



SCIENCE & SECURITY July 2016

CASRA NEWSLETTER – ISSUE 13

Imagine looking at an artwork by Leonardo Da Vinci. While gazing at his elaborate drawing you are given the task to determine which of his lines were drawn left-handed. This is a difficult task requiring full attention, well-trained visual abilities, and comprehensive knowledge of his sketching techniques. You are able to single out the „left” shading only by the hatch marks going downwards from left to right. What a mission!

Customs officers face similar challenges when examining cargo goods using X-ray screening. Illicit items are often small in comparison with the container. Detecting irregularities in the X-ray image and differences to what is described in the waybill are important for effective and efficient cargo screening. In order to increase custom officers’ competencies, CASRA has developed a new training and testing platform, called the Customs X-Ray Simulator. You can find out more on the development of this tool as well as the tailored image libraries for customs organizations in our section “Security in Practice”.

X-ray screening of passenger bags is an essential component of airport security measures. How well prohibited items are detected relies heavily on airport security X-ray screeners. If you would like to know how their detection performance can be improved, you may find the article in our “Research put Across” section particularly informative.

Now we hope you enjoy reading our articles and we wish you pleasant summer months.



Dr. Diana Hardmeier
Director



Prof. Dr. Adrian Schwaninger
Chairman

TOPICS IN THIS ISSUE:



RESEARCH PUT ACROSS

DETERMINANTS OF AIRPORT SECURITY X-RAY SCREENERS’ DETECTION PERFORMANCE

In this article, determinants of airport security X-ray screener’s detection performance are discussed from a scientific and practical point taking into account research we have conducted in the last 15 years. Scientifically validated selection tests, effective and efficient computer-based training, high quality certification tests, threat image projection and practical tests are important enablers for good detection performance results when implemented properly.



SECURITY IN PRACTICE

THE CUSTOMS X-RAY SIMULATOR – A NEW TESTING AND TRAINING PLATFORM FOR CUSTOMS OFFICERS

CASRA has developed a new platform for cargo X-ray image interpretation training and testing, called the Customs X-Ray Simulator. This system was specifically designed for cargo X-ray screening officers by CASRA in close collaboration with customs organizations and other partners in the EU 7th Framework project AXGIS. In our article, we describe challenges when interpreting cargo X-ray images and show how the Customs X-Ray Simulator works.

DETERMINANTS OF AIRPORT SECURITY X-RAY SCREENERS' DETECTION PERFORMANCE

Text: Adrian Schwaninger

X-ray screening of passenger bags is an essential component of airport security measures. How well prohibited items are detected relies heavily on airport security X-ray screeners. In this article, determinants of airport security screener's detection performance are discussed from a scientific and practical point of view taking into account research that we have conducted in the last 15 years.

Figure 1 shows a slightly adapted version of a model published ten years ago [1]. On the left, determinants of detection performance are depicted: Selection tests, computer-based training (CBT), threat image projection (TIP) and practical tests. Supervision and quality control are important to ensure that these processes and tools are implemented in a way that enables screeners to achieve and maintain good detection performance results. In the following, the different components of the model are discussed.



SELECTION TESTS ARE IMPORTANT BUT OFTEN UNDERESTIMATED

X-ray screening is a demanding task in which prohibited items have to be detected even if they are depicted from an unusual viewpoint, superimposed by other objects or placed in cluttered bags (Figure 2). Research has shown that there are large differences between

people regarding visual-cognitive abilities that are needed to cope with such image-based factors (e.g. [2]). Using reliable, valid and standardized selection tests is essential to ensure that only people are employed as screeners who have the visual-cognitive abilities and aptitudes needed in X-ray screening [3, 4]. Supervision and quality control on this matter varies substantially across different European countries. In some of them, a scientifically validated object recognition test is mandatory in addition to other requirements for pre-employment assessment. In many other countries, this is not the case and requirements for employment as a screener are much lower, which provides a first explanation for the variation in detection performance across European airports.

