International Journal of Industrial Ergonomics 44 (2014) 551–560

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

Increasing X-ray image interpretation competency of cargo security screeners

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ARTICLE INFO

Article history:
Received 23 August 2012
Received in revised form
10 October 2013
Accepted 31 March 2014
Available online 15 June 2014

Keywords:
Airport security
Cargo security screening
X-ray screening
Human factors
Object recognition
Detection performance

ABSTRACT

X-ray screening of containers and unit load devices in the area of cargo shipping is becoming an essential and common feature at ports and airports all over the world. The detection of prohibited items in X-ray images is a challenging task for screening officers as they need to know which items are prohibited and what they look like in X-ray images. The main aim of this study was to investigate whether X-ray image interpretation competency of cargo security screeners can be increased by computer-based training. More specifically, effects of training were investigated by conducting tests before training started and after approximately three months of training. Moreover, it was examined whether viewing X-ray images in pseudo color would lead to a better detection performance compared to when X-ray images are shown in greyscale. Recurrent computer-based training resulted in large performance increases after three months. No significant difference in detection performance could be found for tests when using X-ray images in greyscale vs. pseudo color.

Relevance to industry: Cargo X-ray screening is becoming a common feature at ports and airports. The identification and detection of prohibited items in X-ray images highly depends on human operators and their competences regarding X-ray image interpretation. Thus, research on appropriate training methods and enhancements of the human factor are essential to achieve and maintain high levels of security.

1. Introduction

In the last decade, airport security has been substantially enhanced in the areas of passenger, cabin baggage and hold baggage screening. However, air cargo, whether transported on passenger planes or commercial cargo aircrafts, has not yet received a similar level of attention. Nevertheless, the explosion of a cargo plane could highly impact the world's economy, commerce or the global supply chain. At least since 2010 it is clear that cargo is an attractive target for terrorists (TIME, 2010). Consequently, X-ray cargo screening for the inspection of unit load devices (ULDs) and containers is emerging quickly and becoming a common feature at ports and airports. A big advantage of X-ray screening is that images of the contents of a ULD or container can be created quickly, without causing any physical changes within the containers. Concerning X-ray screening technology, remarkable improvements have been achieved over the last decades. For the field of cargo X-ray screening, modern X-ray inspection systems especially tailored to the examination of containers, trucks and rail cars exist, which produce images similar to those obtained through traditional X-ray baggage screening machines at airports (e.g., Reed, 2008, 2009).

Despite the advances in technology, the actual decision whether an X-ray image of a container or ULD contains a prohibited item or not still needs to be taken by a human operator, i.e. a cargo security screener. Cargo X-ray screening, in particular, must be considered an extremely challenging task. The large sizes of containers make it very difficult for the cargo security screeners to detect the proportionally small threat items (e.g. an improvised explosive device (IED)) and contraband goods. Moreover, it could be assumed that perpetrators would intentionally disguise or hide their materials or decompose contraband into component parts distributing it within the container. Still, screening officers are expected to assess the

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http://dx.doi.org/10.1016/j.ergon.2014.03.007
0169-8141/

contents of large containers or ULDs within a few minutes only. Therefore, it is essential to consider human factors in security screening and design systems to support the decision-making of human operators (e.g., Harris, 2002; Kraemer et al., 2009). Selection and training of screening personnel is a highly relevant factor for improving man-machine system performance. The most sophisticated machines become worthless if the people who operate them and visually inspect the X-ray images are not qualified to do so (Al-Fandi et al., 2009; Hardmeier et al., 2005; Schwaninger et al., 2005).

