Full-Length Report

Use It and Still Lose It?

The Influence of Age and Job Experience on Detection Performance in X-Ray Screening

Adrian Schwaninger1,2, Diana Hardmeier2, Judith Riegel1nig2, and Mike Martin2

1School of Applied Psychology, University of Applied Sciences Northwestern Switzerland (FHNW), Olten, Switzerland, 2Department of Psychology, University of Zurich, Switzerland

Abstract. In recent years, research on cognitive aging increasingly has focused on the cognitive development across middle adulthood. However, little is still known about the long-term effects of intensive job-specific training of fluid intellectual abilities. In this study we examined the effects of age- and job-specific practice of cognitive abilities on detection performance in airport security x-ray screening. In Experiment 1 (N = 308; 24–65 years), we examined performance in the X-ray Object Recognition Test (ORT), a speeded visual object recognition task in which participants have to find dangerous items in x-ray images of passenger bags; and in Experiment 2 (N = 155; 20–61 years) in an on-the-job object recognition test frequently used in baggage screening. Results from both experiments show high performance in older adults and significant negative age correlations that cannot be overcome by more years of job-specific experience. We discuss the implications of our findings for theories of lifespan cognitive development and training concepts.

Keywords: age, working experience, cognitive functions, x-ray screening, detection performance, object recognition

In recent years, cognitive aging research has increasingly focused on the effects of midlife development on developmental changes in old age. One possible reason for the renewed interest are emerging longitudinal results from representative population samples. These data suggested cognitive performance to be differentially variable and to show little covariation between changes across domains of cognitive functioning (Martin & Zimprich, 2005). However, whereas changes in experience-related knowledge seem to be small across middle age, fluid abilities demonstrate average declines from the ages of 30 onward (e.g., Schaie, 2005). The latter might be due to the variability in job-induced stimulation of fluid abilities across individuals within representative population samples and the typically low experimental control over job-related cognitive stimulation in representative samples. Therefore, we examined the effects of job-related stimulation of fluid abilities in aviation security screening.

X-ray screening of passenger bags is a highly demanding cognitive task that requires both experience-related knowledge and fluid abilities. Schwaninger, Hardmeier, and Hofer (2005) defined knowledge-based and image-based factors to be important in the x-ray screening task. Screeners need to know which items are prohibited and what they look like in x-ray images. Such knowledge-based factors are related to the memory component of visual object recognition and depend strongly on training (Koller, Drury, & Schwaninger, 2009; Koller, Hardmeier, Michel, & Schwaninger, 2008; Schwaninger & Hofer, 2004). Image-based factors include the effects of superposition and viewpoint of the dangerous item, as well as bag complexity (Schwaninger et al., 2005; see Figure 1). Objects are more difficult to recognize when superimposed by other objects (effect of superposition) or when depicted from a difficult viewpoint (effect of viewpoint). Furthermore, it is more difficult to detect a dangerous item in a close-packed bag because other objects in the bag may distract one’s attention (effect of bag complexity). These factors are related to abilities of visual and spatial cognition (Hardmeier & Schwaninger, 2008). Thus, processes such as visual search, spatial imagination, working memory, attention, and perception – all of which are associated with age-related decline – should be important determinants in x-ray screening performance, and older adults should naturally show lower performance than younger adults.

Previous findings on visual search and aging showed that, as the number of distractors increases, older people perform slower and less accurately than do younger ones when locating targets (Humphrey & Kramer, 1997; Kramer & Atchley, 2000). In addition, older adults make more eye movements and tend to fixate areas for a longer time (Scialfa, Thomas, & Joffe, 1994). The influence of aging on spatial imagination or mental rotation tasks were investigated in many studies (e.g.,
require sustained attention across time. Results concerning the relationship between aging and sustained attention are inconsistent (for an overview, see Roger & Fisk, 2001). Deaton and Parasuraman (1993) found lower performance for vigilance tasks with a cognitive component, such as identification or decision about an item. There is also evidence that aging has a negative influence on perception as age-related changes of eye structures lead to a decrease in the perceived sharpness and brightness of visual stimuli (Cabeza, 2001). Furthermore, deficits in color sensitivity due to the loss of photoreceptors have been reported (Fozard & Gordon-Salant, 2001).

