Use of Threat Image Projection (TIP) to enhance security performance

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Abstract— Threat Image Projection (TIP) is a software system that is used at airports to project images of threat items amongst the passenger baggage being screened by X-ray. The use of TIP is becoming more widespread and is increasingly being included as part of security regulation. This is due to its purported benefits of improved attention and vigilance, and increased exposure to threat items that are linked to improvements in threat detection performance. Further, the data collected by the TIP system can be used to assess individual performance, provide feedback to screeners, and tailor training to specific performance weaknesses; which can generate further performance improvements. However, TIP will only be successful in enhancing security performance if it is used and managed effectively.

In this paper the key areas of effective TIP use and management that enable security performance to be enhanced are highlighted. These include the optimisation of TIP settings, such as the TIP to bag ratio, and image library management. Appropriate setting of these components can lead to improved performance as a facet result of increasing exposure to a suitable range of threat images. The key elements of TIP training are highlighted including the importance of communicating TIP related information and the role of the supervisor in ensuring TIP is used appropriately. Finally, the use of TIP data are examined, including the effective use of TIP for performance assessment and screener feedback and in defining training. The provision of feedback regarding TIP scores has been shown to enhance performance in excess of that achieved by using TIP in isolation.

To date, the vast majority of TIP research has been conducted in relation to the screening of carry-on baggage. In the final part of this presentation the use of TIP to enhance performance in other areas such as Hold Baggage Screening (HBS) and Cargo are considered. HBS TIP is associated with different challenges due to its alternative method of operation (to present complete images of a bag and threat item) which imposes demands for the operational set-up and the construction of the image library. The use of TIP in Cargo is associated with a different set of challenges as a result of the diverse nature of items scanned and the screening environment. However, in both these domains, the use of TIP has been associated with the realisation of benefits in line with those achieved for carry-on baggage screening. Through understanding differences in the context in which TIP is used it is possible to understand the differing requirements for its use and management that will enable the benefits of TIP to be realised, enhancing security performance across locations and screening contexts.

Keywords- Aviation Security, Human Factors, Threat Image Projection, TIP, Human Performance

I. INTRODUCTION

Threat Image Projection (TIP) is a software system that can be installed on security X-ray systems. TIP operates by presenting fictional images of threat items amongst the X-ray images of real baggage that is being screened. At the point at which the threat item is projected the screener does not know that it is fictional and so responds to it as if it were real. Once the screener makes a response, immediate feedback is provided regarding the accuracy of the response, the threat that was presented, and the next actions to be taken. Screener responses and images of missed threats are recorded by the system, providing a wealth of data regarding threat detection.

By providing screeners with increased exposure to threat items during normal screening operations, TIP increases screeners' familiarity with threat items and can act as an On-the-Job Training (OJT) aid. Further, the projection of fictional threats increases the likelihood that the screener will see a threat during their screening shift, thus promoting vigilance. Receipt of immediate feedback can be motivating to screeners and reinforce the importance of their task.

Further benefit can be obtained by the use of the data from TIP. For instance, screeners can be provided with feedback on their overall level of performance, TIP can be used to provide quality control over the screening, and particular strengths and weaknesses in performance can be identified, allowing training to be focused on specific individuals or areas of weakness.

While these benefits are extremely desirable, TIP will only achieve them if it is used and managed effectively. In this paper the key factors that influence the effectiveness of TIP use will be examined, specifically the optimisation of TIP management settings, the design of TIP training, and the use of TIP data. These factors have, to date, been examined in the context of TIP for the screening of carry-on baggage. In the final section of this paper, the use of TIP in other screening domains such as Cargo and Hold Baggage Screening (HBS) will be reviewed.

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II. TIP MANAGEMENT SETTINGS

Control of TIP operation is conducted through the TIP Management System (TMS) component of the TIP system. The TMS is used by those responsible for the administration of the TIP system. It has the facility to set the TIP scheduling and manage the image library. These two facilities control the number of TIP presentations that a screener will see and the nature of the images that will be presented.

