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CASRA NEWSLETTER – ISSUE 16

CASRA is a leading organization in applied research and applications for security screening. In this summer issue of our newsletter the two articles exemplify how applied research leads to important insights and solutions for our project partners and customers.

In the section "Research Put Across", we present a study conducted by CASRA funded by Smiths Detection which examines image enhancement functions in X-ray screening.
In the "Security in Practice" section, we introduce you to a project in which CASRA collaborated with the United Nations for the development of an arms interdiction guide and course to help countering illicit arms trafficking of postal shipments in Latin America and the Caribbean.

We hope you continue to enjoy reading our articles and we wish you a pleasant summer!

Dr. Diana Hardmeier
Director

Prof. Dr. Adrian Schwaninger
Chairman

TOPICS IN THIS ISSUE:

RESEARCH PUT ACROSS

X-RAY IMAGE QUALITY AND THE USEFULNESS OF IMAGE ENHANCEMENT FUNCTIONS

The importance of X-ray image quality and image enhancement functions for the visual inspection of passenger bags has been investigated and discussed in different scientific studies, mainly for airport security screening. Also for other domains, such as security screening at critical infrastructures, it is assumed that a good X-ray image quality and the availability of different image enhancement functions are important for screeners to achieve good performance in detecting prohibited items. Therefore, Smiths Detection asked CASRA to investigate the usefulness of an optimized default image and of the further developed image enhancement functions for the new X-ray machine HI-SCAN 6040C in a scientific study. In addition, the question of how security officers (operators) perceive an optimized background contrast, which is available on that machine, was addressed. Finally, relevant aspects such as how operators normally proceed when analyzing X-ray images, which image enhancement functions are used and how often, were explored.

SECURITY IN PRACTICE

INTERDICTING SMALL ARMS IN POSTAL SHIPMENTS (ISAPS)

Latin America and the Caribbean have, in general terms, experienced a dramatic increase in armed violence in recent years, driven in large part by the illicit trafficking of firearms, its parts/components, and ammunition. Public policies against illicit arms trafficking in Latin America and the Caribbean have led to an increased use of X-ray technology for the screening of postal shipments. Thus, states have called on the United Nations Regional Centre for Peace, Disarmament and Development in Latin America and the Caribbean (UNLIREC) to provide specialized interdiction tools and X-ray screening training to help combat illicit arms trade by developing a *Course for Interdicting Small Arms in Postal Shipments* (ISAPS). The project's main goal is to boost the capacity of Latin American and Caribbean states to reduce the distribution of illicit arms and their parts/components via postal shipments. Crucial milestones of the project were the development of an *Arms, Ammunition, Parts and Components Identification Guide* in collaboration between UNLIREC and CASRA, and a pilot course and study in Costa Rica.

X-RAY IMAGE QUALITY AND THE USEFULNESS OF IMAGE ENHANCEMENT FUNCTIONS

Text: Stefan Michel

In order to prevent acts of unlawful interference and terrorist attacks, security screening at critical infrastructures (e.g. prisons, nuclear power plants, electrical power systems, water supply systems, etc.) is important. Therefore, personal belongings of employees, inmates, mechanics, customers, visitors, and others are visually inspected by security officers (operators) using X-ray machines. State of the art X-ray screening systems provide images in high quality and with a variety of so-called image enhancement functions (IEFs, see Figure 1).

The usefulness of IEFs for airport security X-ray screening was investigated in different scientific studies in the last years (e.g. [1-3]). Manufacturers of X-ray machines have also recognized the importance of the X-ray image quality and the need of supportive IEFs for operators. That is why Smiths Detection asked CASRA to investigate the usefulness of the recently further optimized default image as well as several IEFs for the X-ray machine HI-SCAN 6040C (see Figure 2a and 2b) which is mainly intended to be used for security screening at critical infrastructures. Additionally, a newly optimized background contrast tool, which is available on that X-ray machine, was evaluated within this study. Finally, relevant aspects like how operators normally proceed when analyzing X-ray images, which IEFs are used and how often, were explored.