Although aging seems to be negatively related to cognitive performance, there is some evidence that older adults might be able to compensate for their cognitive deficits by using their working experience to adopt more efficient strategies (Zec, 1995). In addition, one may assume that extensive practice with a task, as is the case with experienced screeners who have trained the task on the job over many years, should improve performance in all age groups (e.g., Kliegl, Smith, & Baltes, 1989).

In this study, we examined the effects of job-related stimulation of fluid abilities in airport security screeners exposed to extensive amounts of speeded visual search and detection tasks. This was designed to answer four questions: First, are critical levels of detection performance achieved across an age range from 20–65 years of age? We expected that, despite potential age effects, all age groups reach a high and critical level of performance. Second, do age-related differences in job-specific fluid performance exist when persons are practiced in that ability and may use any strategy available in the workplace to maximize their performance? Based on findings of age-related declines in fluid abilities across middle age, age differences in screening performance were expected. However, if on-the-job practice of the required skills do compensate for these declines, then no age effects were expected. Third, do older workers profit more from job experience than younger workers? Practicing screening skills may be more important for screening performance in old versus young age, because of the importance of practice to overcome deficits in underlying abilities that peak at younger ages. Fourth, one may argue that, in reality, dangerous items occur rather seldom, and that therefore larger amounts of the practical experience of the older screener go unused. Therefore, it was investigated whether age effects differ depending on the task demands, i.e., when a frequent decision about the threat potential of an item versus the rare detection of a threat event are required.

**Experiment 1**

Experiment 1 examined whether the fluid abilities needed in x-ray screening tasks decline across an age range from 20 to 65 years, and whether the detection performance of experienced aviation security screeners lies at a higher lev-
el than the performance of novices. The influence of age on detection performance in an x-ray screening test as a speeded visual search and detection task was investigated. Additionally, we used a partial correlation test to examine whether experience and practice might compensate a negative effect of aging and whether detection performance increases with more working experience.

Method

Participants

In Experiment 1, a total of 308 cabin baggage screening (CBS) officers between 24 and 65 years of age ($M = 50.28$, $SD = 9.43$) working more than an average of 12 h per week for at least 2.6 years ($M = 10.38$, $SD = 5.56$) participated in this study. All screeners worked at the same European airport.

Materials and Procedure

For Experiment 1, a computer-based x-ray screening test, the X-Ray ORT, was used (Hardmeier, Hofer, & Schwaninger, 2005). The test was conducted in a well-lit computer room with 10 Windows XP computers using the PCQuest software. The x-ray images were presented at full-screen size at a resolution of 1024 × 768 pixels on a 17-inch TFT monitor. Brightness and contrast settings on each screen were set to default values.

The X-Ray ORT requires subjects to recognize guns and knives in passenger bags. It starts with a self-explanatory instruction including some exercise trials to familiarize the participants with the test-taking procedure. After each image, which is displayed for 4 s on the screen, screeners have to decide whether the bag is OK (no gun or knife in it) or NOT OK (a gun or knife in it). In addition, they have to indicate how sure they are in their decision clicking on a slider control. The test takes about 45 minutes to complete. By systematically varying bag complexity, superposition, and the rotation of the prohibited item, the X-Ray ORT measures visual abilities needed to cope with image-based factors in x-ray screening. Eight guns and eight knives are twice displayed in an easy and rotated view in bags with low and high complexity level. All prohibited items are shown with little and with high superposition (for details, see Hardmeier et al., 2005; Schwaninger et al., 2005). The test includes a total of 256 x-ray images in grayscale, half of them contain either a gun or a knife, and the other 128 images are harmless bags. The test is subdivided into four blocks, the order of blocks is counterbalanced across participants, and the order of trials within a block is random. Reliability and validity measures of the X-Ray ORT were calculated based on 453 screeners (Cronbach’s $\alpha$ measures > .89 and split-half reliabilities > .78). Criterion-related validity was calculated correlating test results in the X-Ray ORT with Threat Image Projection (TIP) data. TIP data allows to measure on-the-job performance by displaying fictional prohibited items into real passenger bags (for more information about TIP see Experiment 2). The correlation of $r = .51$, $p < .01$ suggests that image-based factors measured by the X-Ray ORT are indeed important determinants of on-the-job performance in x-ray screening measured using TIP. For more details on reliability and validity see Hardmeier et al. (2005).