A. TIP scheduling

The TIP scheduling settings can influence the effectiveness of TIP at improving screeners' threat detection. TIP scheduling will also influence operational factors such as throughput and so it is important that appropriate values are selected.

The TIP to bag ratio or TIP frequency specifies how often screeners will be presented with a TIP image. Research has shown that higher TIP frequencies that lead screeners to view more fictional threat images are associated with higher levels of threat detection. This has been shown in operational research [1]. However, operational considerations will constrain the number of TIP images that it is desirable for screeners to respond to.

Previous recommendations, taking such operational considerations into mind, had suggested that the TIP to bag ratio should be set in line with the baggage throughput so that screeners view between one and three TIP images in a twenty minute screening shift. Typically, this frequency results in a TIP to bag ratio of one TIP every 50 to 100 bags. More recent research, however, suggests that higher TIP projection rates may be both beneficial and viable.

Low frequency targets tend to be detected at a lower rate than high frequency targets, a phenomenon known as the 'target prevalence' effect [2]. High TIP presentation rates would increase the target frequency and, thus, would be expected to reduce the target prevalence effect. However, it would also be expected that such increases in detection would be associated with an increase in 'non-TIP alarms'. Non-TIP alarms are the instances where screener identifies that a threat is present but no TIP has been displayed. However, at TIP frequencies below 20% it has been found that there may not be a marked increase in non-TIP alarm rate [3].

Further research is required to examine if this effect, identified in laboratory studies, is replicated operationally and to identify the most suitable TIP to bag ratio so that screeners view more fictional threat items, which is anticipated to enhance the performance benefit of using TIP. This is likely to be due to the increased familiarity with threat items and a higher expectation that a threat is likely to be present.

B. TIP library management

The design and management of the library of threat images is critical to the effectiveness of TIP at improving screening performance. The type of images projected by the TIP library will provide an ongoing reminder of the type of threat that screeners are required to search for. Therefore, the type of threats that are projected should reflect the type of threats that screener's must detect. Accordingly, a typical Cabin Baggage TIP system will include four categories of images: Guns, Knives, Improvised Explosive Devices (IEDs), and 'Others'. The Others category would normally include prohibited items such as liquids.

Through the TMS, it is possible to set the proportion of TIP images that are presented that come from each of these categories. Three factors should drive the selection of suitable category projection rates:

- **Known strengths and weaknesses**: If it is know that screeners are highly skilled at detecting one type of threat but less capable at another, it would be beneficial to increase the likelihood of presenting threats from the category at which screeners are less capable as a means of reinforcing the heightened importance of those items.
- **Nature of threat**: If a threat category is believed to be of high importance, perhaps due to intelligence reports at a particular time, it may be beneficial to increase the likelihood of presenting threats of that category to help reinforce to screeners the importance of its detection.
- **Number of images in each category**: If one category of images contains many fewer images than the other categories, it would be desirable to reduce the presentation frequency of that category. This would prevent over-familiarity with the specific images within that category, which could lead screeners to focus on the particular images within that category rather than conducting a complete bag search.

The images themselves must be realistic and representative of the type of threat that screeners are required to search for. The images must not contain 'artifacts' or cues to the fact that the item is a fictional image and not present in a real bag. For instance, threat items should not always appear in the same angle and the threats should not contain unusual features such as a distinctive casing for an Improvised Explosive Device (IED). The appearance of threat items on an X-ray display varies according to the angle at which the item appears in the bag. Therefore, it is important to include threat items at a variety of angles, without including too many repeated inclusions of the same item.

When screeners are repeatedly presented with the same item, there is the potential for the image of the item to be memorized. This could lead to responses being made on the basis of memory rather than conducting a complete bag search. The possibility of repeated presentations can be reduced by:

- Increasing the size of the image library; and
- Regularly updating the library contents.

The balance between these two factors is important. If a smaller image library is used, it must be updated with greater frequency than a much larger library. The exact frequency with which libraries of differing size need to be updated will depend upon the number of TIP presentations that have occurred.