Figure 2a: Image enhancement functions (IEFs) available on HI-SCAN 6040C and used in this study to investigate the impact on detection performance

METHODS: PARTICIPANTS, MATERIALS AND PROCEDURE

The study design is shown in Figure 3. In total, 96 operators (81 males, 15 females) working at critical infrastructures from 15 different companies were tested. Two versions of equal difficulty (A and B) of the X-Ray Competency Assessment Test (X-Ray CAT) were used. Each version of the X-Ray CAT contains 256 images in total. 128 X-ray images contain a prohibited item from one of the four different categories *guns, knives, IEDs,* and *others*; the other 128 bags contain only harmless items. For more information on the main principles and psychometric properties of the X-Ray CAT, see [4].

First, all operators solved version A of the X-Ray CAT and filled out a first questionnaire on socio-demographic information. Based on the detection performance, age, gender, and job experience, six equivalent operator groups were created. Subsequently, each of these groups conducted the X-Ray CAT, version B; however, in each case with only one of the following IEFs: *organic only, organic only plus, organic stripping, organic stripping plus, organic enhancement,* and *HI-MAT plus* (see Figure 2a and 3 for illustrations).

Figure 2b: HI-SCAN 6040C from Smiths Detection

Figure 1: Image enhancement functions (IEFs) tested in earlier studies that were used for the questionnaire in this study

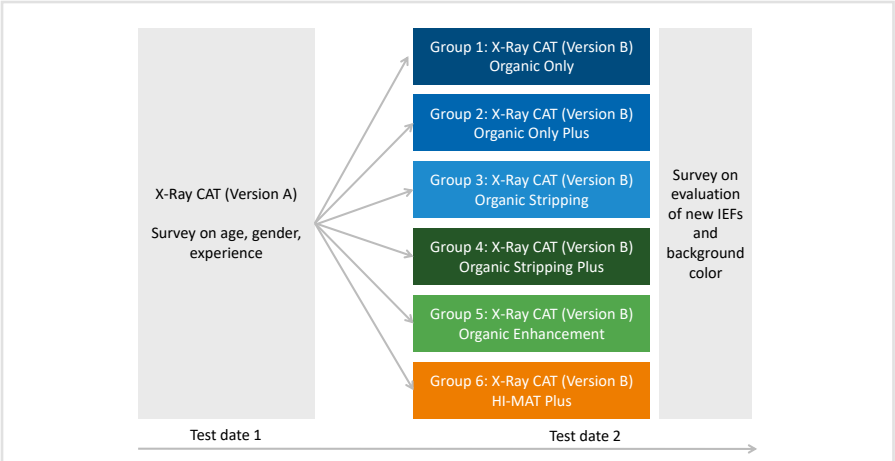


Figure 3: Study design to investigate the research goals

Organic only plus, *organic stripping plus*, and *organic enhancement* are optimized IEFs whereas *HI-MAT plus* is a further developed version of the original image provided by the X-ray machine as a default. Furthermore, a second questionnaire was filled out online by all operators right after version B of the X-Ray CAT was completed. With this questionnaire, we wanted to get a deeper understanding of the above mentioned aspects (e.g. how operators normally proceed when analyzing X-ray images etc.). Additionally, operators had to choose the background color that they thought optimized the X-ray image analysis the most. Furthermore, operators had to rate the background colors regarding their impact on different factors (concentration, fatigue, etc.).

RESULTS

Detection performance of the X-Ray CAT (version B) as well as the results from the second questionnaire were analyzed and are reported in the following sections.

HOW DO OPERATORS NORMALLY PROCEED WHEN ANALYZING X-RAY IMAGES?

Figure 4 shows the results on how operators normally proceed when analyzing X-ray images. Most operators reported that they always look first at the original image and then consider which IEF might be helpful for further analysis. Almost one third of the operators indicated to choose an IEF for analyzing a specific area within the X-ray image after having analyzed the whole image in the original (default) format. More than 10% of the operators reported that they do not use any IEF for analyzing X-ray images.

WHICH IEFs ARE USED AND HOW OFTEN?

In Figure 5, it can be seen which IEFs are used by the operators how frequently. 68% of the operators reported that the *original* image is the one they mostly use for inspecting bags or other belongings, followed by the IEFs *metal only* and *black and white*.

WHICH IEFs DO OPERATORS MISS WHEN ANALYZING X-RAY IMAGES?