Results and Discussion

Detection performance in the X-Ray ORT was calculated using the detection performance measure $d'$ (Green & Swets, 1966). According to signal detection theory there are four possible outcomes depending on the presence of a dangerous item and the decision of the screener (see Figure 2). Judging a containing a prohibited item as NOT OK results in a hit, whereas judging a harmless bag as NOT OK results in a false alarm. Furthermore, judging a bag containing a prohibited item as OK counts as a miss, and judging a harmless bag as OK results in a correct rejection. Hence, a good screener would detect nearly all prohibited items in passenger bags (high hit rate) and hardly ever send harmless bags to be hand-searched (low false alarm rate). $d'$ is calculated by the formula $z(\text{hit}) - z(\text{false alarm})$, where $z$ refers to the $z$-transform. Furthermore, the detection performance measure $d'$ is independent of the criterion. That is, if screeners are more anxious to miss an object, they judge more bags as NOT OK, so that both the hit and false alarm rates increase.

An outlier analysis was performed, and values from 17 screeners higher or lower than two standard deviations from the mean were excluded. To make sure that critical levels of detection performance were achieved across an age range from 20–65 years of age, we compared detection performance between experts and novices (see Figure 3). Novices were 284 job applicants between 19 and 56 years ($M = 38.61$, $SD = 10.14$) who took the X-Ray ORT within the preemployment assessment procedure. An analysis of variance (ANOVA) revealed a significant difference between these two groups $\eta^2 = .28$, $F(1, 590) = 230.24$, $p < .01$. The influence of age on detection performance in an x-ray screening test as a speeded visual search and detection task was investigated. Additionally, we used a partial correlation test to examine whether experience and practice might compensate a negative effect of aging and whether detection performance increases with more working experience.

### Figure 2

Four possible answers when judging an x-ray image.

<table>
<thead>
<tr>
<th>Decision bag NOT OK</th>
<th>Bag contains a prohibited item</th>
<th>Bag contains no prohibited item</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIT</td>
<td>Correct Rejection</td>
<td></td>
</tr>
<tr>
<td>Miss</td>
<td>False Alarm</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Decision bag OK</th>
<th>Bag contains a prohibited item</th>
<th>Bag contains no prohibited item</th>
</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>

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This result is consistent with previous findings showing that detection performance of aviation security screeners in the X-Ray ORT lies at a higher level than those of novices (Schwaninger et al., 2005).

Figure 4 shows the correlation between detection performance and age in years. As expected, a partial correlation between detection performance and age of screeners with years of employment as control variable showed a significant negative correlation between age and X-Ray ORT performance ($pr = -0.27, p < .01$). These results provide evidence that age-related differences in job-specific fluid performance exist even when persons are practiced in that ability and may use any strategy available to maximize their performance. Thus, on average, in the x-ray screening test, older screeners had a lower detection performance than younger ones, which can most probably be best explained by age-related declines in visual and cognitive functions. A partial correlation between $d'$ in the X-Ray ORT and years of employment with age as control variable was also calculated. The result of $pr = -0.04, p = .48$ indicates that age-related changes in detection performance in the X-Ray ORT cannot be overcome by increases of on-the-job experience.

Experiment 2

In Experiment 1, there was a correlation of age on detection performance in the X-Ray ORT. However, the ORT may be considered untypical for actual job experience, which normally entails fewer occurrences of actual prohibited items. Therefore, Experiment 2, carried out with another sample of screeners, examined whether similar effects are found when using an on-the-job measure of x-ray detection performance. Furthermore, it was investigated whether age effects differ depending on the task demands, i.e., a frequent decision about the threat potential of an item versus the rare detection of a threat event. To this end, we used Threat Image Projection (TIP) data. As explained above, TIP is a technology from current x-ray equipment which allows the projection of fictitious x-ray images of prohibited items into x-ray images of real passenger bags (usually every 30–100 bags). TIP data thus provide a valid measure of on-the-job performance in x-ray screening.