Initial research into determining the appropriate number of presentation to occur before for library is updated indicated that

as many as eight presentations would be required to each individual screener before overt recognition of an item takes place [4]. However, detection performance for an individual image does increase with each presentation, indicating an image learning effect. Maguire and Charman [5] indicated that after three presentations of an image detection performance for that image would increase by 10.4%.

These studies, however, had not assessed the question of whether repeated presentations had a positive or negative effect on the performance impact of TIP. Charman and Maguire [6] examined the introduction of a new TIP library in the UK to assess the differing impact of the number of unique and repeated image presentations. The study found that the number of unique images that had been presented and the number of times each image had been presented prior to the library update had an impact upon detection of novel threat images. That is, a high number of unique images encountered and a high number of repeated images had a positive impact on novel threat detection. This effect was not be accounted for by the total number of TIP images that a screener viewed.

These results suggest that, in order to maximize the performance benefits of TIP, an image library should be used for enough time that screeners will see repeated presentations of the same image. However, the library should be updated over time so that screeners continue to view novel TIP images. What remains unclear from this initial work is where the benefits of repeatedly presenting FTIs begin and end. There may also be an optimal number of repeats/unique presentations that is required to enhance novel threat detection and any additional repeats beyond this may add no value to, or may even hinder, security performance.

III. TRAINING IN THE USE OF TIP

A further factor that is important if the use of TIP is to be beneficial in terms of enhancing performance is ensuring that the attitudes of the screening population towards TIP are appropriate. These attitudes will be influenced by the organizational culture at the airport, but also by the information that screeners receive about TIP. Such information includes both the formal training that is provided, and the informal communications that take place once TIP is in use.

In terms of the initial training in the use of TIP, there are a number of key points that need to be addressed. These are:

- Understanding of what TIP is and how it operates;
- The purpose of TIP including the benefits of its use to screeners, trainers, and airport security as a whole;
- How the X-ray screening task will be affected by TIP – in particular to highlight that the task should be conducted in the same way as normal and that TIP images will not look different to real bags;
- How the screener should respond when they believe that they have seen a TIP image;
- The information that is recorded by TIP and what it can be used for. This must be both honest and reassuring, it is important that TIP is not used to single out screeners or as a tool to reprimand them. However, if TIP is going to be used to identify screener errors, they must be warned of this in advance so to prevent mistrust when TIP is in use; and
- The log on and log off process, and why this is important to maintain the integrity of TIP data.

It is important that these messages about how TIP is used are instilled prior to screeners' first experiences with TIP to minimize the possibility for misunderstanding or mistrust regarding the system. It is also important that these messages are reinforced during refresher training and in the communications between supervisors and screeners.

Supervisors within the search area have an important role in ensuring the motivation of screening staff and supporting effective performance in the search area. Providing direction is a key element of the Supervisor role and involves tasks such as providing expert advice and guidance, improving performance, and motivating others [7]. These tasks relate to the effective use of TIP as much as any other aspect of the security search task. In relation to the use of TIP these tasks must be undertaken to prevent misuse of TIP and address misconceptions that screeners may have about TIP. This will ensure that screeners continue to use TIP effectively after training has been completed, and maintain the benefits of TIP once it is in use operationally.

IV. USE OF TIP DATA

Screener responses to the bags that are screened are recorded by the TIP system in a series of output files, each summarizing data from a single X-ray machine over a one month period. The data recorded by the TIP system includes details of the fictional images that were displayed, images of the bag in which the TIP image was projected, the screener response to each image, the response time, the occurrence of non-TIP alarms (i.e. when the screener presses the search button and no TIP image was projected), and the number of bags scanned. This data has the potential to provide very rich information about operational screening performance which if exploited effectively can lead to performance benefits as a result of using TIP that exceed those associated with using TIP without making use of the TIP data.

A. Understanding overall airport performance levels

Summaries of TIP data allow airports to get a true perspective on their security standards in X-ray screening. They provide an indication of operational threat detection rates by threat type over a large number of varied images. Airports can also use TIP data to monitor the success of new training initiatives, examine the impact of introducing new equipment, or performance at different times. Conducting these types of TIP data analysis can help identify areas for improvement and inform airport policy (e.g. shift patterns, management of passenger throughput, and frequency of refresher training) leading to further improvements in security performance.