Table 1 shows which image enhancement or other functions operators miss for the X-ray image interpretation. Most operators reported that they are satisfied with the available IEFs. However, some indicated that they would benefit from the possibility to analyze bags and other belongings using multi-view or 3D rotatable X-ray imaging.

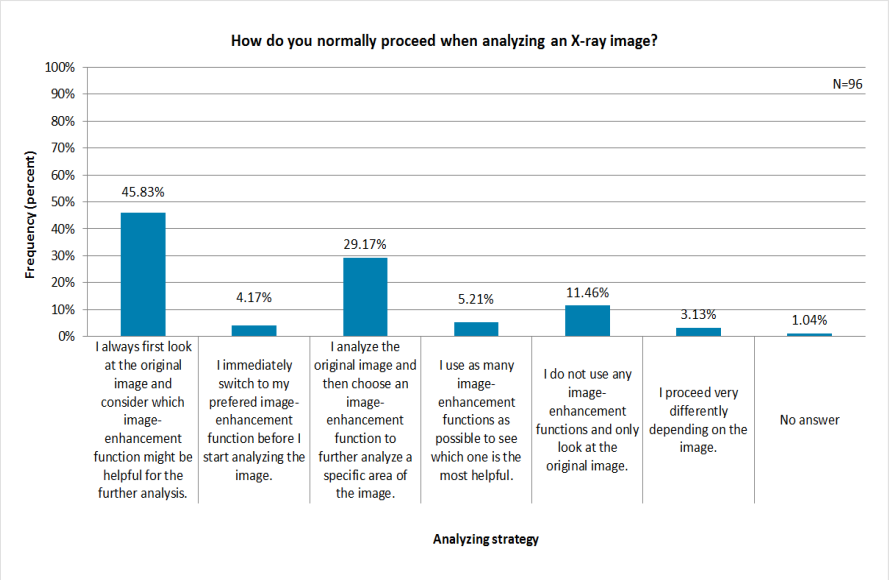


Figure 4: Frequency of answers from operators on how they normally proceed when analyzing images

WHAT CHARACTERIZES A GOOD X-RAY IMAGE?

Operators reported that a good X-ray image is characterized by high resolution differences in terms of color, accentuation of different materials, and low superposition of the items within the X-ray image (see Table 2 for more information).

HOW DO OPERATORS EVALUATE DIFFERENT BACKGROUND CONTRASTS IN AN X-RAY MACHINE?

Operators rated the background color of different X-ray images on how it is supporting the X-ray image interpretation (see Figure 6). Together, a light-gray and dark-gray background was rated as more supporting for analyzing X-ray images (54%) compared to a white background (46%). Additionally, operators reported that a gray background color is less tiring and promotes concentration and attention in comparison with a white background (see Figure 7).

DETECTION PERFORMANCE FOR GUNS USING ORGANIC ONLY VS. ORGANIC ONLY PLUS

The X-Ray Competency Assessment test (X-Ray CAT) Version B (see study design in Figure 3) was analyzed to investigate the benefit of the recently optimized IEFs. As can be seen in Figure 8, a significant increase of detection performance for the category of guns was found when the further developed IEF *organic only plus* was used compared to the IEF *organic only*.

DISCUSSION

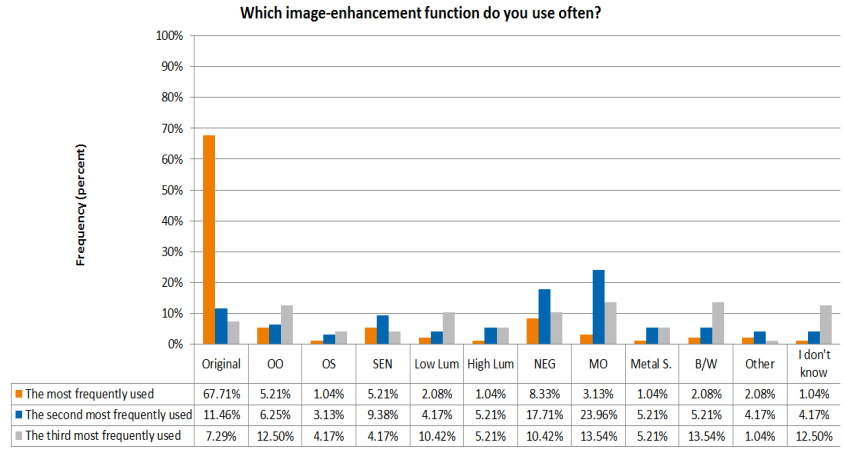
Most operators reported that they first analyze the default X-ray image (original) and then decide if and which IEF(s) to choose for further inspections of the whole image or for specific areas with-

