Airport security human factors: From the weakest to the strongest link in airport security screening

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Abstract

Airport security screening is a challenging task. In fact, according to several experts, the human operator is often the weakest link of the security system. In this article, the results of human factor studies conducted over the last five years involving several international airports in four European countries are summarized. It is shown how human operators can in fact become the strongest link if they are selected and trained effectively. Recent developments and results of scientific studies in the following areas are briefly presented and discussed: Pre-employment assessment and selection tests, adaptive computer-based training, 3rd generation threat image projection, certification and competency assessment of x-ray screeners.

Introduction

Several factors determine the performance of human operators (screeners) at an airport security checkpoint (Figure 1). There are large differences between people with regard to aptitudes and abilities needed in security screening. This is the reason why selection tests as part of the pre-employment assessment procedure are valuable instruments to increase performance in airport security screening. X-ray screeners need to know which items are prohibited and what they look like in passenger bags. Computer based training is a very important tool to achieve and maintain x-ray image interpretation competency because it allows exposing screeners to objects that they usually do not encounter in real life (e.g. improvised explosive devices). Although TIP is not a very effective training tool, it is a good technology to increase and maintain motivation and alertness of screeners. Humans often fail to react appropriately if something happens that they do not expect. Therefore, it is also very important to conduct frequent practical tests with real threat objects so that screeners become used to reacting appropriately if they encounter a real threat during the screening operation, for example when a covert (infiltration) test is conducted. In order to achieve a good performance at the security checkpoint, these different factors need to be taken into account. To coordinate all performance improvement efforts a properly developed and maintained system of supervision and quality control is necessary. This should include initial and recurrent screener certification and competency assessment.

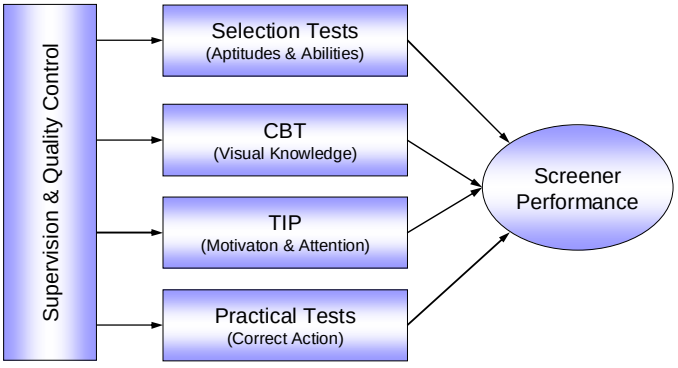

Figure 1 Determinants of screener performance.

Pre-Employment Assessment and Selection Tests

It has become clear in recent years, that there are large differences between people with regard to aptitudes and abilities needed in airport security screening (see for example Schwaninger, Hardmeier, & Hofer, 2005; Hardmeier, Hofer, & Schwaninger, 2005, 2006a). Performance can be increased

substantially if reliable and valid selection tests are used as part of pre-employment assessment. For example Hardmeier et al. (2006a) could show that screeners selected with the X-Ray Object Recognition Test (X-Ray ORT) performed already after one year significantly better than other screeners who worked since several years at the airport but were not selected using this test. Moreover, Hardmeier, Hofer, and Schwaninger (2006b, this volume) found that visual aptitudes and abilities needed for coping with image-based factors such as viewpoint, superposition by other objects and bag complexity did not increase very much with on the job experience and training. This result was predicted by Schwaninger, Hardmeier, and Hofer (2005) and stresses the importance of using reliable and valid tests such as the X-Ray ORT as part of a pre-employment assessment system.

