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A Human Being as a Part of the Security Control System at the Airport

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Abstract

The passenger and baggage security in airport screening system is one of the most important factors that determine air transport safety and security. It prevents objects and materials that could be used to commit an act of unlawful interference from being placed on board an aircraft. The security screening system consists of x-ray screening devices, walk-through metal detectors and specialised software. However, a key element of the security screening system is the human – the security screener (SSc). The equipment and software helps the screener to find prohibited items, but also detects and records his/her errors. The whole security control point (SCP) can be regarded as a complex socio-technical system. It's effectiveness is dependent, inter alia, on the type of x-ray devices used, a variant of SCP organisation or the technical condition of the equipment, but mainly on the quality of the security screeners' work. Special attention is paid to the types of errors and their frequency. We analyze the quantitative relationships between types of errors and also between the frequency of errors and the frequency of virtual threat images projection (TIP). This last technology is a kind of intelligent support system and at the same time verifies the screener's work. The study was based on measurements under real conditions at the Katowice-Pyrzowice International Airport. In the framework of this research two basic types of errors made by SSc were identified. The results show that the number of errors is dependent from the frequency of the stimulus, represented by TIP images. As a result, it was possible to determine the recommended frequency of threat images projections. The study is supplemented by a comparison of the screeners' effectiveness in laboratory conditions against real conditions, while working at the security control point.

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1. Introduction

The airport security depends on many factors, which are discussed in more detail in the literature (Gerstenfeld, Berger 2011, Uchroński 2011, Skorupski, Uchroński 2014a). In the most general terms, these factors can be divided into technical (Skorupski, Uchroński 2014b) and human ones. Humans play different roles in an airport management system (AMS) and appear at many different levels of its functioning. At the strategic level, they establish regulations and legal standards. At the tactical level, a human being assumes the role of the organiser and controller (supervisor) of the activities carried out by all services, whereas at the operational level, a human being takes on the role of a person screening passengers and their luggage as well as patrolling airport premises in search of people who might have unlawfully entered the restricted area at an airport. On the other hand, it is also the human being that constitutes the main source of risk, which is to be counteracted by airport security (Price, Forrest 2013).

Security screeners (SSc) performing their tasks with the use of x-ray equipment will be of interest in this paper. Typically, when evaluating this kind of cabin and hold baggage security control we pay particular attention to the technical equipment – the type and functions of the device used. However, it is worth noting that the assessment of the contents of baggage is the responsibility of the human in most cases. The ability to identify prohibited items, and thus the safety of passengers depends largely on his or her experience and skills. Although the specialised equipment for the screening of people and baggage that security screeners have at their disposal is becoming increasingly more advanced, it will always be the human being who will constitute a link between technology and a decision-making process, whereas equipment will always be merely an element supporting a human being in his/her work.

This paper analyses some aspects of the activity of a human being, i.e. a security screener, with regard to that screener's effectiveness in eliminating threats. We will focus particularly on the types and frequency of errors made by SSc, because they allow us to determine the effectiveness level of baggage security screening.

2. Security screener as an element of an airport security system – the literature review

The role that the human factor plays in civil aviation, in particular in civil aviation security, became a subject of research not long ago, i.e. in the 1970s. The events that occurred in the US on 11 September 2001 gave a direct impetus to the intensification of activities and to creating new, more restrictive regulations (Seidenstat, Splane 2009). Attention was also directed to training the personnel in threat detection skills and in reacting appropriately to any kinds of non-standard behaviour on the part of passengers (Alards-Tomalin et al. 2014, Dąbrowska 2011). This is because human error, which is caused by deliberate action or deficiencies in training, may have catastrophic consequences for an airport, a carrier and passengers (Price, Forrest 2013). The awareness that a human being is a factor that may significantly influence the level of air transport security causes this factor to be treated with special care in civil aviation security. This care is manifested, for example, in the checks that are carried out by national quality auditors, who secretly test airport security systems. These tests involve, among other things, provocation, i.e. an attempt to bring a prohibited or dangerous item hidden in the luggage on board an aircraft. The results of such tests provide a basis for evaluating the work of a particular security screener (Schwaninger et al. 2004).