Table 1: Missing image enhancement funcitons (IEFs) from operators' point of view. Categories are only reported when more than one person stated them

CATEGORIES	FREQUENCY
Nothing is missing	50
Multi-view or 3D rotatable X-ray imaging	13
Higher resolution, more possibilities to zoom	4
Accentuation of wires & cables	2

Table 2: Answers from operators on what characterizes a good X-ray image. Categories are only reported when more than one person stated them

CATEGORIES	FREQUENCY
Resolution	47
Differences (color/accentuation of materials)	15
Low superposition	12
Contrast	6
Multiple-views	6
Different image enhancement functions	2



	Original	OO	OS	SEN	Low Lum	High Lum	NEG	MO	Metal S.	B/W	Other	I don't know
The most frequently used	67.71%	5.21%	1.04%	5.21%	2.08%	1.04%	8.33%	3.13%	1.04%	2.08%	2.08%	1.04%
The second most frequently used	11.46%	6.25%	3.13%	9.38%	4.17%	5.21%	17.71%	23.96%	5.21%	5.21%	4.17%	4.17%
The third most frequently used	7.29%	12.50%	4.17%	4.17%	10.42%	5.21%	10.42%	13.54%	5.21%	13.54%	1.04%	12.50%

Figure 5: The most often, second, and third most often used image enhancement functions (IEFs) reported by operators. The operators knew the IEFs already from the X-ray machine they are working with (e.g. HI-SCAN 6046si): OO = Organic Only, OS = Organic Stripping, SEN = Super Enhancement, Low Lum = Luminance Low, High Lum = Luminance High, NEG = Negative Image, MO = Metal only