Adaptive Computer Based Training

Visual cognition and object recognition studies have shown that you can only recognize an object if it is similar to something you have seen before (Graf, Schwaninger, Wallraven, & Bülthoff, 2002; Schwaninger, 2004b, 2005a). The consequences for x-ray screening are illustrated in Figure 2. Each bag contains a threat object and each of them looks quite different in the x-ray image than in reality. This is one reason why many threat items are difficult to recognize without training. A second reason is that several objects are not known from everyday experience, which accounts at least for the self defense gas spray depicted in Figure 2c and the improvised explosive device (IED) depicted in Figure 2d. In addition, some threat objects look quite similar to harmless objects. For example the switch-blade knife depicted in Figure 2b resembles a pen or a laser pointer. Another problem is image difficult resulting from viewpoint changes (see Koller & Schwaninger, 2006 for a recent study). If an object is depicted from an unusual viewpoint, it becomes difficult to recognize. This is illustrated in Figure 3. Each of the three objects is known from everyday experience. However, most people have great difficulties in recognizing the images at the top without training because they are depicted from an unusual viewpoint. These examples illustrate how important it is to use a large threat image library in which objects are depicted from many different viewpoints. Based on a close collaboration between vision scientists and aviation security experts we have built a multiple views library that currently contains more than 50'000 threat item images based on more than 700 different types of threat objects depicted from many different viewpoints. Based on police and intelligence information, this image library is constantly being updated and loaded into a computer based training system (CBT) to keep screeners ready and prepared using weekly recurrent training. This CBT (X-Ray Tutor) is based on the results of scientific studies on how the human brain processes visual information to recognize objects (Schwaninger, 2004b, 2005a). A sophisticated algorithm allows virtual placement of threat objects in X-ray images of passenger bags. This automatic algorithm of X-Ray Tutor is very effective, scientifically approved and takes into account effects of viewpoint, superposition by other objects and bag complexity (Bolfing, Michel, & Schwaninger, 2006; Schwaninger, Hardmeier & Hofer, 2005; Schwaninger, Michel & Bolfing, 2005). Due to this specialized feature, X-Ray Tutor always

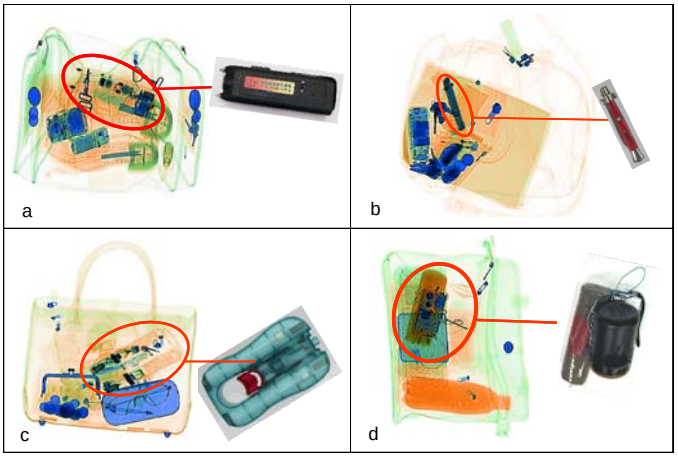

Figure 2 Different types of threat items in x-ray images of passenger bags. a Electric shock device, b switch blade knife, c self defense gas spray "Guardian Angel", d improvised explosive device (IED).

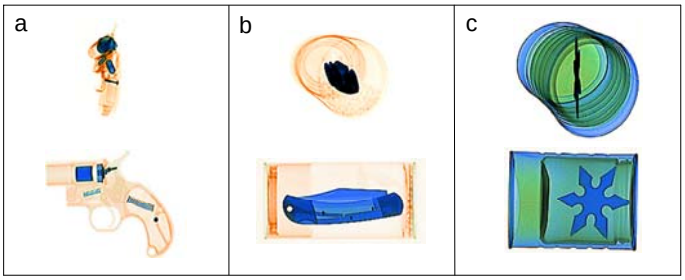

Figure 3 Objects are difficult to recognize when depicted from an unusual viewpoint.

presents screeners fresh images which constantly challenge interpretational skills. Each training session is adapted to each individual in order to achieve optimal training effects. Most importantly, screeners receive immediate feedback for each image containing a threat object. The effectiveness of such adaptive CBT has been proven in several scientific studies, showing that screeners become able to detect threat items reliably within a few seconds of image inspection. In addition to substantially increasing detection performance, training with X-Ray Tutor also increases efficiency by reducing false alarm rates and processing times (for details see Ghylin, Drury, & Schwaninger, 2006; Schwaninger, 2004b; Schwaninger & Hofer, 2004; Hofer & Schwaninger, 2004).