The mechanism of the civil aviation security system is based on the principle of limited trust. Any activities that are undertaken with regard to a passenger and his/her luggage are aimed to detect prohibited items, which a passenger-terrorist could use to commit an act of unlawful interference (Butler, Poole 2002). Apart from the bags content knowledge, a screener's psychophysical abilities that allow him/her to effectively carry out his/her tasks are also important. A person who is unable to distinguish between colours or has significantly reduced visual acuity cannot work as a security screener, if only because of the very nature of the image that is generated by an x-ray source (Flitton et al. 2013). What is also important for this job is screeners' experience because it allows them to carry out their tasks independently and effectively as well as an attitude that guarantees that they will work conscientiously and diligently.

Depending on whether we are dealing with hand luggage or checked-in baggage screening technology is a bit different. The screening of checked baggage is largely carried out automatically (Wells, Bradley 2012). A human being, however, constitutes an important element of this process since the ability to think analytically and assess the risk while considering all the factors that are specific to a particular case makes a human an integral part of the security system. On the other hand, the effectiveness of an airport security system, including the checked baggage screening system, depends on a human being's psychophysical abilities, level of training and motivation. Schwaninger et al. (2004) pointed out that a security screening system at an airport is as effective as the employees who carry out the screening. The paper presents two methods of testing security screeners' effectiveness: the prohibited items test (PIT) and the object recognition test (ORT). These methods are aimed to determine the relationship between the type of a prohibited item, its location in the baggage and the possibility that it will be detected by a security screener. The authors of the present paper expand this approach by directing more attention to the characteristics of a particular security screener him-/herself than to the baggage he/she is inspecting. The article by Feng et al. (2009) presents an attempt at analysing the relationship between the reliability of a baggage screening system and its effectiveness. Two kinds of errors committed by security screeners were taken into account and principles of conduct were proposed for a two-level screening system. However, the assumptions that were made about the probability of security screeners committing an error were unrealistic. In the present paper the authors examine the actual probabilities that were obtained based on measurements.

In their paper, Graves et al. (2011) analysed the factors that influence the effectiveness of baggage and passenger screening systems at an airport while taking ac-count of the fact that such systems should be designed by considering security screeners as a critical factor in their performance. McCarley's (2009) paper points to the important role of any kind of aids, even minor ones, that indicate that special attention should be paid to a particular item of luggage in increasing the effectiveness of security screeners' work. In their article, Wales et al. (2009) used the Threat Image Projection (TIP) system to assess a security screener's competence. A linear relationship between the response time and the number of images of prohibited items that had been detected was established. The authors of the present paper also employ the statistics of the TIP system to evaluate a screener's experience, which makes it possible to achieve the paper's aim, i.e. to quantitatively determine a given security screener's effectiveness in detecting prohibited items.

When analysing the literature with regard to particular research methods one can notice several trends. Many of the relationships that exist within the analysed system are intuitive and subjective in character and they cannot be unequivocally described. It is therefore necessary that decision-making processes should be analysed in the context of uncertainty (Dubois, Prade 1992). As a result, fuzzy methods or methods using the rough set theory must be adopted (Greco et al. 2001). Wu and Mengersen (2013) suggest that there is a need to analyse airport security systems by adopting a two-criterion approach, i.e. by taking both the processing time (throughput) and the effectiveness of security screening into account. Problems of this kind are interdisciplinary. The use of domain experts can be very helpful in such situations. Methods of multi-criteria group evaluation of variants under uncertainty (Skorupski 2014) can be useful to ensure the effectiveness of inference on the basis of free expert opinions. The processing time and security costs have been analysed, for instance in (Hainen et al. 2013; Kirschenbaum 2013; Stewart, Mueller 2014). This paper presents some measurements and analysis that may help in describing the second of these criteria.

3. Security screeners' errors and effectiveness of the security control system

The effectiveness of baggage control process performed remotely by the screener is affected by numerous factors. They can be divided into two main groups. The first one is related to the class of x-ray device used and was analysed in (Skorupski, Uchroński 2014b). The second group is related to the human – the security screener and can include:

- an overall assessment of the screener's potential, depending on his/her experience, level of training and the overall attitude to his/her duties: restrictive or lenient,
- number of errors committed during baggage control,
- organizational factors, characterizing the degree of screener's involvement throughout the whole baggage security control process.