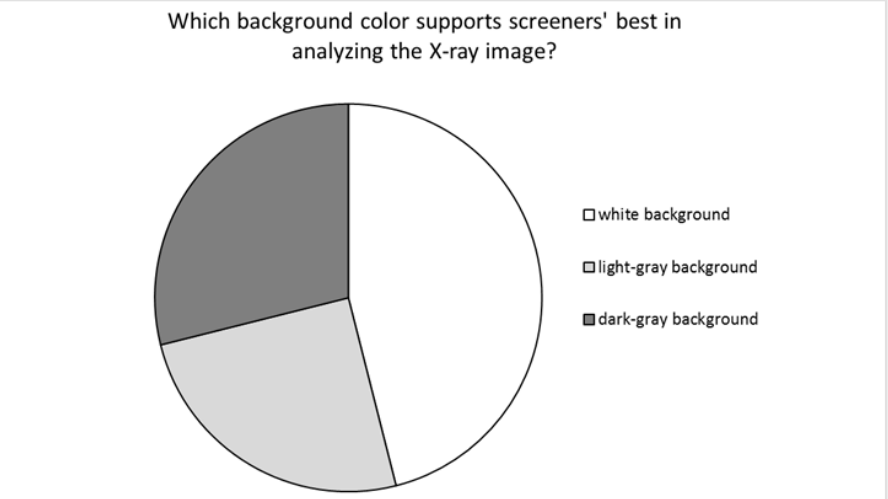


Figure 6: Ratings on suitability regarding different background colors

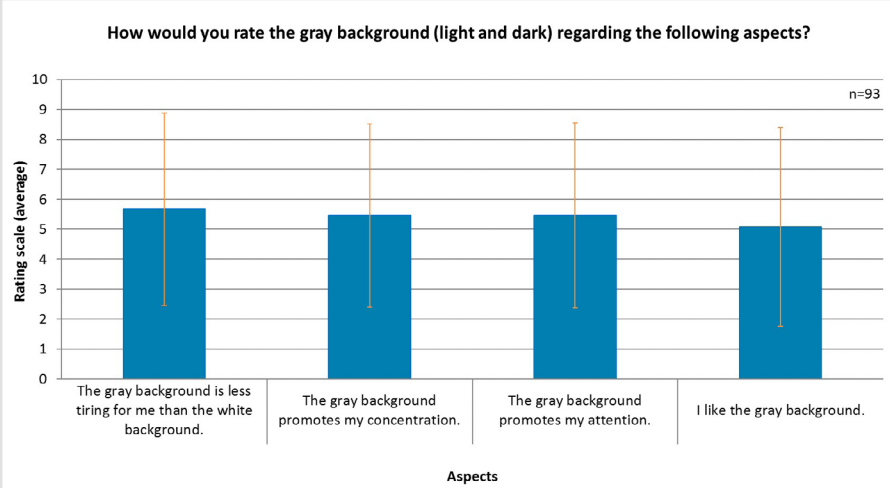


Figure 7: Average ratings and standard deviations of the gray background color regarding different aspects on a 10-point scale

in the image. Furthermore, operators stated that a good X-ray image is characterized by high resolution, low superposition, good distinction of colors, and good accentuation of different materials, as well as a high contrast. These results support the findings from [1] where the nature of the bag as well as the quality of X-ray images were factors with relevance for airport security X-ray screeners' visual inspection performance. For X-ray machine manufacturers, focusing on further enhancing of the default image (e.g. resolution, contrast, colors, etc.) could therefore pay off.

Nevertheless, operators should be trained in order to learn which IEFs to use on what occasion since more than 10% reported that they do not use any IEF for analyzing the X-ray images. Some stated that they use as many IEFs as possible to see which one is the most helpful. Maybe they just do not know the respective advantages of each IEF.

Most operators are satisfied with the IEFs they have on their X-ray machine. However, some operators wish for multi-view or 3D rotatable X-ray imaging. This underlies the efforts, which are currently taken, in order to implement 3D CT machines in aviation security and other domains.

When analyzing the detection performance (A') for the different tested IEFs, the optimized IEF *organic only plus* led to a significant increase of detection performance for guns. One of the benefits of this function is that metallic parts within the X-ray image are better visible whereas the previous IEF *organic only* mostly obscured metallic parts with a gray area. Therefore, working on the optimization of IEFs and testing the usefulness of IEFs by measuring the detection performance is recommended as there is still need for improvement for IEFs provided by X-ray machines.

Based on subjective ratings, a gray background color supports operators better than a white one when analyzing X-ray images. Operators reported that a gray background color promotes concentration and attention, and is less tiring. Giving the possibility to change the background color of the X-ray images is therefore recommended. However, additional research on the influence on detection performance when using a dark background color is needed to better substantiate potential benefits.

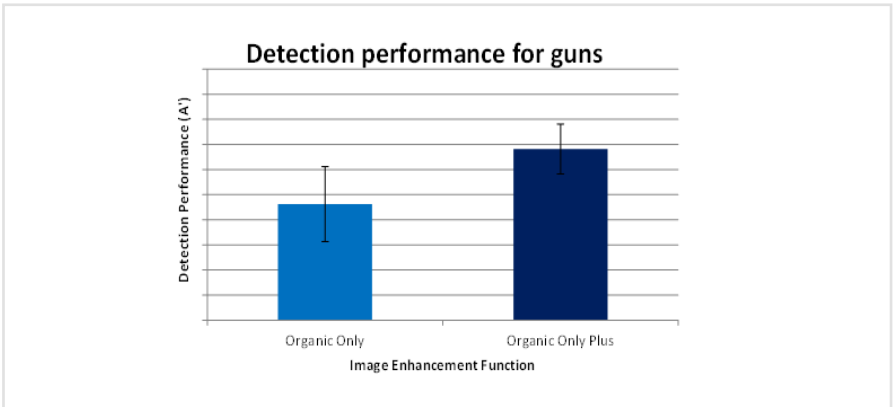


Figure 8: Mean and standard deviation of the detection performance (A') for organic only and organic only plus for the category of guns. Detection performance values are not reported due to security reasons

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INTERDICTING SMALL ARMS IN POSTAL SHIPMENTS (ISAPS)

Text: Slavtcho Groshev

Due to the increasing number of goods transported across borders, the use of technologies such as X-ray screening have gained an ever-greater importance in the prevention of illicit traffic of arms. Under the Programme of Action to Prevent, Combat, and Eradicate the Illicit Trade in Small Arms and Light Weapons in all its Aspects (PoA), states agreed upon prioritizing actions that will lead to reduced crime and ensure public security. *Interdicting Small Arms in Postal Shipments* (ISAPS) is a capacity building project of the United Nations Regional Centre for Peace, Disarmament and Development in Latin America and the Caribbean (UNLIREC) conducted in collaboration between UNLIREC and CASRA. The main aim is to boost the capacity of Latin American and Caribbean states to combat the distribution of illicit arms via postal shipments. Crucial milestones of the project were the development of an *Arms, Ammunition, Parts and Components Identification Guide* and a pilot course and study in Costa Rica.