Figure 4 summarizes the results of a study conducted with 72 participants. None of them had received CBT before. For the period of six months, each week 1-2 training sessions of 20 minutes were conducted using X-Ray Tutor. Four tests were conducted in which new IEDs were used that had not been shown previously during training (for details of the study see Schwaninger & Hofer, 2004). As you can see in Figure 4a, there were large increases of detection performance as a result of training. This was the case for both display durations of 4 and 8 seconds. In order to assess training effectiveness we calculated % increase as compared to baseline measurement (first test results). As you can see in Figure 4b relative detection performance was increased by about 71%. The analysis of response times revealed interesting findings with regard to efficiency. Training with X-Ray Tutor resulted in a much faster detection of IEDs. The response times for hits, i.e. correct decisions on x-ray images containing a threat item, dropped from about 5 seconds before training to about 3.5 after six months of training. For harmless bags average response times remained constant at about 5 seconds, consistent with a thorough search process.

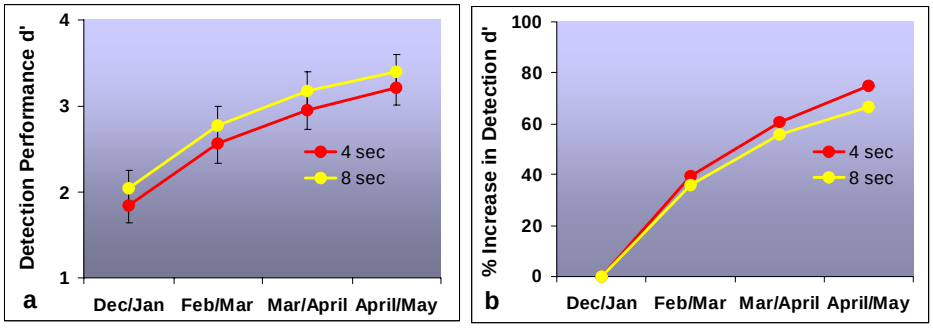

Figure 4 Results of the study by Schwaninger and Hofer (2004) showing large increases of absolute detection performance (a) and % increase of detection performance relative to baseline measurement (b).

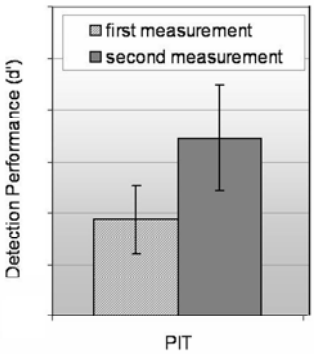

Figure 5 Training effect after two years of recurrent CBT.

In a recent study the effects of recurrent CBT on screener detection performance was investigated with 334 airport security screeners using X-Ray Tutor during a period of two years (Hardmeier, Hofer, & Schwaninger, 2006b, this volume). Most screeners trained at least twice a week for 20 minutes. Detection performance was measured using the Prohibited Items Test (PIT). This is a reliable and valid instrument to measure how well screeners can detect all kinds of threat items in x-ray images (Schwaninger, Hardmeier, & Hofer, 2005; Hardmeier, Hofer, & Schwaninger, 2006a). As can be seen in Figure 5 there was a large increase in detection performance before and after two years of recurrent CBT. Consistent with several earlier studies this result confirms that adaptive CBT can increase the ability to detect threat items in x-ray images substantially.