In this paper we deal with factors from the second group and in particular with the issue of screeners' errors. This paper is a continuation of our previous work (Skorupski, Uchroński 2014c). We have extended the study by the analysis of the impact of screener's experience on the response time to the displayed TIP image, and also we have made a comparison of the SSc effectiveness in the real world to the laboratory conditions.

In general, it can be stated that there are several groups of causes contributing to the errors made by the operator of an intelligent telematic system, an example of which is TIP, considered in this paper. These include:

- baggage characteristics: the complexity of the evaluated image, orientation of a prohibited object in relation to the screener and the degree of overlap between the different images adjacent to the forbidden item (Michel et al. 2010),
- technical factors: the type and condition of the telematic support equipment that generate and transmit x-ray images (Kirschenbaum et al. 2012),
- environmental factors: workplace organisation, lighting, temperature,
- individual short-term factors: nervousness, lack of sleep, weariness (resulting from the monotony of work and lack of incentives), fatigue (due to the length of the work, work at night or due to an excess of stimuli) (Wang, Chuang 2014),
- individual long-term factors: level of training, experience, security culture (Stroeve et al. 2011).

Within the research, measurements were carried out at Katowice-Pyrzowice International Airport from January to April 2014. Types and frequency of the errors were specified. We have established that screeners make the following types of errors:

- They do not point (notice) the virtual prohibited item located in the image of the scanned baggage. We called it the type A error. It is a very worrying situation. Because if the screener did not notice the image of the virtual prohibited item it can be assumed with the same probability that they will not notice a real prohibited item. A large number of such mistakes would mean that the whole security system of the airport is of poor quality. This is because the main purpose of the baggage security control, i.e. detecting the prohibited item, is not fulfilled.
- They point as dangerous the bags which in fact contain neither a virtual, nor a real prohibited item. We called it type B errors. This situation can be interpreted in two ways. We can assume that the operator had (due to the analysis of the image displayed on the screen of the x-ray scanner) reasonable concern and suspicion as to the content of baggage so he/she showed alertness, which undoubtedly is a positive feature. However, it is also possible that in order to get a good rating, he/she marked automatically, and without a thorough analysis of the image, many scanned baggage as suspicious.

From the security point of view, the most important are the type A errors. The essence of the security control carried out by an operator with the use of x-ray scanners is the ability to recognise the images of the prohibited items. The number of type A errors is the measure of this ability. In turn, type B errors can disorganize the screeners' work, resulting in the need for very frequent manual control of the baggage. This reduces the throughput of such a system, but more important is that a large number of false alarms weakens the screener's vigilance.

4. The dependence of errors on the screener's experience

The theoretical knowledge that screeners acquire during training in civil aviation security establishes certain frameworks and patterns which they will use when performing their duties. However, just like in any other occupation that requires employees to operate equipment, assess the situation, relate facts to one another or make decisions, one cannot become theoretically prepared for all possible situations that can occur in real life. This is particularly true of non-standard situations or emergencies (Bazargan, Guzhva 2011; Malakis et al. 2010a; Schwaninger et al. 2004). Such situations require solving unusual decision-making problems and being able to assess possible options for action in a factual, substantive and calm way as well as in the context of the current legal and organisational regulations or infrastructural limitations. A screener acquires these skills over time while working at a security screening checkpoint, thus gaining experience (Fruhen et al. 2014).

It is very difficult to assess experience of a security screener, i.e. the extent to which he/she is able to work independently or even supervise and train new employees. This is because it is a subjective matter and, additionally, an employee's performance depends on his/her personality as well as his/her ability to work in a group; therefore, it is hard to carry out an unambiguous assessment in this area (Malakis et al. 2010b).

The effectiveness of security screeners in detecting prohibited items was measured during the period from March 2013 to February 2014. The statistics of errors that had been recorded by baggage screening equipment with the TIP system were used for this purpose. Measurements were made of the number of TIP images which were not recognised by a security screener (type A error) and the number of identifications of a prohibited item that was not really there (type B error).

