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CASRA NEWSLETTER – SPECIAL ISSUE 20

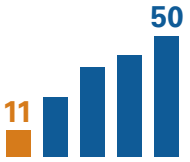
CASRA IS CELEBRATING ITS 10TH ANNIVERSARY

The Center for Adaptive Security Research and Applications (CASRA) originates from the Visual Cognitive Research Group (VICOREG) of the University of Zurich which was founded back in 1999.

CASRA itself was founded in 2008 and is celebrating its 10-year anniversary this year! Therefore, with this 20th edition of the CASRA Newsletter, we want to take you on a journey spotlighting how we have evolved in these challenging, interesting and successful years until today.

EMPLOYEES

CUSTOMERS



PROJECTS TO DATE

PUBLICATIONS TO DATE

FIELDS

APPLICATIONS

Our vision is to enable people and technology for a safe and secure world. The main objective of CASRA is to increase security and to facilitate the flow of goods and people at airports and other environments involving humans and technology. We pursue an interdisciplinary and holistic research approach by combining applied psychology, software engineering and data science. We deliver ever-improving state-of-the-art applications to our end-users to strengthen security, to increase operational efficiency and provide our knowledge to society through publications in scientific journals and contributing to conferences and working groups.

CASRA members are from the following organizations:

- University of Applied Sciences and Arts Northwestern Switzerland (FHNW), School of Applied Psychology, Institute Human in Complex Systems (MikS)
- Applied Psychological Science Solutions (APSS)

FOLLOWING THE TIMELINE FROM OUR ORIGIN DAYS TO THE PRESENT

Text: Diana Hardmeier, Milena Kuhn, Stefan Michel, Adrian Schwaninger

2000

IMAGE-BASED FACTORS

In the year 2000, first studies with screeners showed that the detection of prohibited articles in X-ray images is more difficult than one might think.

By analyzing the process of X-ray image interpretation together with screeners, we realized that having a high quality X-ray image is not enough for screeners to be able to detect prohibited articles effectively nor efficiently. Further to the necessary expertise on how prohibited articles look like, screeners must be able to cope with other factors such as rotation (a), superposition (b) of prohibited articles and bag complexity (c, see Figure 1). With our strong background in psychology, we identified a connection to general visual cognition abilities known as the ability to do mental rotation, figure ground segregation and visual search. Based on this and interviews with screeners, we developed the first X-ray image interpretation test (at that time using Adobe Photoshop) taking into account these image-based factors. Results of those early studies [1] confirmed that being able to cope with these factors is in fact extremely relevant for threat detection in X-ray images and success depends on the visual cognitive abilities, which screeners need to bring to the table from the very beginning.

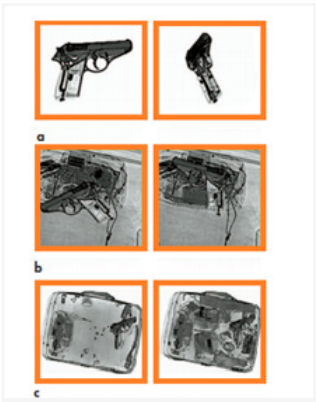


Figure 1: The three image-based factors rotation (a), superposition (b) and bag complexity (c)

As a result, the first pre-employment selection test (the X-Ray ORT, see "pre-employment") was developed in order to select job applicants based on their visual cognitive abilities.

2002

PRE-EMPLOYMENT

The first version of the X-Ray Object Recognition Test (X-Ray ORT) that measures a screener's ability to cope with rotation, superposition of prohibited articles and bag complexity was developed back in 2002. Eight guns and eight knives were placed in several bags varying bag complexity, the rotation difficulty and the superposition. After some revisions, we had a test that reliably measured screeners' ability with proven reliability and validity as shown in scientific studies [1, 2, 3].

The X-Ray ORT is still in use worldwide for screener pre-employment assessment and in research studies today. Early on, the effectiveness of the test was shown in practice, since screeners who were selected with the test were in average 20% better in later competency assessments (A') than those who were not selected with the test [3].

