SCIENCE & SECURITY Issue 23

CASRA NEWSLETTER

Summer is in the air and it is time for our first newsletter in 2020!

In this 23rd issue, the section "Research Put Across" addresses the transition from 2D multi-view to advanced 3D CT imaging in hold baggage screening from the perspective of personnel selection. 3D CT imaging features 3D rotation of X-ray images of passenger baggage and other image processing functions that are not available in 2D multi-view imaging. We present a study that we have conducted to investigate whether the same visual-cognitive abilities are needed for 3D CT versus 2D multi-view screening of hold baggage.

In the "Security in Practice" section, we are particularly pleased to introduce you to our new solution for testing and training X-ray screeners, the complete suite XRT4! It builds upon two decades of applied research and we provide insights into our scientifically based training and assessment, the strong technical features of our solution, and how we continuously improve it together with our customers.

As always, we are looking forward to receiving any feedback you might have as well as your input on topics you would like us to address in upcoming newsletters.

With best wishes for a nice summer.

Dr. Diana Hardmeier
Director

Prof. Dr. Adrian Schwaninger
Chairman

TOPICS IN THIS ISSUE:

RESEARCH PUT ACROSS

X-RAY SCREENING OF HOLD BAGGAGE: WHAT VISUAL-COGNITIVE ABILITIES ARE NEEDED FOR 2D AND 3D IMAGING?

The task of an airport security officer is to visually inspect X-ray images of luggage and take a decision within seconds whether it is a harmful piece of baggage or not. While still many airports conduct security screening with 2D multi-view X-ray imaging technology, newer technology is based on 3D CT imaging and brings along new features such as 360° rotation and slicing through the bag. Important to know is: "Are the same visual-cognitive abilities needed for 3D CT image inspections?" This article describes results from a first study and what these results imply for future personnel selection.

SECURITY IN PRACTICE

X-RAY TUTOR 4 (XRT4): BUILT UPON TWO DECADES OF APPLIED RESEARCH

Through continuous improvement, research and strong connections to partners and customers, CASRA presents the new testing and training solution XRT4! The computer-based training, which supports screeners through all the employment phases, incorporates the scientifically proven individually adaptive training algorithm. XRT4 allows to train with single-view, dual-view and 3D CT modules, while adapting the user interface to most common vendors. XRT4 Expert gives even the opportunity to create individual and personalized modules for training and testing. This article explains how the solution has evolved and how the results have been implemented into XRT4.

X-RAY SCREENING OF HOLD BAGGAGE: WHAT VISUAL-COGNITIVE ABILITIES ARE NEEDED FOR 2D AND 3D IMAGING?

Text: Sarah Merks

Up to this day, security screening of hold baggage at many airports is still being conducted with 2D multi-view X-ray imaging technology. Newer technology is based on 3D CT imaging. Such systems offer the possibility to rotate a bag around 360 degrees, slice through a luggage and they provide state-of-the-art explosives detection systems (EDS). With the transition from 2D multi-view to advanced CT imaging, the question arises whether airport security officers (screeners) need the same visual-cognitive abilities when visually inspecting CT images of hold baggage. This article describes results from a first study and what these results imply for future personnel selection.

The task of airport security officers (screeners) is to visually inspect X-ray images of luggage, which consists of visual search and decision making [1–4]. In cabin baggage screening (CBS), prohibited items are guns, knives, improvised explosive devices (IEDs) and other items such as for example a self-defence gas spray [5]. While the prohibited item categories are limited, there is a large variety of different exemplars and shapes of prohibited articles [6, 7].

Individually adaptive computer-based training has been shown to be very important and effective to achieve and maintain a good detection performance in visual inspection of X-ray images [1, 8–10]. Besides this knowledge about prohibited articles and their appearance in X-ray images, so-called image-based factors, have been shown to be important as well: Prohibited articles in X-ray images are more difficult to recognize when depicted from unusual viewpoints, when superimposed by other objects and when placed in visually complex bags [11–13]. Screeners who can better cope with such image-based factors have better detection performance in X-ray image inspection [14,15]. This is related to certain visual-cognitive abilities, like logical thinking, figure-ground segregation and spatial imagination, which have been shown to correlate with detection performance in X-ray image inspection of cabin baggage [16].

