 2004). The advanced security system evaluated in this study has the potential to not only increase the situational awareness of users, but, with additional programming, also use data collected within the system to automatically generate daily feedback for operators. If combined with a system that generates probes for the purpose of

regulating schedules of reinforcement, an automated feedback system could assist in maintaining situational awareness levels over time.

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Figure Captions

Figure 1. Frequency of telephone usage per 3 hour observation shift.

Figure 2. Frequency of radio usage per 3 hour observation shift.

Figure 3. Frequency of announcements made over the public address system per 3 hour observation shift.

Figure 4. Frequency of entries into the daily activities log per 3 hour observation shift.

Figure 5. Frequency of alarms generated by the security system per 3 hour observation shift.

Figure 6. Frequency of manual camera movements per 3 hour observation shift.

Figure 7. Percent of intervals engaged in on-task behaviors per observation sessions per 3 hour observation shift.

Figure 8. Percent of events that elicited an appropriate response out of the total number of events per observation session.