COMPUTER-BASED TRAINING IS ESSENTIAL BUT NOT ALWAYS EFFECTIVE

In order to learn which items are prohibited, what they look like in X-ray images, and to keep up to date with new

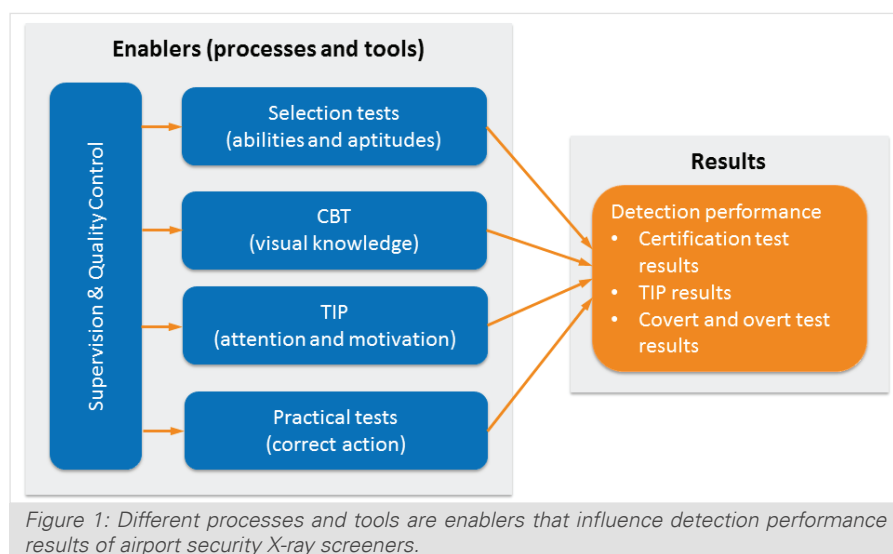


Figure 1: Different processes and tools are enablers that influence detection performance results of airport security X-ray screeners.

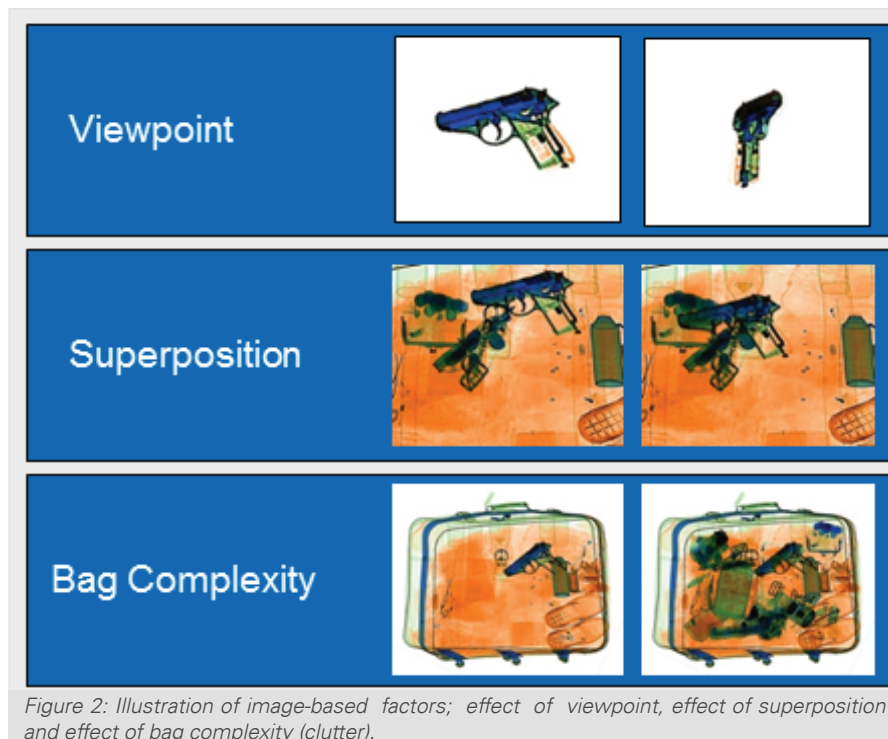


Figure 2: Illustration of image-based factors; effect of viewpoint, effect of superposition and effect of bag complexity (clutter).