As visual-cognitive abilities are assumed to be relatively stable (but vary substantially between people), screeners who have been selected based on the X-Ray Object Recognition Test (X-Ray ORT) perform better on the job than screeners who did not have to take such a test in the pre-employment assessment process [17]. To improve personnel selection, it is therefore interesting to investigate visual cognitive abilities as determinants of visual inspection performance.

VISUAL-COGNITIVE ABILITIES IN HOLD BAGGAGE SCREENING (HBS)

Previous research focused mainly on visual cognitive abilities as predictors for cabin baggage screening. However, the task of a screener in hold baggage screening (HBS) differs substantially from cabin baggage screening. During the flight, passengers cannot access items stored in the hold of an aircraft, so guns or knives do not pose a threat, and hold baggage screening targets only fully functioning IEDs [18]. Furthermore, hold baggage screeners are assisted by explosive detection systems (EDS) which indicate the presence of potentially harmful material within a bag in X-ray images [19]. Therefore, screeners in HBS only analyse images that have been alarmed by the EDS and decide whether the specific alarmed object is harmless or whether it might be an IED and therefore additional security checks must be performed [18]. Thus, the task in HBS mainly consist of deciding whether an X-ray image contains an IED or not, whereas visual inspection in CBS consists of visual search and decision making [1–4].

Although 2D imaging technology is still being used for security screening of hold baggage at many airports, newer technology is based on 3D CT imaging (see Figure 1). 3D CT imaging allows screeners to look through an alarmed object by using a slice view. Moreover, 3D rotatable images might also facilitate the recognition of prohibited items that, in certain 2D views, would be superimposed by other items in a complex bag. The relevance of image-based factors for personnel selection might therefore change when inspecting static 2D versus 3D rotatable images, as the viewpoint and superposition effect may disappear and the need for mental rotation would then become less important. The implementation of advanced 3D CT systems could therefore have an impact on the requirements of visual-cognitive abilities needed for achieving and maintaining a good detection performance.

WHAT VISUAL-COGNITIVE ABILITIES ARE NEEDED FOR 2D HBS?

Previous studies on cabin baggage screening have found that several visual cognitive abilities, like figure-ground segregation, form constancy, logical thinking and spatial imagination are related to a high detection performance with 2D imaging technology [7,16,20].

The first aim of our study was to examine whether results would be different for hold baggage screening. This was the case: We found that a high detection performance with 2D imaging technology for hold baggage screening was, just as for cabin baggage screening, related to spatial imagination. But, there was no relation to other abilities relevant for cabin baggage screening, such as figure-ground segregation, form constancy and logical thinking. A high performance in hold baggage screening was however related to other visual cognitive abilities, such as perceptual speed and visual memory. As mentioned earlier, visual inspection in HBS is mainly a decision task whereas visual inspection in CBS consists of search and decision making [1,3]. Therefore, it is not surprising that certain aspects of visual processing becomes less relevant in HBS. Our results suggest that abilities like figure-ground segregation or form constancy might be more related to the visual search component and therefore less relevant for HBS compared to previous findings on CBS, while spatial relation – the ability to mentally rotate an object - is an important aspect for both CBS and HBS. Furthermore, visual memory seems to be important for the decision making in HBS screening.

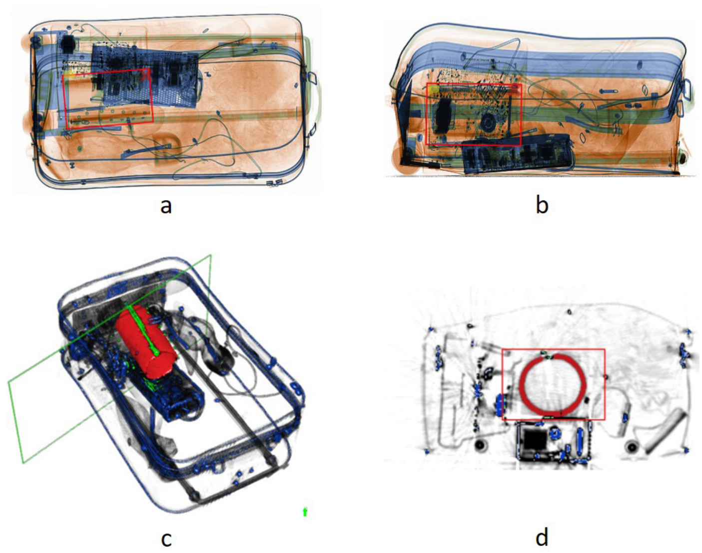

Figure 1: Bag with an IED recorded with 2D and 3D imaging: (a) 2D default image, (b) 2D image with 90 degrees difference in perspective, (c) 3D-rotatable CT image, and (d) CT slice image

WHAT VISUAL-COGNITIVE ABILITIES ARE NEEDED FOR 3D HBS?