3rd Generation TIP: Combining the Benefits of TIP with Effective CBT

Threat image projection (TIP) is a technology that allows projecting fictional threat items (FTIs) on x-ray images of real passenger bags while screening them at the airport security checkpoint. If a screener does not detect a TIP image within a specified amount of time (a “miss”), a feedback message appears indicating that a FTI was missed. Feedback messages are also shown when a FTI is detected (a “hit”) or in the case of a non-TIP alarm, i.e. when the screener indicated that there was threat but no FTI has been projected. TIP is now used in several countries and the following advantages have been associated with it: Increased alertness of screeners, increased motivation and work satisfaction, screeners can be

exposed to threat items that are normally not found in real bags, analyzing TIP data can be used to measure detection performance. Usually the TIP to bag ratio is set to a value between 1:50 and 1:200, i.e. a TIP image is shown to a screener every 50 - 200 bags on average. Because screeners are only exposed to a few threat items per day when using TIP, this technology is not an effective training tool. However, TIP has a training value if it is combined with adaptive CBT. Figure 6 shows the architecture of a 3rd generation TIP system (3i-TIP) which combines the benefits of TIP and CBT for increasing screener performance (Schwaninger, 2004a). A large TIP image library of 20'000 images is used in which hundreds of different types of threat objects are depicted from many different viewpoints (the library is currently being upgraded to 50'000 FTIs). The 3i-TIP system uses a dual-mode. In the adaptive mode, each screener starts with FTIs shown in easy viewpoints. View difficulty is then increased based on individual TIP performance. The goal of the adaptive mode is to keep TIP challenging every day in order to increase and maintain screener motivation and alertness. In testing mode, every screener sees the same FTIs. This provides the basis for reliable individual competency assessment if data is aggregated over several months and a large TIP image library is used (Hofer & Schwaninger, 2005). TIP data can be analyzed off-line with TIP DataVis to create reports and graphics for risk assessment, quality control and individual screener competency assessment purposes. Missed FTIs are sent from the x-ray machines via the network to the 3i-TIP server which uses image processing to analyze image difficulty resulting from

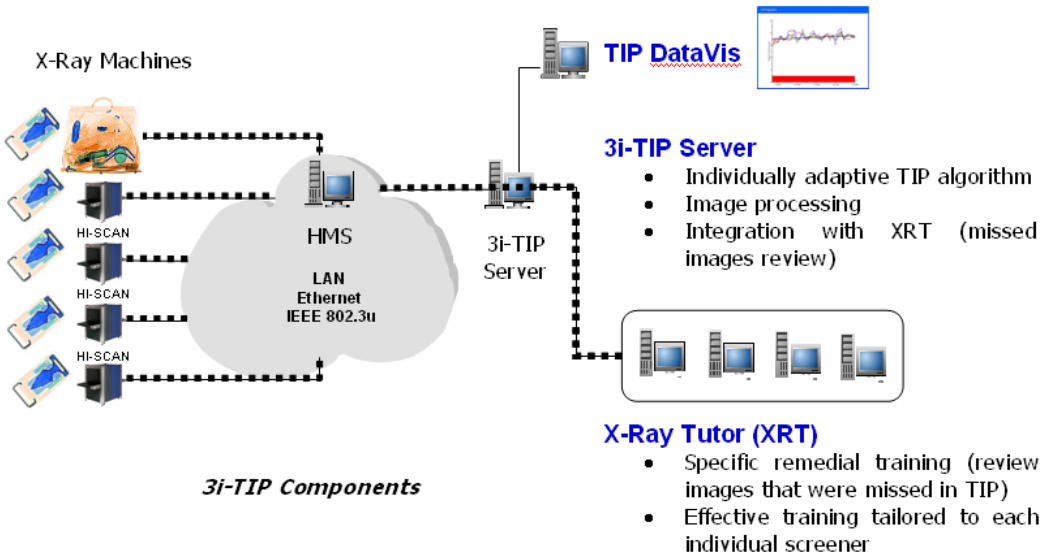

Figure 6 Architecture of a 3rd generation TIP system (3i-TIP) which is operational at several European airports.