CERTIFICATION TEST MUST BE RELIABLE, VALID AND STANDARDIZED

Certification using X-ray competency assessment tests is essential to ensure that screeners have acquired and maintained the required detection performance. European Regulation mandates recurrent certification at least every three years; while we still would recommend an annual or at least a bi-annual mode. This also provides a strong incentive for screeners to take CBT seriously. Regarding supervision and quality control, it is important to mention that the tests should be reliable, valid and standardized. How this can be achieved by following principles and requirements for assessing X-ray image interpretation competency has been defined in a white paper involving scientific, operational and regulatory experts [10]. This white paper has been adopted by the European Civil Aviation Conference (ECAC) and the International Civil Aviation Organisation (ICAO). While in some European countries the responsible appropriate authorities, airports and service providers know these principles and requirements and ensure their implementation, there are other countries where this is not the case. It is clear that harmonization regarding this matter is crucial to achieve comparable competencies of screeners across European airports.

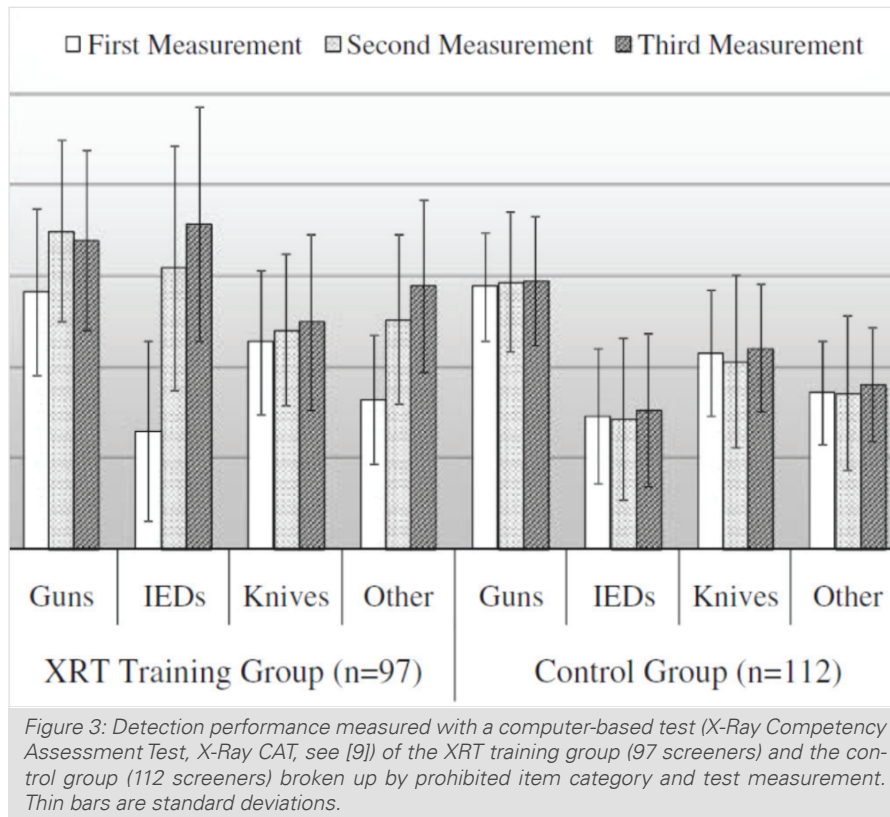
THREAT IMAGE PROJECTION IS IMPORTANT FOR ATTENTION AND MOTIVATION

As pointed out in an article published seven years ago [11], scientifically proven selection tests, effective CBT and high quality certification tests are important prerequisites for good operational X-ray detection performance but they cannot guarantee it. The reason is simple: You could have screeners with great visual-cognitive abilities that have

and emerging threats, computer-based training (CBT) can be a very effective and efficient tool [5, 6, 7]. However, not every CBT is effective. For example, in a study conducted by Koller, Hardmeier, Michel, and Schwaninger [8], training with an individually adaptive CBT containing a large library of prohibited items (X-Ray Tutor, XRT) was compared to two other CBT systems that were not adaptive and had smaller image libraries. Detection performance was measured with an X-ray competency assessment test [9] before and after three and six months of training (about 20 minutes per week). While large increases in detection performance were observed for the XRT training group, there were only small training effects for the other two CBT systems. Figure 3 illustrates the results broken up by prohibited items category for the comparison between XRT and one other CBT in the first study.