Method

Participants

In Experiment 2 data were obtained from a different European airport. 155 CBS screeners between 20 and 61 years ($M = 37.92, SD = 10.34$) took the X-Ray ORT, and on-the-job detection performance was measured using TIP data. Screeners were working a minimum of 12 h per week for at least 1.61 years ($M = 5.98, SD = 3.60$) and were comparable in job-related knowledge. Again, an outlier analysis was calculated, and all values higher or lower than two standard deviations from the mean were excluded. Thus, five screeners were excluded for the X-Ray ORT and 11 for the TIP data analysis.

Materials and Procedure

All aviation security screeners took the X-Ray ORT in a well-lit computer classroom. The x-ray screening test was run on Windows XP computers using the PCQuest software. All x-ray images were presented at full-screen size at a resolution of 1024 x 768 pixels on a 17-inch TFT monitor. Brightness and contrast settings on each screen were set to default values.

In addition, TIP data were evaluated. For CBS screeners, the TIP system projects fictitious dangerous items into x-
ray images of real passenger bags in random order (1–3% of all bags). After each TIP image screeners receive a feedback message that a fictitious prohibited item was present so that no negative impact on screening operations occurs. A TIP image library based on FAA specifications (Federal Aviation Administration, USA), which is available on current TIP systems, was used, and TIP data were aggregated over a period of 2 years.

Results and Discussion

Overall, Experiment 2 replicated the results from Experiment 1. There was a partial, significant correlation between detection performance in the X-Ray ORT and age of screeners controlling for years of employment ($pr = –.27$, $p < .01$). Thus, on average, increased age of aviation security screeners was associated with decreased detection performance in the correct interpretation of x-ray images. Furthermore, Experiment 2 examined whether the correlation between age and detection performance can also be shown when measuring on-the-job performance using TIP. Again, the partial correlation between $d’$ in TIP and age of screeners, taking years of employment as control variable into account, showed a significant negative effect ($pr = –.34$, $p < .01$) and indicated that older screeners also perform worse in everyday working life when on-the-job practice exists. Figure 5 shows the correlations between detection performance $d’$ and the age of screeners in the X-Ray ORT and the TIP. The correlation of $r = –.18$, $p < .05$, between $d’$ in the X-Ray ORT and years in age indicates that in this sample experience in the X-Ray ORT could have positively influenced detection performance (since the partial correlation between detection performance in the X-Ray ORT and age controlling for years of employment was substantially higher, see above).

Indeed, the partial correlation between $d’$ and years of employment controlling for age was in fact significant in the X-Ray ORT ($pr = .35$, $p < .01$), but not for TIP data ($pr = .02$, $p = .78$). In the TIP task, which measures on-the-job performance more accurately, no beneficial effect of experience on detection performance was found. Contrary to the previous result, screeners who have been employed for a long time seem to profit more from experience in the X-Ray Object Recognition Test and with a sufficient amount of practice might be able to achieve similar performance levels as young adults. This effect could be due to the different selection procedure of new employees at the two airports (see General Discussion).

Overall, the results from Experiment 1 were replicated. Furthermore, analysis of on-the-job data (TIP) provided clear evidence that the frequency of occurrence of dangerous items does not influence detection performance substantially and has therefore neither a beneficial influence on performance of older nor on that of younger workers.

General Discussion

In this study, we investigated the relationships between age and x-ray detection performance of airport security screeners using two different x-ray screening tasks. Additional analyses examined whether the age effect could be reduced by working experience. Overall, the result revealed that increased age was in fact associated with decreased detection performance in x-ray screening tasks. There were substantial correlations between $d’$ in the X-Ray ORT and age. This effect of aging could also be found with TIP data, a measure of on-the-job detection performance. Further analyses on correlations between detection performance in x-ray screening and years of employment suggest that on-the-job practice generally does not help to increase detection performance in both test conditions.