The idea of TIP system is to project a virtual prohibited item on the image of the piece of baggage being screened. A database of images of items prohibited for air transport, that is included in TIP software, contains different images, depending on whether we are dealing with a hand baggage or a hold baggage. In the latter case, all kinds of explosives and pyrotechnics are prohibited. The catalogue of prohibited items is much broader in case of hand baggage. It includes also objects with sharp ends and liquids. Colloquially, we simply call these images TIPs, and in the situation when the system displays an image from the database we can say that a TIP is displayed.

The operator's task is to detect the virtual object in the image and confirm this fact by pressing the button on the x-ray device. This increases the screeners' awareness, as they are forced to search for prohibited items in the baggage image more often than is the case when the TIP system is not used. If the response is correct, the system confirms that the screener has detected the TIP and records his/her reaction time. In case of no reaction, the system informs about an error and records this fact for further analysis. Such data is the basis for the research presented in the following sections. As a measure of type A errors we assumed the ratio of the number of unrecognized TIPs to the total number of displayed TIPs. As a measure of type B errors we assumed ratio of the number of false positives (the number of luggage mistakenly identified as containing prohibited items) for all checked baggage.

To find the relation between the number of errors and reaction time and experience, measurements were carried out for three employees who had just begun working as security screeners. Table 1 presents data on number of screened bags, number of TIPs displayed and the percentage of type A and type B errors in relation to number of TIPs and number of bags respectively. Table 2 presents the data on the number of type A and type B errors and also the screener's reaction time when committing both types of errors. The graphical representation of two relationships is presented on Figure 1 and Figure 2.

Table 1. Percentage of errors made by security screeners with respect to the number of months of work experience.

Month	Number of TIPs	Number of bags	Percentage of type A errors	Percentage of type B errors
1	61	3185	62,30%	2,07%
2	261	10 625	39,85%	1,62%
3	199	8577	25,13%	3,96%
4	218	9058	23,85%	2,40%
5	186	8271	20,97%	1,09%
6	242	10 158	18,60%	0,99%
7	193	8060	24,35%	0,99%
8	195	8507	14,36%	1,16%
9	174	7198	17,24%	0,93%
10	188	8184	15,43%	0,75%
11	127	7809	18,11%	0,78%
12	85	6131	23,53%	0,46%

The measurement results clearly show that the number of errors (both type A and type B) committed by inexperienced security screeners during their first months of work is large. The number of errors decreases over time as the employees gain experience. It can be noticed that the error rate decreases to an acceptable according to the regulations level after about five months and it can be said that the rate stabilises after about eight months.

Some interesting facts can be seen from the analysis of response times while making errors. Firstly, security screener while committing an error of type A responds much faster. It is clear that the decision to qualify a bag as free from prohibited items is almost automatic. Inexperienced screener analyzes baggage longer, as can be seen from Figure 2, but after about 6 months of work this time is twice-three times shorter. It is equal to the response time for the entire population of screeners, which results from our other research. On the other hand, while committing an error of type B response time is much longer. It can be concluded that, if the displayed image of the piece of baggage is questionable and its assessment makes some trouble, the screener (as evidenced by the longer time of analysis) prefers to mark the bag as potentially dangerous and to perform the manual inspection. In the case of committing a type B error, the reaction time is not as unequivocally dependant on the screener's experience as in the case of type A error. Table 2 shows that after a year of work experience this time increases. This time, in the general case, can be even greater as demonstrated by our study on a larger sample of screeners (including very experienced).

Table 2. Security screeners reaction time with respect to the number of months of work experience and type of error.