Research on X-ray security screening of passenger baggage at airports has shown that performance of human operators (i.e. airport security screeners) is determined by several factors (e.g., Michel and Schwaninger, 2009; Schwaninger, 2006). First of all, not every person has the potential to become a good screening officer, as certain aptitudes and abilities are required for this task (Hardmeier et al., 2005; Hardmeier and Schwaninger, 2008; Schwaninger et al., 2005). For that reason it is advisable to apply scientifically proven selection tests, such as the X-Ray Object Recognition Test (X-Ray ORT), as part of pre-employment assessment procedures, so that right from the beginning only people well suited for the screening job are chosen for this task (Hardmeier et al., 2005; Schwaninger et al., 2005). Furthermore, in order to detect prohibited items reliably, a screening officer must know which items are prohibited and what they look like in X-ray images. Many prohibited items are rarely seen in everyday life and might look quite different from reality when displayed as an X-ray image (e.g. IEDs). According to object recognition theories and visual cognition, object shapes not similar to the ones stored in visual memory are difficult to recognize (Graf et al., 2002; Schwaninger, 2004a, 2004b). Schwaninger et al. (2005) found that the detection of prohibited items is dependent on knowledge-based and image-based factors. Knowledge-based factors refer to knowledge required for the detection of prohibited items, i.e. knowledge on which items are allowed vs. prohibited, what objects look like in reality, and what they look like in X-ray images of passenger bags or containers. This underlines the importance of class-room, computer-based (CBT) and on-the-job training. Image-based factors relate to the difficulty of inspecting an X-ray image. According to Schwaninger (2003) and Schwaninger et al. (2005) three image-based factors are relevant in X-ray screening: viewpoint of an object, superposition of an object by other objects and the complexity of a bag/container. Depending on perceptual experience and the ability to mentally rotate objects, rotated items are more difficult to recognize (effect of viewpoint). Moreover, when prohibited objects are superimposed by other objects (effect of superposition), or when bags are closely-packed and contain many items which could attract attention (effect of complexity), the identification of prohibited items becomes more challenging. Results of different studies could show that coping with image difficulty resulting from these factors can be improved through training (e.g., Hardmeier et al., 2006b; Koller et al., 2008). Yet, a person's learning process is greatly dependent on visual abilities and cannot merely be attributed to training (Hardmeier et al., 2006b). Regarding knowledge-based and image-based factors, individually adaptive computer-based training (CBT), e.g. with X-Ray Tutor (XRT), is considered to be a very powerful tool for achieving and maintaining a good X-ray image interpretation competency in cabin baggage and hold baggage screening (Halbherr et al., 2013; Hardmeier et al., 2006b; Koller et al., 2008; Schwaninger and Hofer, 2004). For one thing, it allows exposing screening officers to objects they usually do not encounter in everyday life (e.g., IEDs) and for another thing, screeners get trained to identify all sorts of objects in different views (rotations), when superimposed by other objects and in bags (containers) of different complexities.

Considering the objective of increasing container security at ports and airports by improving X-ray screening, the aim of this project was to find out whether the screening officers' performances in detecting prohibited items in cargo X-ray images can be enhanced through implementing recurrent CBT. Moreover, another essential aspect concerning screening performance is the speed at which an operator performs bag/container searches while maintaining an optimal performance level. Results of previous studies with XRT revealed that training not only increased detection performance of screening officers but also reduced reaction time (Koller et al., 2009; Michel et al., 2007b; Schwaninger and Hofer, 2004; Schwaninger and Wales, 2009; Wales et al., 2009). This is relevant for (cargo) X-ray screening applications where throughput matters.

State-of-the art X-ray screening machines, especially for cabin and hold baggage screening, are able to produce high quality and material coded colored images. Additionally, they offer a variety of so called "image-enhancement functions" (IEFs) such as color inversion, edge-enhancement, organic only, metal only etc. (for illustrations, see e.g. Michel et al., 2007a). IEFs are applied to bring out detail which is obscured or to highlight certain features (e.g., organic content). However, previous studies (Klock, 2005; Michel, Koller et al., 2007) investigating the usefulness of IEFs for cabin baggage (CBS) and hold baggage screening (HBS) have casted doubt on whether IEFs are useful. Results varied for the different threat types (guns, knives, IEDs and other threat items). The findings of these studies highlight the importance of systematically investigating the usefulness of IEFs in order to optimize human–machine interaction. In order to obtain colored X-ray images, dual energy technology (high and low energy beams) is required (for more details see Fainberg, 1992; Ogorodnikov and Petruin, 2002). For cargo X-ray screening machines, the application of dual energy technology is still difficult and of high costs. In this study, images were recorded with single energy technology, providing greyscale images. As humans can only discern a few dozen grey level values while they can distinguish thousands of colors (Gonzales and Woods, 2002), it could be assumed that the application of color would help to better distinguish between objects. Moreover, color adds vivacity to images und can thus decrease boredom or fatigue and increase attention (Abidi et al., 2005). Color coding could therefore significantly improve detection performance in X-ray screening. In our study, we investigated if showing the original greyscale image in pseudo colors could improve the detection of prohibited items in cargo X-ray images, and, if so, for which kind of items or images this application was of particular help.

Previous studies focusing on cabin baggage screening have proven the effectiveness of CBT in increasing X-ray image interpretation of screening officers (Halbherr et al., 2013; Koller et al., 2008; Michel et al., 2007b; Schwaninger, 2004b; Schwaninger et al., 2008, 2007; Schwaninger and Wales, 2009). Recurrent CBT is considered to be an indispensable prerequisite for achieving and maintaining good operational performance at security checkpoints. For all airports within the EU, recurrent training consisting of image recognition training and testing either in the form of classroom or computer-based training is obligatory for all persons operating X-ray equipment (European Commission, 2010). For this study, a new CBT system for the area of cargo X-ray screening was created (Cargo-XRT) and tested with cargo security screening officers at an international European airport. The main aim of this study was to investigate if X-ray image interpretation competency of cargo security screeners could be increased by introducing CBT with the C-XRT. Moreover, it was examined whether detection performance is better when pseudo colored images are displayed compared to when the original greyscale images are shown. Further analyses were conducted in order to find out which type of threat items