According to EU regulation, for class-

room and/or CBT, at least 6 hours every 6 months are mandatory for X-ray screeners. While most, if not all, airports in Europe are compliant with this requirement, there are large differences regarding its implementation. Effectiveness and efficiency of CBT systems used are only one aspect. Regarding supervision and quality control, it is also important to ensure that the CBT libraries are periodically updated based on systematic threat assessment to keep training interesting and up-to-date. Setting goals on training achievement and analyzing training data is also relevant for ensuring CBT effectiveness. At some airports the CBT has not been updated for several years with the consequence that screeners became bored. Some screeners simply clicked through images during training in order to achieve a certain amount of the required training hours knowing that no one would verify whether they reached higher training levels.



trained with an effective CBT and have passed certification, but they still fail a covert test because they were not attentive and/or motivated when the covert test was conducted. Threat image projection (TIP) can be a great tool for increasing attention and motivation [1, 12]. Visual attention research has shown that rare targets are frequently missed [13, 14]. With TIP, this problem can be reduced. Moreover, X-ray screening becomes much more interesting and motivating because with TIP, screeners are exposed to the prohibited items they have to look for at work and because they receive immediate feedback on their performance.

Supervision and quality control is also very important for TIP. If a small image library is used without regular updates, screeners can become eagle eyed at spotting TIP images resulting in high

TIP scores that have little to do with covert test results [12]. Moreover, some (older) TIP software has projection algorithms that result in TIP artifacts which can make the projected fictional threat items (FTI) almost pop out of X-ray images (e.g. unnatural color blending and placement, no distortion and size correction of FTI). In order to fully benefit from TIP, a large image library with periodical updates should be used together with realistic projection of FTI. Ensuring that the recently updated EU Regulation on TIP is implemented properly is a prerequisite for TIP effectiveness.

PRACTICAL TESTS (COVERT AND OVERT) ARE NEEDED FOR SUCCEEDING INSPECTIONS

As mentioned earlier [1, 11, 12], humans often fail to react correctly if

something happens that they do not expect. How often covert tests are conducted has a large impact on covert test results [15]. Conducting covert tests on a regular basis, ideally in combination with overt tests (where screeners have to describe the content of X-ray images) as training and quality control procedure is essential for achieving good results in airport inspections. This is of particular importance when TIP is used to avoid overreliance on TIP feedback messages, which can result in missing a covert test [11].

At some airports covert and overt tests are conducted every week and screeners know that the probability of getting tested within a year is high. At other airports, covert and overt tests were conducted so rarely, that screeners not only failed in airport inspections because they simply did not expect covert tests, but they also failed overt tests for reasons of stress caused by a situation they were not used to.

WHAT ADDITIONAL TOOLS DO WE HAVE AT DISPOSAL TO IMPROVE AIRPORT SECURITY?

Research conducted since 9/11 shows how X-ray screeners' detection performance can be improved. The challenge lies in implementing the different processes and tools in a way that enables X-ray screeners to achieve good detection performance results. Other aspects have not been covered in this article. For instance, behavior analysis can help detecting malicious intent independent of the prohibited item carried and this can be combined with checkpoint screening. Risk-based approaches and unpredictability have large potential not only regarding detection and deterrence but also for increasing efficiency. X-ray machines with explosive detection for cabin baggage screening are extremely useful when taking into account that

the human eye has difficulties in distinguishing certain explosives from benign organic material when conventional X-ray imaging is used. Creating smarter security checkpoints is great, but as long as they entail X-ray screeners, personal selection, effective training, performance measurement, feedback and motivating work design will remain of crucial importance to achieve good human-machine system performance.