B. *Provision of feedback to screeners*

TIP data provides information about performance which can be fed back to screeners. Without feedback, people tend to be overconfident in their abilities and this overconfidence can be associated with poor performance and limited improvement. Appropriate feedback is central to maintaining skill by providing knowledge of performance and motivation to improve. Research conducted by QinetiQ on behalf of the UK Department for Transport (DfT) investigated the provision of different types of TIP performance feedback [8]. Threat detection performance improved for screeners who received feedback compared with those who did not. Moreover, diagnostic feedback that included the presentation of missed images appeared to produce better security performance.

C. *Design of training*

TIP data analysis can also be used to identify training needs, for instance to identify screeners (as individuals or groups) who require refresher training, or to identify particular types of threat where additional training would be beneficial. Analysis of this kind can be extremely powerful in terms of ensuring that training is targeted at areas of specific training need. Thus focussing training time on areas where it is most needed and increasing the likelihood that the training will be effective at enhancing performance.

D. *Assessment of screener performance*

As TIP data links the responses made to TIP images to the screener who made that response there is the potential that TIP data could be used to assess individual screener performance. This data can be used to identify those who are performing lower than a set standard and thus provide quality assurance over the screening process.

Analysis of individual TIP scores, while valuable, has significant variation [9]. The variation in individual TIP data scores is influenced by three sources of variation: the difficulty of the images presented, the number of images presented, and screener competence [10].

If the TIP scores of individual screeners are to be interpreted accurately, it is important that the difficulty of the images projected and the number of images projected are taken into account so that only the screener competence is accurately measured in a fair and standardised way.

Standardisation of TIP data analysis to take into account the factors described above can be complex. However, in the UK, the Threat Image Projection Competency Assessment Tool (TIP–CAT™) is used to analyse TIP data, allowing for image difficulty and number of presentations. The standardised nature of the process is ensured through a 'weighting' technique. The difficulty of a threat item is weighted so that one screener who has seen only 'difficult' images is not treated in the same way as another screener who has seen 'easy' images. This allows fair data to be captured regarding individual performance and used to target performance interventions accurately.

V. USE OF TIP IN CARGO AND HOLD BAGGAGE SCREENING

The guidance presented in this paper related to the management, training and data analysis requirements for TIP to be effective at enhancing security performance have been developed based on research into TIP in Cabin Baggage screening. More recently, researchers have examined the application of TIP in Hold Baggage Screening (HBS) and in Cargo screening to identify if the same performance improvement could be achieved.

A key difference that must be considered when examining the use of TIP in different domains is in the method of operation used by the TIP system. Cabin baggage TIP systems and most Cargo TIP systems use the Fictional Threat Image (FTI) method of operation. FTI TIP presents an image of a fictional threat item superimposed over the image of a real bag that is being scanned through the X-ray machine. In contrast, HBS TIP uses the Complete Threat Image (CTI) method of operation. CTI TIP systems present a complete image of a fictional bag containing a threat item between the images of real bags that are being scanned.

The CTI method of operation has a number of benefits, in that there is complete control of the threat-bag combination, meaning that the images presented to screeners are often more realistic than those achieved by FTI systems. When using CTI TIP it is also possible to record screener's responses to fictional non-threat images and understand more about the decision-making process as relates to these bag types. However, the use of CTIs imposes requirements on the operational set-up and management of TIP that are different to when FTIs are used.

In terms of the operational set-up, a key requirement for the use of CTI TIP is that screener's cannot see the real bags entering the X-ray machine. If screeners can see bags entering the X-ray machine, this would provide an immediate cue to the presence of TIP – for instance, when a small suitcase enters the X-ray machine and the image of a large rucksack is presented. In terms of the management of TIP, CTI image libraries must be much larger than those required for FTI TIP. The complete image of the bag provides many cues that screeners could learn and thus recognize the presence of a TIP image. Therefore, careful design of CTIs is required to ensure that they provide an effective test of screener performance.