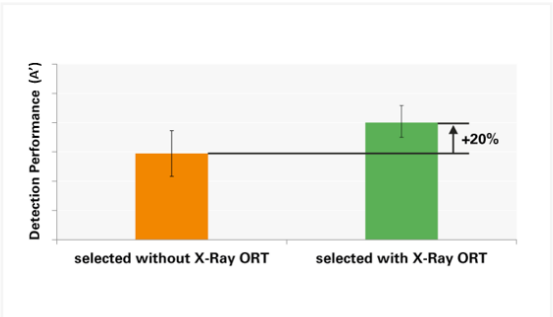


Figure 2: Effectiveness of applying the X-Ray ORT as a pre-employment tool

2002

COMPETENCY AND CERTIFICATION TEST

Not only ability, but also visual knowledge is key for the detection of prohibited articles in X-ray images. In order to measure visual knowledge, we developed the first competency assessment test, called Prohibited Items Test (PIT) in 2002. At that time, the test included seven categories of prohibited articles: guns, sharp objects, blunt and hunt instruments, highly inflammable substances, explosives, chemicals and other prohibited articles. After having shown that the reliability and validity of the test meets test psychological requirements, the test was used for competency assessment in research projects and later for certification purposes.

In 2006, we developed a new version of the test called X-Ray Competency Assessment Test (X-Ray CAT) and kept on doing so every second year since then [4].

Figure 3: Prohibited Items Test (PIT)

2006

COMPUTER-BASED TRAINING RESEARCH

Around 20 years ago, airport security screeners reported to have difficulties detecting improvised explosive devices (IEDs) in X-ray images, simply because they - fortunately enough - were not confronted with that kind of threat during their everyday work. Obviously, screeners could not be expected to recognize prohibited articles of which they did not have a visual representation in memory.

The necessity to train screeners was recognized early on, hence a computer-based training (CBT) called X-Ray Tutor was developed [5]. It was important to us, that X-Ray Tutor not only contained high quality images and relevant prohibited articles, but also took into consideration important learning principles such as immediate and comprehensive feedback, individually adaptive image presentation and level- and progress concepts [6].

In order to determine how the best performance in threat detection can be achieved with CBT, applied research studies were conducted in the following years [7, 8, 9]. Training with X-Ray Tutor resulted in large increases of detection performance, in particular for detecting IEDs (Figure 4). Further studies have shown that X-Ray Tutor is a very effective and efficient tool for increasing and maintaining detection performance of screeners [10, 11].

To this day, training is still one of the most important instruments to increase and maintain X-ray image interpretation competency.

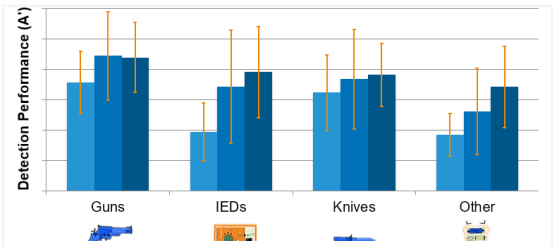


Figure 4: Improvement of the detection performance (A') of different threat categories after CBT

X-RAY TUTOR

2008

The history and great success of X-Ray Tutor shows the importance of applying scientific knowledge on visual information processing and object recognition for effective and efficient training of X-ray image interpretation. The first version of X-Ray Tutor was developed using the simple programming language Microsoft Visual Basic and C++. It was far less sophisticated than the current version: prohibited articles, for example, were merged by hand into passenger bags and only a few thousand images were available. Nevertheless, due to its effectiveness, this first training version was installed at all airports in the USA and at several airports in Switzerland and Germany. Thanks to these projects, the individually adaptive merging algorithm was developed, with which it was possible to merge prohibited articles automatically into passenger bags based on screeners' performance. The merging algorithm helped to avoid that screeners learned the threat-to-bag combinations by heart and allowed to create millions of harmful bags for training on the fly.

By 2008, the new version of X-ray Tutor (XRT2) was operational at many airports worldwide featuring higher image quality, more sophisticated training algorithms and other functionalities. Figure 5 shows the interface of XRT2. Soon after, our first customers used our online accessible hosted solution. Since 2011, we have regularly conducted usability studies in order to measure and increase the usability and user experience with our system.

In the last 10 years, X-Ray Tutor image libraries have continuously been developed to meet the needs of other industries such as mail, prison, critical infrastructure, customs, and prison screening.

Today, we are finalizing our newest version of X-Ray Tutor (XRT4) featuring not only single-view, but also dual-view and 3D technology (see also section "XRT4"). Regardless of the software version, our scientific approach and basic principles to train screeners effectively and efficiently, adapted to their individual performance in order to detect a large amount of prohibited articles within short time remained over all the years.