Illegal arms traffic is a serious issue in Latin America and the Caribbean. Living there as a young man between the ages of 15 to 29 poses a great risk: The likelihood of being killed by small arms is four times greater than the world's average [1]. More than 100'000 homicides are reported per year in the region, two thirds of them being small arms crimes, making it the highest rate in Central America (70%), followed by the Caribbean (61%), and South America (60%) [2]. While the rate of homicide and degree of victimization differ among countries[1], the region has the largest number of victims killed with small arms - seven times higher than in Europe or Asia [1].

Figure 1: Identification Guide cover

According to the World Customs Organization Illicit Trade Report [3], 4'045 interdiction operations resulted in more than 5 million weapons, weapon parts/components, and rounds of ammunition being seized worldwide in 2014. Postal shipments were cited as one of the top three preferred concealment methods preferred by arms traffickers, 69% of which were detected at the point of import while 50% of these reported interdictions took place at central postal hubs, dispatch offices, and airports. Governments and citizens both expect the respective authorities to impede the import of goods that endanger public safety and to prevent import tax evasion. In order to effectively combat illegal shipments of small arms and their parts/components, states have called on the United Nations Regional Centre for Peace, Disarmament and Development in Latin America and the Caribbean (UNLIREC) to provide specialized interdiction tools and X-ray screening training for the relevant organizations.

A capacity building project called *Interdicting Small Arms in Postal Shipments* (ISAPS) was developed in collaboration between UNLIREC and CASRA with the support of the Postal Union of the Americas, Spain and Portugal (PUASP), the Universal Postal Union (UPU), and the Federal Republic of Germany to help address the following UNLIREC aims:

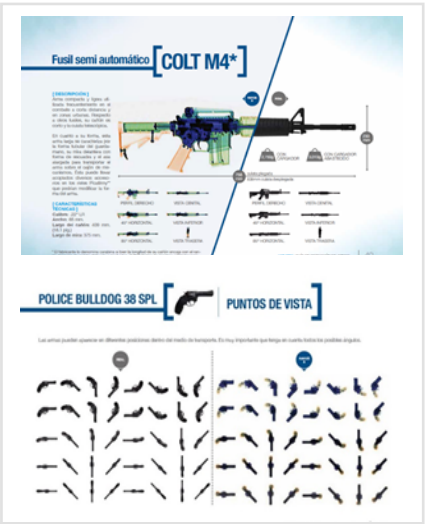

Figure 2: General information and viewpoint sheets from the Identification Guide

- Boost the capacity of Latin American states to reduce the distribution of illicit arms and their parts/components via postal shipments.
- Establish the highest possible quality of standards and control processes for detecting and handling illicit goods at the points of entry, exit, and transit.
- Strengthen the self-sustaining capacities of national authorities to reduce weapons distribution via postal shipments.
- Implement international instruments and standards relevant to preventing and combating illicit trafficking of small arms and their parts/components.
- Increase the state awareness of the importance of the selection of personnel and specialized training and testing processes for improved detection and optimal X-ray screening performance.

Within the project, UNLIREC and

[1] Countries such as Mexico, Peru, and Argentina show a higher level of victimization than number of homicides while an opposite effect occurs in Honduras, El Salvador, and Venezuela where the number of homicides is superior to the level of victimization in the population.

CASRA collaborated to develop an *Arms, Ammunition, Parts and Components Identification Guide* (called Identification Guide hereafter) and an ISAPS course with online learning as well as theoretical presentations and hands-on X-ray screening training with practical exercises on assembling/disassembling weapons to help become familiar with shapes and materials of the main parts and components (blended learning) as effective, efficient, and practical training tools for states in Latin America and the Caribbean. The course was piloted in Costa Rica and an accompanying study was conducted to evaluate the effectiveness of online learning and blended learning for illicit item detection.