viewpoint difficulty, superposition and bag complexity (Bolfing, Michel, & Schwaninger, 2006; Schwaninger, Michel, & Bolfing, 2005). The images are then sent to the CBT system (X-Ray Tutor) for missed images review. This means that at the beginning of an X-Ray Tutor training session a screener is first exposed to the TIP images that were missed while working at the checkpoint. This provides specific remedial training based on individual TIP data. In addition, the individually adaptive algorithms of X-Ray Tutor provide efficient training tailored to each individual screener. During a training session with X-Ray Tutor a screener is exposed to about 400 x-ray images whereas about half of them contain threat items. This results in very efficient and effective CBT (see scientific studies mentioned in the previous section). Thus, 3rd generation TIP technology combines the benefits of TIP (motivation and alertness) and adaptive CBT (effective and efficient training). It thereby provides a solid basis for increasing performance of screeners. However, as mentioned above, it is also essential to conduct practical tests with real threat objects frequently so that screeners learn to react appropriately when they are exposed to real threats at the checkpoint for example during a covert (infiltration) test.

Certification and Competency Assessment

The main aim of certification procedures is to ensure that adequate standards are consistently and reliably achieved across different airports and countries. Certification can be regarded as providing quality control over the screening process. It can provide important information on strengths and weaknesses in aviation security procedures in general as well as on each individual screener. Certification and competency assessment can also be a valuable basis for qualifying personnel, measuring training effectiveness, improving training procedures and increasing motivation. In short, certification and competency assessment can be very important instruments to improve aviation security.

The implementation of certification procedures has several challenges. First, what should be assessed has to be identified. Then, it should be considered how procedures for certifying different competencies can be implemented. Several countries, organizations and even companies are currently developing their own certification or quality control systems so that international standardization therefore becomes another important challenge.

The results of screener certification are very important for appropriate authorities, aviation security institutions and companies. Moreover, failing a test can have serious consequences, depending on the regulations of the appropriate authority. Therefore, it is essential, that a test is fair, reliable, valid and standardized. In the last 50 years, scientific criteria have been developed that are widely used in psychological testing and psychometrics. These criteria are essential for the development of tests for measuring human performance.

The Competency Assessment Working Group (CAWG) by InterTAG has addressed these issues regarding x-ray image interpretation in a White Paper (Schwaninger, Bridges, Drury, Durinckx, Durrant, Hodge, Hofer, Jongejan, Maguire, McClumpha, Neiderman, Steinmann, Wüest, 2005). This document has been included in ECAC Doc 30 and it has also been adopted by ICAO. Guidance material on other components of certification (e.g., theoretical and practical exams) are currently being developed in the ECAC Training Task Force and by the ICAO Training Group. Such internationally coordinated efforts are essential to achieve and maintain common standards in aviation security worldwide.

Summary

In recent years, large investments into technology have been made in order to adapt to the new threat situation. However, the most expensive technology is of limited value if the humans who operate it are not selected and trained appropriately. Security and efficiency can be increased dramatically if scientifically approved selection tests are used in a pre-employment assessment procedure. In addition, effective CBT is needed for initial and recurrent training to increase threat detection performance of x-ray screeners. TIP is a valuable tool for increasing motivation and alertness of screeners while working at the security checkpoint. 3rd generation TIP technology combines the benefits of TIP with effective CBT. However, it is also essential to conduct practical tests with real threat objects frequently so that screeners learn to react appropriately when they are exposed to real threats at the checkpoint, for example when a covert (infiltration) test is conducted. Last but not least an initial and recurrent certification system is needed to ensure that adequate standards in aviation security are consistently and reliably achieved.