A second aim of our study was to compare visual cognitive abilities related to HBS detection performance with 2D imaging versus 3D imaging. The results suggest that processing speed loses relevance for 3D imaging compared to 2D imaging. While perceptual speed correlated with detection performance with 2D imaging, there was no relation to detection performance with 3D imaging. One reason for this could be that the screeners that participated in this first study generally took more time to analyze 3D images compared to when visually inspecting 2D images, as they were trained 2D screeners with no experience with 3D imaging. Furthermore, it is obvious that 3D screening in general is slower than 2D screening due to additional functionalities like rotating and slicing. It is therefore possible that visual cognitive abilities related to processing speed might lose their relevance for predicting detection performance with 3D imaging, especially if screeners are new to the 3D technology.

In regards of visual processing, again, different aspects were related to detection performance with 2D imaging compared to 3D imaging. For 2D screening, spatial relation and visual memory were related to high detection performance, while only the ability to mentally visualize a 3D object was relevant for 3D screening. It makes sense that spatial relation, the ability to mentally rotate an object, becomes less important with 3D rotatable images, since the screener can physically rotate the image. Visual memory, which is mostly needed to match a mental representation with the objects in the X-ray image seems to only be relevant for 2D screening, but not for 3D screening. A reason for this could be that with 3D rotatable images, screeners no longer match mental representations of an IED with objects in the X-ray image. Instead, they might look for components like explosive material and detonators, which are accordingly coloured.

Last, logical thinking was not related to HBS detection performance at all, neither for 2D imaging nor for 3D imaging. This is not consistent with previous research on CBS [16]. Logical thinking is very close related to the concept of fluid intelligence and working memory [21]. Working memory allows for temporary storing and processing information and to perform several tasks at the same time. Therefore, working memory is very important for the CBS inspection task, which consists of search and decision making for several different threat categories. However, working memory capacity might lose relevance in HBS, which consists in decision making for only one threat category.

WHAT DOES THIS MEAN FOR FUTURE PERSONNEL SELECTION?

Overall, the results of this first study suggest that different visual cognitive abilities are relevant for 2D HBS compared to 2D CBS. Furthermore, the study suggests that screening with 3D imaging systems might also require different visual cognitive abilities. The possibility of rotating the X-ray image of a bag and its content around 360 degrees seems to facilitate the recognition of prohibited items when depicted from unusual viewpoints, when superimposed by other items and when placed in visually complex bags. This might explain why fewer visual cognitive abilities become relevant for 3D screening compared to 2D screening. However, the screeners participating in this study were already selected using the X-Ray Object Recognition Test (X-Ray ORT) in the pre-employment assessment process, which measures visual cognitive abilities. In a next study it should be investigated whether novices to 2D and 3D X-ray screening show a different relationship between certain visual-cognitive abilities and detection performance. It should also be elucidated in more detail what visual-cognitive skills future 3D screeners need and if there are differences between cabin and hold baggage screening.

PLANNED STUDIES FOR 3D CBS

In January 2019, CASRA started with a 4-year project that is focussing on the introduction and training of 3D CBS. On one hand, the project is investigating research questions in regard of the optimal implementation of new EDSCB standards. This work focuses on requirements for the selection and training of 3D screeners. Furthermore, different concepts of operation for EDSCB C3 standard are evaluated. And, the relevance and optimal use of 3D CT functionalities, like rotation and slicing, are examined.

The project also evaluates the potential of virtual reality (VR) technologies for interactive learning, training and competence measurement in the context of the transition from 2D X-ray to 3D CT machines for security checkpoints. This includes VR learning modules for the introduction of screeners to new 3D CT technologies and equipment; a VR object learning environment for 3D object recognition; and a VR simulated environment for checkpoint and remote screening for training and competence measurements of screeners. For the successful realisation of these studies, we are still looking for project partners, ideally airports or security service providers, who already have experience with 3D CT CBS. If you are interested in any of the above-mentioned subjects, please do not hesitate to contact CASRA at info@casra.ch.