THE ARMS, AMMUNITION, PARTS AND COMPONENTS IDENTIFICATION GUIDE

X-ray screening is a highly demanding task. It requires specific knowledge of what prohibited items look like as well as visual abilities to deal with image-based factors (container complexity, item superposition, and viewpoint) [4, 5]. While knowledge can be obtained on the job, targeted selection and training is essential [6, 8-13]. CASRA provided UNLIREC with expertise on X-ray image interpretation and content that became a central part of the Identification Guide (see Figure 1). The guide is divided into four main parts: The introduction briefly covers the objectives and context of the guide. The second part contains, amongst others, general information about how X-ray machines work, what an X-ray image looks like, and how material and density affect the colors of materials in an X-ray image. The third part contains information sheets on threat items from the categories pistols, revolvers, shotguns, rifles, submachine guns, rocket launchers, and ammunition. In each category, there is general information about the threat item, both photographs and X-ray images of multiple viewpoints, and information about materials and parts/components (see Figure 2). Finally, the fourth part of the guide addresses methods of concealment.

Figure 3: X-Ray Object Recognition Test (X-Ray ORT) and X-Ray Competency Assessment Test (X-Ray CAT)

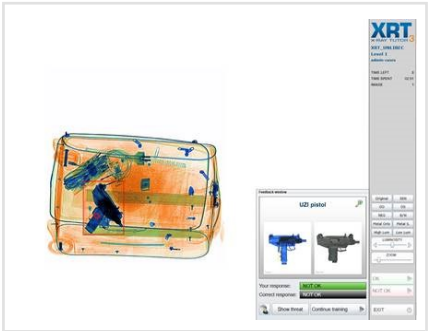

Figure 4: X-Ray Tutor 3 (XRT3)

COURSE FOR INTERDICTING SMALL ARMS IN POSTAL SHIPMENTS (ISAPS)

The pilot of the ISAPS course was conducted with 40 officials with control responsibilities from Costa Rica's Post Office, the Directorate of Intelligence and Security, Judicial Investigation Agency, Air Surveillance Service, National Customs Service, Ministry of Public Security and Fiscal Control Police. The participants first took an X-Ray Object Recognition Test (X-Ray ORT) [6] to establish a baseline of object recognition capabilities (see Figure 3). X-Ray Competency Assessment Tests (X-Ray CATs) in X-ray screening were then used to measure the initial level and subsequent progress in X-ray image interpretation competency (see Figure 3). Course participants were trained online with X-Ray Tutor 3 (XRT3) on the Hosted Solution provided by CASRA (see Figure 4). They also received three

Figure 5: Theoretical presentations and practical training in the ISAPS course

full days of theoretical presentations and practical X-ray screening training on the identification of arms and their parts/components by UNLIREC (see Figure 5). The practical training also involved the simulation of interdictions of packages using varying methods of concealment - depending on the type of object - with a specific focus on parts/components.

EFFECTIVELY INCREASING DETECTION PERFORMANCE IN X-RAY IMAGE INTERPRETATION FOR POSTAL SHIPMENT SCREENING

In the last decade, several studies have shown that computer-based training (CBT) is important to achieve good detection performance in X-ray image interpretation (for more information see [8-13]). The test results in the ISAPS study confirmed these previous findings by showing statistically significant improvements in detection performance as measured by A' [7] of more than 0.10 on average owing to online learning and blended learning. The study results showed that on average, parts/components of weapons were more difficult to recognize than assembled weapons, highlighting the importance of dedicated training. The Identification Guide and the ISAPS course stand to benefit all of Latin America and the Caribbean by providing a set of effective, efficient and practical training tools for personnel tasked with interdicting postal shipments of illicit small arms, their parts/components, and ammunition. Furthermore, the pilot course and study provide encouragement to further refine the training toolset in future projects.

CALL FOR ACTION

If your organization is interested in implementing the ISAPS course, please contact UNLIREC at martinez@unlirec.org.

For an in-depth description of the project, please contact CASRA at info@casra.ch or UNLIREC at martinez@unlirec.org

UNLIREC

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