This article was written for the August 2016 issue of *Aviation Security International* www.asi-mag.com

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THE CUSTOMS X-RAY SIMULATOR – A NEW TESTING AND TRAINING PLATFORM FOR CUSTOMS OFFICERS

Text: Claudia Lüchinger and Daniela Kirin

Global freight transport for rail and road is projected to grow 2.5% between 2000 and 2030 [1]. This increase in cargo calls for an effective and efficient screening process by the customs authorities. The sheer amount of freight, the various types of containers and transport vehicles, as well as the composition of the goods themselves, challenge cargo X-ray screening officers. For this reason, CASRA has developed a new platform for cargo X-ray image interpretation training and testing, called the Customs X-Ray Simulator. This simulator was specifically designed for cargo X-ray screening officers in close collaboration with customs organizations and other partners in the EU 7th Framework project ACXIS.

In the paragraphs ahead we will explore important aspects of the daily work routines of cargo X-ray screeners, identify the challenges in these processes and explain how training with the Customs X-Ray Simulator can improve the X-ray screening competency of customs officers. Besides the practical implications, we will also provide an inside look into the scientific research behind computer-based training and the development of the Customs X-Ray Simulator.

CHALLENGES IN X-RAY SCREENING OF CARGO AT CUSTOMS

Most land borders and ports nowadays use X-ray screening for unit load devices (ULDs)¹ to detect smuggled items and security threats. This technology is particularly useful as it provides an X-ray image of the shipped content which can be visually inspected without the need for physical interference. The truck is sent through an X-ray scanner, after which the scan image is analysed by the opera-



tor (in this case a customs officer). If a further analysis is needed, the shipment is put aside for manual inspection. Taking the decision whether the freight is clear or not is a difficult task since the inspected ULD can be rather large in scale while the illicit items can be comparably small (e.g. pills, bricks of cocaine, precursors to drugs, see Figure 1 and 2 for an example). Adding to the matter of differences in scale, there are additional elements that need to be taken into consideration: The variety in texture and composition of the goods themselves, the packaging of the products, the types of vehicles used to transport the freight. Detecting small irregularities in the X-ray image is often the key for identifying illicit goods transported in a ULD.

Another key aspect in the screening process is identifying whether the load matches the information on the waybill. The types of goods as well as the amount of goods listed on the waybill must be compared to the actual shipment contained in the X-ray image. This is not only relevant in order to detect prohibited items but also because inconsistencies between declared and transported goods may have an impact on the taxation.

For all these reasons, visual inspection of cargo X-ray images may take

anywhere from just a few seconds up to minutes. On that account, how do customs officers cope when faced with such challenging tasks? What influences their X-ray screening performance?

TWO KEY DETECTION PERFORMANCE FACTORS

Knowledge-based and image-based factors have a large impact on human detection performance [2]. Knowledge-based factors in cargo X-ray screening refer to knowing which items are prohibited, what prohibited and benign items look like, and whether they match the load description on the waybill. Knowledge-based factors are of special importance for recognizing objects that are rarely seen in everyday life and that look quite different in an X-ray image than in reality (e.g. contraband goods and improvised explosive devices, so called IEDs). Image-based factors refer to visual characteristics of X-ray images that an officers needs to take into account. Objects are more difficult to recognise if depicted from an unusual viewpoint, when superimposed by other objects or if the load is heterogeneous and complex.

THE IMPORTANCE OF CBT FOR CAR-

¹ A ULD is a pallet or container used to load freight on to a transport vehicle. It allows a large quantity of cargo to be bundled into a single unit.



Figure 1: Top row left: X-ray image, top row right and bottom row: Prepared pineapples and bananas simulating hidden drug scenarios, photographed from above, perpendicular to the X-ray image.