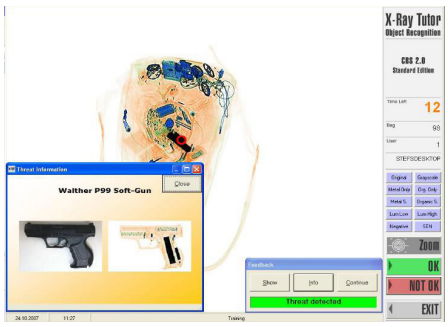


Figure 5: Interface of X-Ray Tutor Version 2.0 (XRT2)

SYSTEMATIC THREAT ASSESSMENT

2012

The Systematic Threat Assessment (STA) started in 2012 and has been an essential part of several long-term research projects of CASRA co-funded by the Swiss Federal Office of Civil Aviation (FOCA).

The main scope of the STA is to collect and analyze data from various sources (e.g. social media, deep web, propaganda), searching for possible new threat scenarios against the civil aviation, to assess the scenarios and to derive countermeasures as shown in Figure 6. The aim of this approach is to keep screeners up-to-date, informed and trained regarding new and emerging threats.

Over the years, we were faced with an incredible increase of data that needs to be evaluated. Therefore, the STA evolved from manually collecting and classifying data to a more and more automated, systematic process, including the effort of developing machine-learning algorithms.

Figure 6: Systematic Threat Assessment

HUMAN-MACHINE INTERACTION AND TECHNOLOGY DEVELOPMENT

Performance in X-ray screening depends on humans, machines and their interaction. Over the years, X-ray technology has further developed and today a variety of viewing systems (e.g. multi-view or 3D) and automatic detection algorithms (e.g. explosive detection) are available. In 2008, we conducted the first study on multi-view X-ray systems for cabin baggage screening [12]. These systems show X-ray images from two different viewpoints, which helps screeners detect prohibited articles when they are rotated or superimposed by other items. For example, the knife in Figure 7 is easier to detect when the bag is also shown from a different perspective. With a multi-view X-ray system, a knife is easier to detect because the bag is shown from a different perspective (Figure 7b).

In more recent studies [13,14], we started to investigate how human-machine interaction can be improved to increase the detection of explosives in cabin baggage by using multi-view explosive detection systems, and how 3D imaging can further improve human-machine system performance.

New technology brings advantages but also new challenges for the screeners operating the X-ray machines, thus we at CASRA are continuously interested in studying, understanding and improving the interaction between the two.

2014

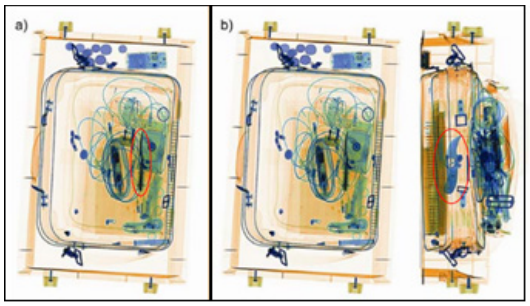


Figure 7: Single-view (a) vs. multi-view (b)

SOCIO-TECHNICAL SYSTEMS

2014

Security checkpoints can be regarded as socio-technical systems in which humans and machines interact with each other. In 2014, we started using qualitative and quantitative methods to analyze airport security checkpoints in a holistic way [15]. With 3D computer simulations and big data, we started to investigate how effectiveness, efficiency and passenger experience can be improved in security screening [16]. Figure 8 shows the most recent model which we use to examine how security effectiveness and efficiency can be increased by using unpredictability measures and risk-based screening.

Figure 8: 3D Simulation of airport security checkpoints

XRT4

The upcoming X-Ray Tutor 4 (XRT4) is going to be the newest installment of CASRA's training platform. For the first time in the history of the software application, it does not only support X-ray screeners with single-view but also with dual-view and 3D CT training courses. In addition, XRT4 offers both machine-agnostic and machine-specific user interfaces. As in previous installments, XRT4's concept and behavior is strongly influenced by scientific research studies and cooperation with end-users. Moreover, our large image libraries for different screening applications are continuously updated by considering new and emerging threats as well as end-user requirements. State-of-the-art web technologies ensure that XRT4 runs on almost any platform and allows for unprecedented connectivity between locations.