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X-RAY TUTOR 4 (XRT4)

Text: Slavtcho Groshev, Flavia Kohler, Milena Kuhn

BUILT UPON TWO DECADES OF APPLIED RESEARCH

The Center for Adaptive Security Research and Applications (CASRA) was founded in 2008, but its roots go back to the Visual Cognition Research Group (VICOREG) of the University of Zurich (1999-2008). In the early 2000s, first research projects on X-ray screening began at Zurich Airport. We found that visual abilities and targeted training are important determinants of the performance of airport security officers (screeners) [1-4]. As a result, the first version of X-Ray Tutor and first versions of tests for screener selection and competency assessment (Figure 1) were developed and evaluated in further research projects at airports in different countries. In 2004, the United States Transportation Security Administration (TSA) deployed X-Ray Tutor 1, and in 2005, X-Ray Tutor 2 at all airports in the USA [5]. One year later, the European Commission funded the VIA research and development project with six European countries and ten airports. This project confirmed the importance of our approach for selection, training and competency assessment of screeners in all participating countries and airports [6].

In 2011, X-Ray Tutor 3 was released, helping pioneer web-based screener training and assessment across multiple screening domains (Figure 2). Our applications for training and testing in the area of aviation security would soon be in use in more than 40 countries at more than 900 airports and other sites worldwide [7].

In 2012, we started developing an approach that leverages intelligence for regular updates to training content (Systematic Threat Assessment, Figure 3) [8, 9]. Since then, our STA team uses different technologies for continuously analyzing several information sources including the surface and deep web to assess current threats and identify new and emerging threats. Threat scenarios are evaluated regarding feasibility, impact, and possible mitigation measures to develope targeted countermeasures (in particular threat reports and new training content).

Further EU-funded research led to the first version of X-Ray Tutor 4 that could be run across modern internet browsers for training and assessment of customs operators in 2016 (Figure 4) [10, 11].

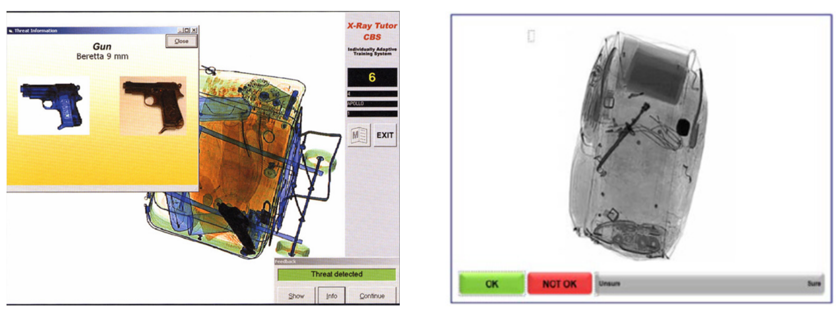

Figure 1: X-Ray Tutor 1 (left) and first versions of tests for screener selection and competency assessment (right)

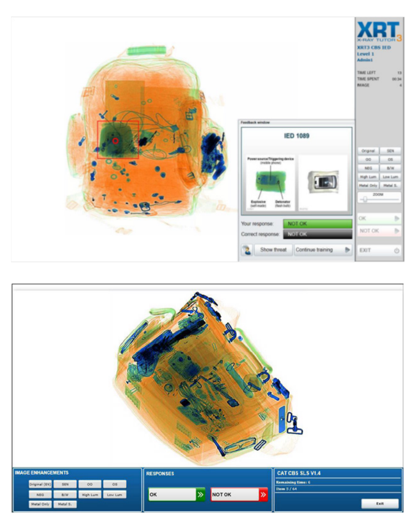

Figure 2: X-Ray Tutor 3 (top) and advancements in tests for screener selection and competency assessment (bottom)

Notably, the system featured the simulation of automated target recognition (ATR) and waybill display functions with relevance for customs inspections.

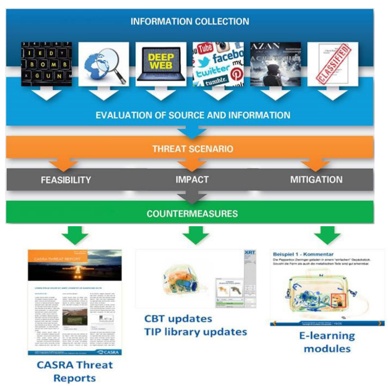

Figure 3: Systematic Threat Assessment

Subsequent research focused on newer X-ray screening technology offering 2D multi-view and 3D imaging with automated explosives detection [12, 13]. This work has culminated in our new all-encompassing training and testing solution, X-Ray Tutor 4 (XRT4, Figure 5), supporting selection, training and assessment of screeners with single-view, 2D multi-view, and 3D imaging.