References

Bolfing, A., Michel, S., & Schwaninger, A. (2006). Assessing image difficulty in x-ray screening using image processing algorithms. Proceedings of the 2nd International Conference on Research in Air Transportation, ICRAT 2006, Belgrade, Serbia and Montenegro, June 24-28, 2006, 253-258.

Ghylin, K.M., Drury, C.G., & Schwaninger, A. (2006). Two-component model of security inspection: application and findings. 16th World Congress of Ergonomics, IEA 2006, Maastricht, The Netherlands, July, 10-14, 2006.

Graf, M., Schwaninger, A., Wallraven, C., & Bülthoff, H.H. (2002). Psychophysical results from experiments on recognition & categorisation. Information Society Technologies (IST) programme, Cognitive Vision Systems - CogVis (IST-2000-29375).

Hardmeier, D., Hofer, F., & Schwaninger, A. (2005). The object recognition test (ORT) – a reliable tool for measuring visual abilities needed in x-ray screening. IEEE ICCST Proceedings, 39, 189-192.

Hardmeier, D., Hofer, F., & Schwaninger, A. (2006a). Increased detection performance in airport security screening using the x-ray ort as pre-employment assessment tool. Proceedings of the 2nd International Conference on Research in Air Transportation, ICRAT 2006, Belgrade, Serbia and Montenegro, June 24-28, 2006, 393-397.

Hardmeier, D., Hofer, F., Schwaninger, A. (2006b, this volume). The role of recurrent cbt for increasing aviation security screeners' visual knowledge and abilities needed in x-ray screening.

Hofer F., & Schwaninger, A. (2005). Using threat image projection data for assessing individual screener performance. WIT Transactions on the Built Environment, 82, 417-426.

Hofer, F. & Schwaninger, A. (2004). Reliable and valid measures of threat detection performance in X-ray screening. IEEE ICCST Proceedings, 38, 303-308.

Koller, S., & Schwaninger, A. (2006). Accessing X-ray image interpretation competency using the X-Ray Tutor Competency Assessment Test X-Ray CAT. Proceedings of the 2nd International Conference on Research in Air Transportation, ICRAT 2006, Belgrade, Serbia and Montenegro, June 24-28, 2006, 399-402.

Schwaninger, A. & Hofer, F. (2004). Evaluation of CBT for increasing threat detection performance in X-ray screening. In: K. Morgan and M. J. Spector, The Internet Society 2004, Advances in Learning, Commerce and Security (pp. 147-156). Wessex: WIT Press.

Schwaninger, A. (2004a). Increasing efficiency in airport security screening. Proceedings of AVSEC World 2004, November 3-5, Vancouver, B.C., Canada.

Schwaninger, A. (2004b). Computer based training: a powerful tool to the enhancement of human factors. Aviation Security International, FEB/2004, 31-36.

Schwaninger, A. (2005a). Object recognition and signal detection. In: B. Kersten (Ed.), Praxisfelder der Wahrnehmungspsychologie (pp. 108-132). Bern: Huber.

Schwaninger, A., Bridges, A.P., Drury, C., Durinckx, F., Durrant, P., Hodge, T., Hofer, F., Jongejan, R., Maguire, R.L., McClumpha, A., Neiderman, E., Steinmann, C., Wüest, W. (2005). Principles and Requirements for Assessing X-Ray Image Interpretation Competency of Aviation Security Screeners. White Paper, International Aviation Security Human Factors Technical Advisory Group (InterTAG), Competency Assessment Working Group (CAWG).

Schwaninger, A., Hardmeier, D., & Hofer, F. (2005). Aviation security screeners visual abilities and visual knowledge measurement. IEEE Aerospace and Electronic Systems, 20(6), 29-35.

Schwaninger, A., Michel, S., & Bolfing A. (2005). Towards a model for estimating image difficulty in x-ray screening. IEEE ICCST Proceedings, 39, 185-188.