GO X-RAY SCREENERS

Computer-based training (CBT) can be a powerful tool for increasing X-ray image interpretation competency of airport security X-ray screeners. As an example of training evaluation in the domain of cargo X-ray screening, a study published two years ago investigated whether CBT can also improve X-ray image interpretation competency of cargo screeners [3]. The X-Ray Tutor (XRT) training system, developed by CASRA, was adapted to fit the needs of cargo X-ray screening for the study. The results of the study revealed significant increases in detection performance for screeners having trained weekly using the C-XRT (a test version of the Customs X-Ray Simulator). In addition, average inspection time per image decreased as a result of training. These re-

sults are consistent with earlier studies at airports and they show that CBT can be a powerful tool for increasing effectiveness and efficiency of cargo X-ray screeners.

THE EU FUNDED ACXIS PROJECT

ACXIS (Automated Comparison of X-ray Images for Cargo Scanning) is a research project funded by the European Union under the 7th Framework Program (see www.acxis.eu for details). The ACXIS consortium (including CASRA) conducts research and development for improving effectiveness and efficiency of cargo screening. The project has been described in the CASRA Newsletter No. 12 (March 2016). One of the key components of the project is training and validation. The insights gained from the ACXIS project so far have been very

valuable in developing a new training system for customs officers. What does the system look like and who might benefit from it?

THE CUSTOMS X-RAY SIMULATOR

CASRA has developed a training system called the Customs X-Ray Simulator. This new platform can be used for training purposes and to assess X-ray image interpretation competency of cargo customs officers. It also serves as a platform where information can be shared nationwide with other customs sites.

The navigation on the software suite requires no prior knowledge. Due to the high degree of individualization, new procedures may be integrated in to test and training modules. The following sections explain key aspects of the software.

Creation of Own Content

The content manager of the Customs X-Ray Simulator allows creating customized image libraries by uploading own content, e.g. X-ray images, scans of waybills and/or manually added information from the waybill. These contents are combined into libraries that can be used to create test and training modules. Such modules can be bundled into training series and assigned to certain persons or groups of personnel, with the option to allow access for a designated period of time.

For example, series A contains objects hidden between pallets in the container, whereas series B contains objects attached to the walls and the cooler of the refrigerator truck (Figure 2). If an increase in frequency of one of the two smuggling methods is being registered at a specific border, series A or B can be assigned to the staff of a certain cus-

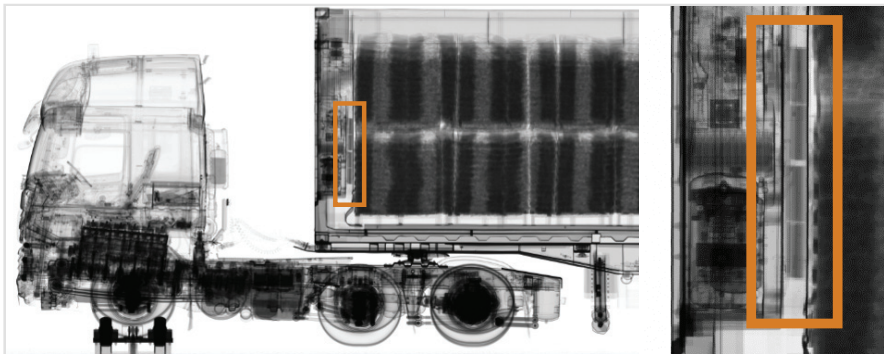


Figure 2: A section of the Customs X-Ray Simulator interface showing an X-ray image of a container with smuggled drugs hidden behind the cooler.

images depicting illicit objects from different angles in order to improve their X-ray image interpretation competency. The interface of the Customs X-Ray Simulator features a variety of supportive functions (Figure 3). In addition to the zoom function, also available to the user is the button “Waybill”, which displays a list of additional information and/or a scanned copy of the waybill documents. Along with this come several image enhancement functions:

- NEG: Creates a “negative” of the image
- SEN: “Super Enhancement”, increases the contours
- LOW LUM: “Low Luminosity”, reduces the brightness
- HIGH LUM: “High Luminosity”, increases the brightness
- B/W: “Black/White”, displays the image in grey scales
- PSEUDO COLOURS: Colours the image, 4 available colour schemes

toms site for specific training purposes. New cases can also be uploaded to the library and allocated to the corresponding module. The images and case specific information may be exchanged with other national customs agencies on a centralised database (see “Centralized database”).

dividual presentation slides (containing information relevant to the organization) or slide blocks to launch or conclude a simulation and provide theoretical background knowledge.