HBS TIP using the CTI method of operation has been examined in the UK since 2001. Operational trials of HBS TIP found that TIP worked effectively in the HBS operational environment and produced a significant quantity of performance data. The introduction of TIP had a positive effect on screener performance, with improvements in detection of threats over the course of the evaluation [11]. Analysis indicated that the improvements in threat detection were unlikely to be due to screeners learning the appearance of TIP images – as the detection of novel threat items improved each month. Thus it was concluded that HBS detection performance improved as a virtue of using TIP.

Anecdotal evidence from the operational trials found that HBS TIP was popular amongst screeners. In discussions with both screeners and security managers responsible for the operation of TIP there was a consensus that HBS TIP is an

extremely valuable tool. The combination of the presentation of realistic threat images and the receipt of immediate feedback makes the screening task more interesting and provides a challenge for screeners.

The operational trials did, however, identify a number of challenges to the use of TIP in the HBS context and using the CTI method of operation. First of all, the design of the non-threat TIP images was identified as an area where further consideration and clarity of design would be beneficial. Secondly, there were limitations on the TIP data in that the systems do not record the possibility of a bag being rejected (or a TIP being detected) due to image time out – rather than a reject decision being made by the screener. These factors limit the benefits that can be obtained from the use of TIP data – in particular it was not considered suitable at present to use HBS TIP systems to assess screener competence. However, it was clear that some benefits can still be realized in terms of screener performance and thus the consideration of TIP in screening domains other than Cabin baggage screening can be beneficial in terms of enhancing performance.

Cargo screening differs from the Cabin Baggage context in terms of what is screened and how, the environment in which screeners work, and what is considered to be a threat. In the UK, the term 'Cargo' currently covers mail and personal effects in addition to general freight and may therefore include items ranging from small packages to aircraft engines. As Cargo X-ray machines also tend to be larger than those used in Cabin Baggage, more items can be put through at the same time and this may have implications for defining what a 'bag' is when managing the TIP to bag ratio.

Cargo screeners work in demanding physical environments away from the public and their screening work may be intermittent between other duties. The threats they search for may differ between individual companies, and are not always the same as threats within Cabin Baggage screening (e.g. knives are not considered to be a threat to Cargo or, indeed, HBS). Therefore, the management and content of the TIP image library needs to take this into account.

In terms of the method of operation, it would be difficult to use CTIs in many Cargo screening locations because operators load items onto machines themselves. However, the use of Complete Non-Threat Images may prove useful for monitoring purposes. The use of FTIs in Cargo, however, has their own challenges. For instance, if an Cargo consignment has an inventory, operators will be looking for items that are not on the list rather than items which may be threats.

Across both Cargo and HBS there is a great deal of variation in practices and equipment configurations. Some of the benefits of TIP that have been seen in the Cabin Baggage domain may not be realized until the TIP library and data recording have been appropriately defined and implemented. However, previous research indicates that TIP can be useful within the Cargo and HBS domain by providing On-the-Job Training (OJT), increasing vigilance, and providing data regarding overall performance.

VI. CONCLUSIONS

In this paper we have examined the use of TIP to enhance security performance, in particular the detection of threat items. In particular we have explored the factors associated with the management, training, and data analysis of TIP systems that mean that they can be used to enhance security performance across the domains in which TIP is used. The positive results that have been seen in operational trials of TIP have led to more widespread use of TIP and increasing inclusion of TIP in regulation. However, without effective TIP practices those benefits will not be realized and the use of TIP may even have detrimental effects.

Across Cargo, HBS, and Cabin baggage screening domains there are three key areas in which TIP related practices need to be implemented, these are:

- TIP management;
- Screener training; and
- TIP data analysis.

The findings reviewed in this paper indicate how effective practices can be achieved across these areas so that TIP enhances security performance. Many of these practices are central to ensuring that benefit is realized from TIP, others provide methods by which TIP use can be used to generate ongoing improvements in performance.

While the key recommendations in this paper relate the Cabin Baggage screening domain, evidence indicates that they will also be relevant in Cargo and HBS. However, this applicability will need to be assessed in conjunction with consideration of the TIP method of operation used and the practical constraints associated with each screening domain.

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