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Figure 5. Correlation between detection performance ($d’$) in the X-Ray ORT (left) and TIP (right) from Experiment 2. The $d’$ values have been multiplied by an arbitrary constant for security reasons.
Considering detection performance in the X-Ray ORT, a speeded visual object recognition task, results show substantial correlations between recognizing guns and knives in x-ray images of passenger bags and the age of screeners. Furthermore, this age effect could also be shown with TIP data, a more realistic task in which a large variety of prohibited items are projected into x-ray images of real passenger bags in random order. Taken together, our results suggest stable negative age effects in a selective sample of airport security screeners that were not overcome by the amount of job experience and extensive job-specific use of speeded visual search and detection abilities.

In general, the absence of correlations between detection performance and years of employment support the assumption that on-the-job practice does not help to increase performance in x-ray screening. However, results regarding the X-Ray ORT were not consistent. In Experiment 1 no effect could be found, whereas Experiment 2 revealed a significant correlation between the detection of guns and knives in the X-Ray ORT and years of employment. This positive correlation could be due to the different selection procedures at airports. For several years now, job applicants at Airport 1 were selected with some basic x-ray images among other tests. Because the X-Ray ORT measures mainly fluid abilities needed in x-ray screening, due to this selection criterion, screeners at Airport 1 may have been better in the interpretation of x-ray images when they were hired compared to screeners of Airport 2 and, thus, show no effect of additional working experience. In addition, the preselection process may have led to a difference in the proportion of younger and older screeners in both experiments. Unfortunately, it cannot be determined from the current data to which degree the differences in these proportions may have influenced our results. Furthermore, this positive effect of working experience on x-ray screening could only be shown for the X-Ray ORT. No influence of practice on TIP performance was found.

The correlations shown in Figure 4 and Figure 5 reveal large interindividual differences. In fact, there are screeners over 60 years who perform at a remarkably higher level than some screeners half their age. Whether this difference between older screeners is due to individual differences in profiting from work experience or additional training have to be investigated in further studies. As Schwaninger et al. (2005) pointed out, the importance of knowledge-based factors in x-ray screening tasks should also be taken into account. In order to recognize prohibited items in passenger bags, one has to know which items are prohibited and what they look like in x-ray images. The appearance of some objects in x-ray images is quite different than in reality (for example, a taser weapon). Furthermore, some objects such as improvised explosive devices (IEDs) are normally not seen at checkpoints when TIP is not activated. Previous studies in airport security showed that specific individually adaptive computer-based training increases detection of prohibited items in passenger bags (Koller, Drury, & Schwaninger, 2009; Koller, Hardmeier, Michel, & Schwaninger, 2008; Schwaninger & Hofer, 2004). Aviation security screeners who participated in this study did not receive specific computer-based training, but still show a rather high amount of working experience (up to 26 years). Whether a specific job-related training can reduce the age effect has to be investigated in further studies.

In general, most of our findings are consistent with earlier findings on age-related changes in cognition across middle adulthood. However, this study on age effects in airport security provides further insights into area-specific applications and transferability of research studies into real-world conditions. Our result concerning the domain-specific age effect agrees with previous studies showing that age influences different processes such as visual search, spatial imagination, working memory, and attention. However, overall our results are not consistent with studies showing an experience-related increase in performance. Zec (1995), for example, reported that experienced individuals adopt more efficient strategies and thus increase their performance. It could also be assumed that older screeners might compensate their deficits with their knowledge, working experience, and probably their working strategy. However, with one exception there were no significant partial correlations between detection performance (X-Ray ORT and TIP) and years of employment when age was controlled for. Thus, in general, aviation security screeners cannot compensate their decline in job-specific fluid abilities with higher working experience. This holds true for both types of tasks examined as detection performance in TIP did also not increase with more working experience. However, further studies should investigate whether older worker can compensate a negative age effect through a reflected job experience such as systematic adaptive computer-based training systems.

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References


Adrian Schwaninger

University of Applied Sciences Northwestern Switzerland (FHNW)
School of Applied Psychology (APS)
Institute Human in Complex Systems (MikS)
Riggenbachstrasse 16
CH-4600 Olten
Switzerland
Tel. +41 62 286-03-28
E-mail: adrian.schwaninger@fhnw.ch