Simulator Interface

During training, it is important to expose users to a broad variety of X-ray

Furthermore, it is possible to create in-

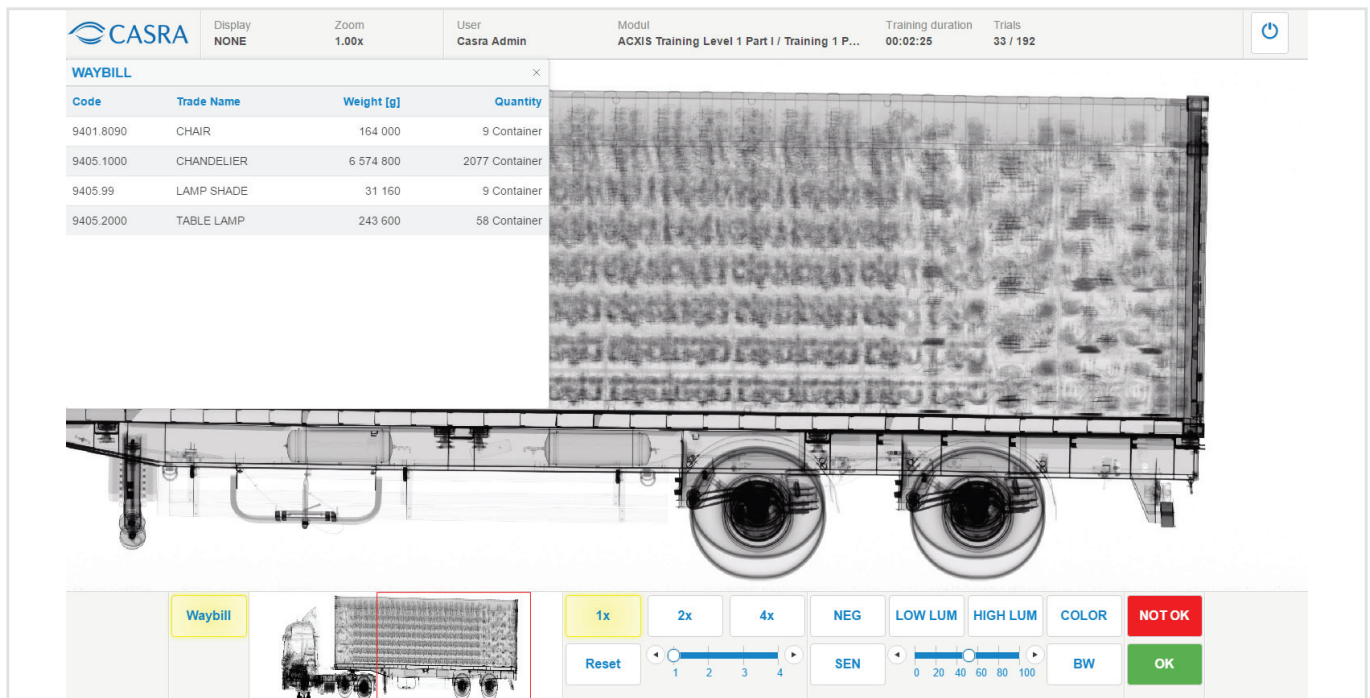


Figure 3: A typical user interface of the Customs X-Ray Simulator test and training program.

Immediate Feedback

Feedback is essential for learning and motivation. After every given response to an image, the customs screening officer is presented with a trial feedback. In the feedback window the required action is displayed and if a target object was present a photograph and an X-ray image of this object is displayed to further support the learning process. After the completion of a training session a block feedback with an overview of the number of images analyzed, correct responses, training times and further details of the simulated scenario is displayed (Figure 4).