The following sections present scientifically based training and assessment aspects, key technical features of XRT4 as well as strong partnerships with customers for the continuous improvement of our solution.

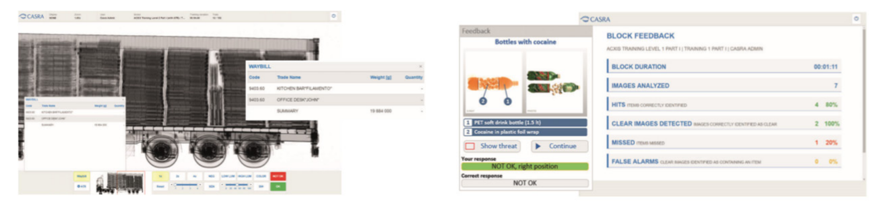

Figure 4: Customs X-Ray Simulator developed in the EU-funded ACXIS project

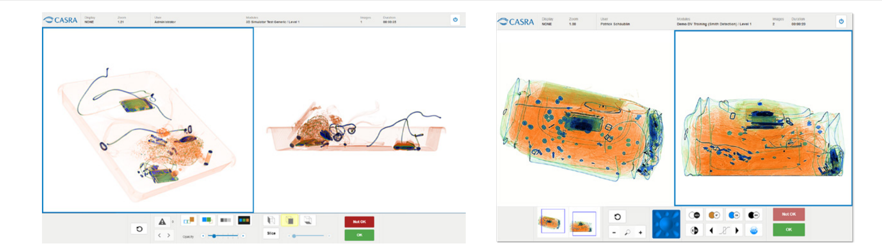

Figure 5: XRT4 user interface examples

SCIENTIFICALLY BASED TRAINING AND ASSESSMENT

Our research has shown that efficient and effective X-ray image interpretation depends on one's ability to deal with bag complexity, superposition and object view-point (image-based factors) and one's knowledge about which items are prohibited and what they look like in X-ray images (knowledge-based factors) (Figure 6) [2]. Due to our individually adaptive training algorithm, users of XRT4 are presented with images tailored to their individual knowledge and skills, taking into account learning progress and image-based factors. This makes training interesting, motivating, effective and efficient, leading to large improvements in detection performance (Figure 7) [14, 15].

For computer-based training, it is valuable that screeners using equipment with automated explosives detection capabilities can be trained accordingly. XRT4 supports the display of machine alarms (e.g. based on automated explosives detection) so that screeners can be trained under highly realistic conditions (Figure 8).

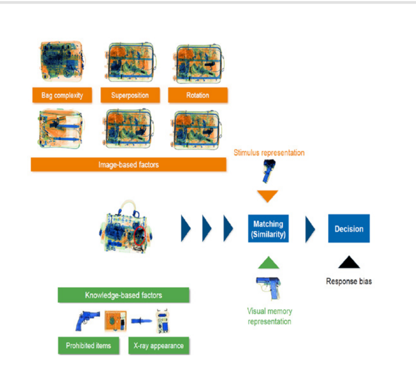

Figure 6: XRT4 leverages knowledge-based and image-based factors underlying the X-ray image interpretation task

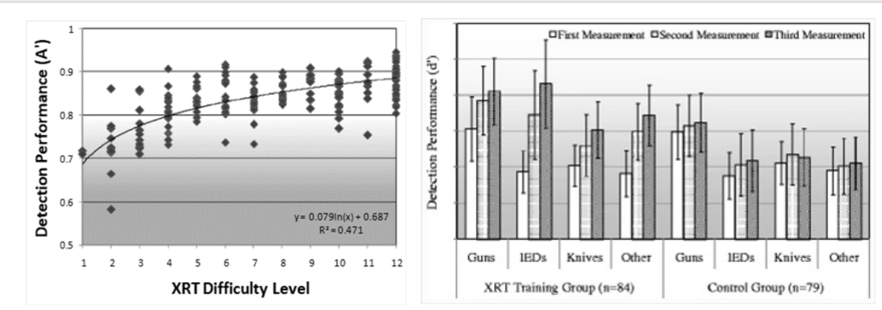

Figure 7: Improvements in detection performance over time (left) and in comparison with non-adaptive training (right)

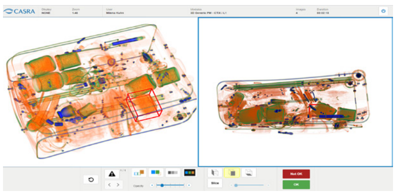

Figure 8: Simulated automated explosives detection alarm in XRT4

CASRA offers large libraries of prohibited articles that are continuously updated based on our Systematic Threat Assessment (Figure 9).