Figure 9: XRT4 will include training and testing modules for multi-view and 3D

OUTLOOK

CASRA will stay true to its vision of enabling people and technology for a safe and secure world. We will conduct applied, interdisciplinary and holistic research to answer relevant and/or research questions in the areas of human factors, human-machine interaction and systems as well as cognitive and computational modelling. We will further broaden and develop key projects such as the systematic threat assessment and dive deeper into system simulations, data science and big data. Finally, XRT4 will soon be available for practitioners and end-users from various industries, supporting screeners to effectively and efficiently train their skills and detection performance with a state-of-the-art software solution.

We hope you enjoyed this special installment of the CASRA Newsletter and are looking forward to have you with us for many years to come.

REFERENCES

[1] Schwaninger, A., Hardmeier, D., & Hofer, F. (2004). Measuring visual abilities and visual knowledge of aviation security screeners. *IEEE ICCST Proceedings*, 38, 258-264. [PDF]

[2] Hardmeier, D., Hofer, F., & Schwaninger, A. (2005). The x-ray object recognition test (x-ray ort) – a reliable and valid instrument for measuring visual abilities needed in x-ray screening. *IEEE ICCST Proceedings*, 39, 189-192. [PDF]

[3] Hardmeier, D., Hofer, F., & Schwaninger, A. (2006). 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. [PDF]

[4] Koller, S., & Schwaninger, A. (2006). Assessing X-ray image interpretation competency of airport security screeners. *Proceedings of the 2nd International Conference on Research in Air Transportation, ICRAT 2006, Belgrade, Serbia and Montenegro, June 24-28, 2006*, 399-402. [PDF]

[5] Schwaninger, A. (2003c). Training of airport security screeners. AIRPORT, 2003(5), 11-13. [PDF]

[6] Schwaninger, A. (2004b). Computer based training: the enhancement of human factors. Aviation Security International, 2004(2), 31-36. [PDF]

[7] 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. doi:10.13140/RG.2.1.2216.8567 [PDF]

[8] Michel, S., de Ruiter, J., Hogervorst, M., Koller, S., Moerland, R., & Schwaninger, A. (2007). Computer-based training increases efficiency in x-ray image interpretation by aviation security screeners. Proceedings of the 41st Carnahan Con-ference on Security Technology, Ottawa, October 8-11, 2007. [PDF]

[9] Schwaninger, A., Hofer, F., & Wetter, O. (2007). Adaptive computer-based training increases on the job performance of x-ray screeners. *Proceedings of the 41st Carnahan Conference on Security Technology, Ottawa, October 8-11*, 2007. [PDF]

[10] Halbherr, T., Schwaninger, A., Budgell, G.R., & Wales, A. (2013). Airport security screener competency: a cross-sectional and longitudinal analysis. International Journal of Aviation Psychology, 23(2), 113-129. doi:10.1080/10508414.2011.582455 [PDF]

[11] Koller, S.M., Drury, C.G., & Schwaninger, A. (2009). Change of search time and non-search time in X-ray baggage screening due to training. Ergonomics, 52(6), 644-656. doi:10.1080/00140130802526935 [PDF]

[12] von Bastian, C., Schwaninger, A., & Michel, S. (2008). Do multi-view X-ray systems improve X-ray image interpretation in airport security screening? *Zeitschrift für Arbeitswissenschaft, 3*, 166-173. [PDF]

[13] Hättenschwiler, N., Mendes, M., & Schwaninger, A. (2018). Detecting Bombs in X-Ray Images of Hold Baggage: 2D Versus 3D Imaging. *Human Factors*, doi:10.1177/0018720818799215 [PDF]

[14] Hättenschwiler, N., Sterchi, Y., Mendes, M., & Schwaninger, A. (2018). Automation in airport security X-ray screening of cabin baggage: Examining benefits and possible implementations of automated explosives detection. *Applied Ergonomics, 72*, 58-68. [PDF]

[15] Michel, S., Hättenschwiler, N., Kuhn, M., Strebel, N., & Schwaninger, A. (2014). A multi-method approach towards identifying situational factors and their relevance for x-ray screening. Proceedings of the 48th IEEE International Car-nahan Conference on Security Technology, Rome Italy, October 13-16, 2014, 208-213. doi:10.1109/CCST.2014.6987001 [PDF]

[16] Sterchi, Y., & Schwaninger, A. (2015). A first simulation on optimizing EDS for cabin baggage screening regarding throughput. Proceedings of the 49th IEEE International Carnahan Conference on Security Technology, Taipei Taiwan, September 21-24, 2015, 55-60. doi:10.1109/CCST.2015.7389657 [PDF]

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