Administration and Reporting Functions

Thanks to the administration functions users can be monitored and managed easily. New user accounts can be swiftly imported via templates and organised in user groups. The reporting functions provide the administrator with overviews of each user’s training, test

behaviour, and results. Reports may be exported for further data analysis.

Centralized Database

X-ray images, information from the waybill, registration documents, and customized tags can be uploaded on to the shared database. The application architecture supports fully web-based clients by using HTML5 and AngularJS. The software can be used on-premises by installing it on a server, located on the customs administration’s premises. In this case, the configuration data and the user’s results are stored on a local centralized database. This option enables the nationwide review and exchange of images and information between different customs sites.

ences and information relevant to effective and efficient X-ray screening at customs. Through flexible definition of access rights and information sharing possibilities, this system can also foster the collaboration between different customs sites on national and international level.

CONCLUSION

The use of a computer-based training, such as the Customs X-Ray Simulator, can significantly improve X-ray image interpretation competency of customs officers. Moreover, this new platform allows exchanging knowledge, experi-

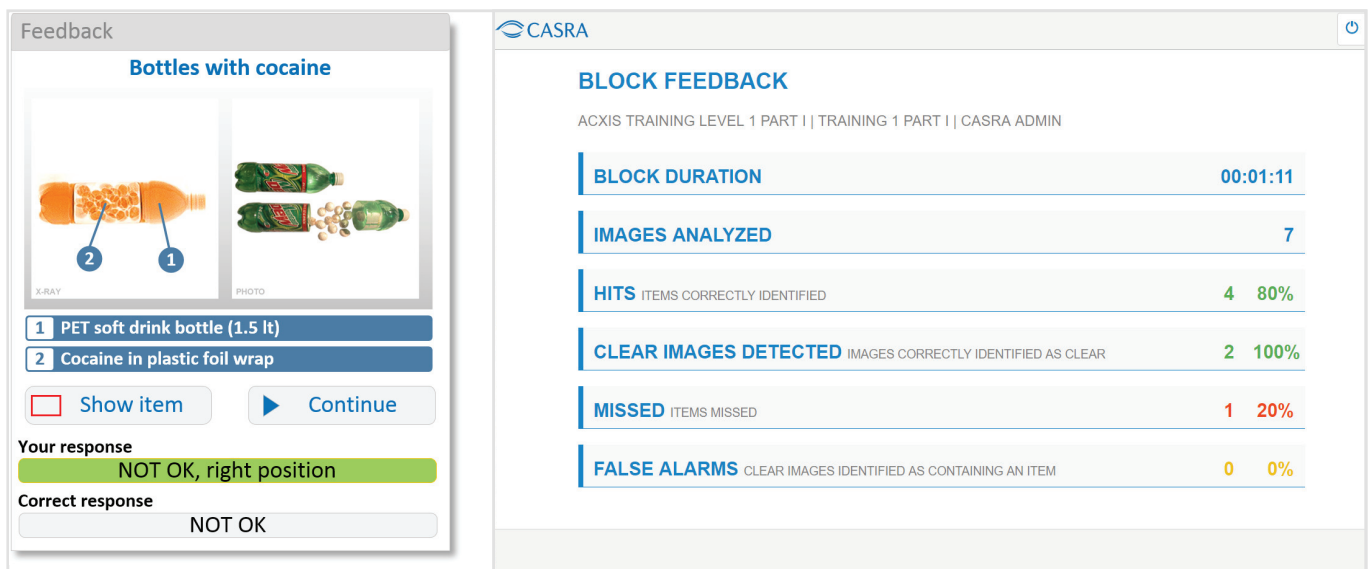


Figure 4: Display of the feedback feature on the interface of the Customs X-Ray Simulator test and training program.

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Science & Security – CASRA Newsletter

ISSN [1664-5715](#)

Published three times a year

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