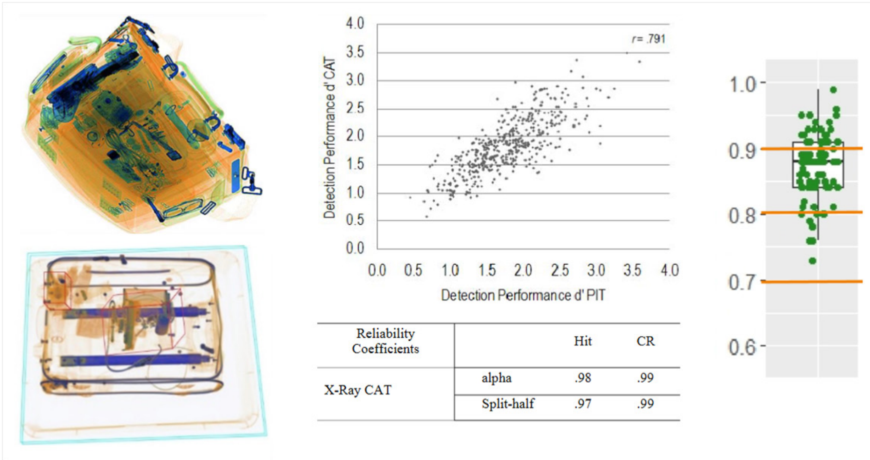

Figure 10: Proper test creation requires determining the task to be tested (e.g. searching threats vs resolving alarms, left), ensuring psychometric quality such as validity (center top) and reliability (center bottom) and pilot testing to define appropriate pass marks that make the test challenging but fair and standardize it (test results of screeners right)

Figure 9: A small part of the large XRT4 threat item library

Further, XRT4 uses representative threat categories and prohibited articles are shown in varying, realistic configurations in representative bags or containers.

Other key benefits of XRT4 are scientifically based pre-employment and competency assessment tests like the X-Ray ORT and X-Ray CAT [16-18]. It is essential that tests are fair, reliable (relating to "consistency" or "repeatability" of measurements), valid (measuring what they are intended to measure), and standardized (piloted with a representative group of participants to establish norms) (Figure 10).

STRONG TECHNICAL FEATURES

End-users can expect a pleasant and intuitive experience as XRT4 was designed with high user friendliness in mind by building upon regular customer and end-user feedback (Figure 11). The application is being further improved continuously, ensuring that the needs of customers are considered. Even trainees have the option of providing feedback while they train.

Leveraging a decade of experience of delivering web-based training, we built XRT4 with modern web technologies, allowing it to run on most platforms and browsers, such as Chrome, Firefox, etc. (Figure 12). No additional plugins are needed to run the software in a browser and local hosting options are available on request as well.

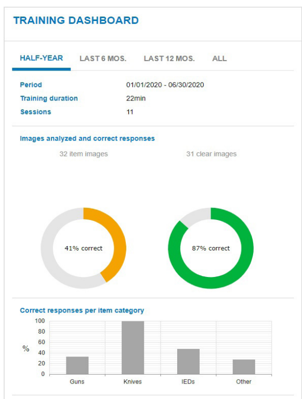

Figure 11: Home screen dashboard in XRT4

Customers get access to customizable reports through the web interface of XRT4, allowing easy learning progress and training content difficulty monitoring (Figure 13). The software also makes use of a state-of-the-art data warehouse, allowing the integration of training and assessment data in local clients' business intelligence systems.

XRT4 offers generic as well as manufacturer specific user interface selection for each training and assessment module (Figure 14). Training of operators in a simulated screening environment aims to increase confidence when using similar, real screening technology. However, flexibility when equipment changes or when different equipment is used by the same personnel is supported as well.

Depending on the chosen version (XRT4 and/or XRT4 Expert), customers can additionally upload and fully manage their own image content as well as training and assessment series (Figure 15). We thus support customers with highly varying demands towards the flexibility of the application and the way in which it is administrated and its content made available to screeners.

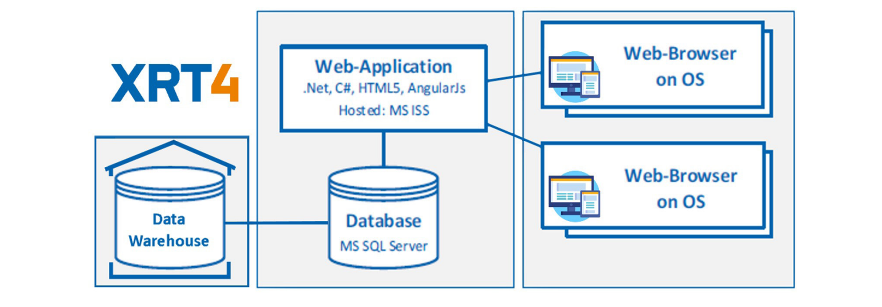

Figure 12: XRT4 as a modern, web-based application

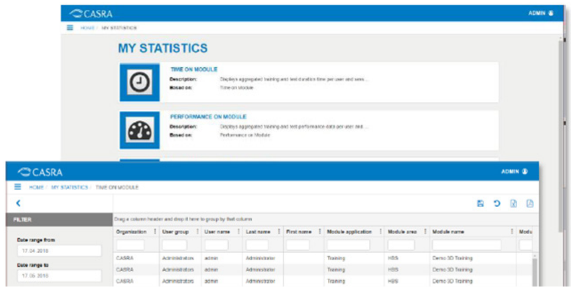

Figure 13: Integrated reporting functions in XRT4

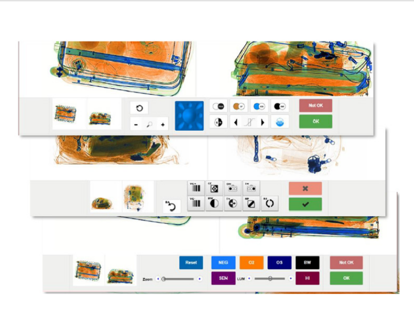

Figure 14: Examples of different user interfaces in XRT4

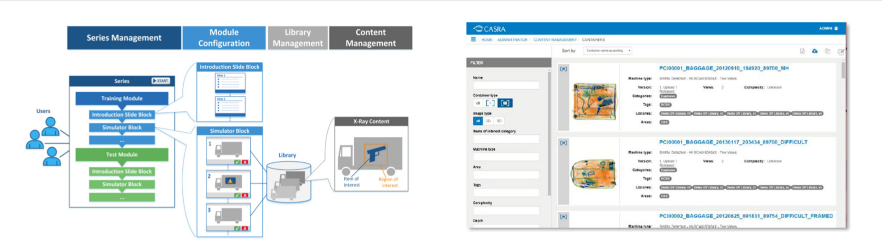

Figure 15: XRT4 Expert feature illustations

CONTINUOUS IMPROVEMENT IN END-USER PARTNERSHIPS

The Canadian Air Transport Authority is known worldwide for delivering a highly professional, effective and consistent level of security service. We have had a great collaboration with CATSA for 15 years [19, 20]. In 2018, we were awarded a multi-year contract by the Canadian Air Transport Security Authority (CATSA) through a competitive procurement process to provide XRT4 to all 89 Canadian airports.

Securitas Aviation, a global leader in security services, participated in beta testing of XRT4 as well as multiple studies with us. The implementation of XRT4 was tested with 300+ screeners in seven countries to evaluate its advantages and disadvantages. Securitas Aviation explains how XRT4 fulfills their needs in our CASRA_ Newsletter Issue 22: "an important aspect of training screeners is to familiarize them with as much threat articles as possible. The ability to train our screeners as close to reality as possible, e.g. having the same interface as the X-ray equipment on which they will be performing their task, is also a real added value. Whether it be for the screening of CBS, HBS, Supplies, Cargo, etc. with the use of single view, dual view or 3D CT equipment, the training software should be flexible enough to be able to provide training on these simulator types. Furthermore, having an excellent reporting system in the training software will allow us to analyze our screeners' data, closely monitor their performance and remain fully compliant with regulations. XRT4 does a great job at fulfilling all of these key functionalities we would expect from a training software" [21].

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Science & Security – CASRA Newsletter
ISSN 1664-5715

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