Month	Number of type A errors	Number of type B errors	Reaction time (type A error) [s]	Reaction time (type B error) [s]
1	38	66	2.8	4.5
2	104	172	2.4	4
3	50	340	2.2	4.1
4	52	217	1.9	4.2
5	39	90	1.7	3.9
6	45	101	1.3	3.6
7	47	80	1.4	3.9
8	28	99	1.0	3.9
9	30	67	1.2	3.9
10	29	61	1.0	4.6
11	23	61	1.3	4.9
12	20	28	1.2	5.2

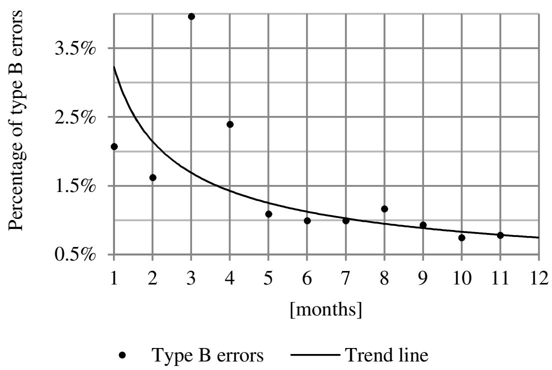

Fig. 1. The relation between the percentage of type B errors and screener's work experience (Table 1).

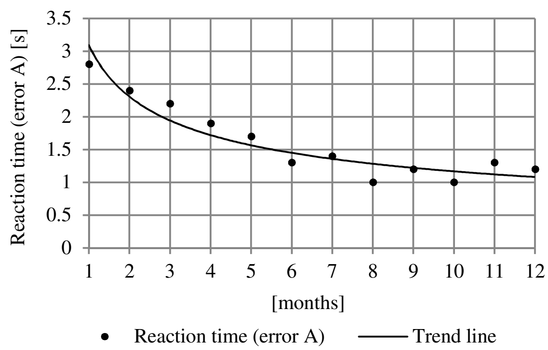

Fig. 2. The relation between reaction type during type A errors and screener's work experience (Table 2).

5. Relation between the screener's errors and TIP frequency

The frequency of the stimulus, defined as the TIP appearance in the x-ray image, has been listed in Section 3 as one of the causes of errors. In order to find the proper frequency of TIPs an experiment involving 93 security screeners from Katowice–Pyrzowice International Airport was conducted. Results averaged for all employees together, show no statistical relation between the frequency of errors and the TIP frequency. However, closer analysis of the results of measurements allows for the identification of four groups of screeners:

1. Those who commit few type A errors and few type B errors. These persons have an ideal profile for the security screener position.

2. Persons of a precautionary nature. They commit few errors of type A and a lot of type B errors. These screeners are carrying out a rational principle: 'better express doubts and proceed with manual baggage check than overlook the forbidden item'.
3. Persons restrained in identifying suspicious baggage. They commit a lot of type A and few of type B errors. Doing so may result from both a psychological determinants but also from difficulties in the perception of images of prohibited items.
4. Those who commit a lot of type A and type B errors. This type of person is the least useful in the security screener position. Employees in this group indicate baggage for manual control at random, without a deeper analysis of the image from the TIP system.

For the presentation of the dependence of the number of errors on the frequency of the stimulus, representatives of the above four groups were chosen. Sample measurements from the period January–April 2014 are presented in Table 3 and in Figures 3 and 4.

Table 3. Characteristics of errors made by the screeners from different groups.

Screener type	Number of TIPs	Number of bags	Percentage of type A errors	Percentage of type B errors
Group 1	161	9739	7.5	0.50
Group 2	172	10678	15.1	2.20
Group 3	185	11187	38.9	0.67
Group 4	257	16943	26.5	3.27

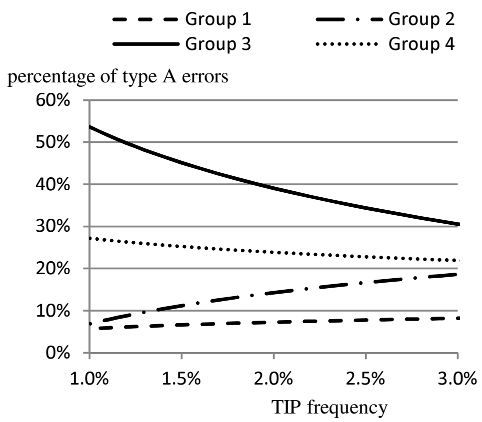

Fig. 3. Relation between the TIP frequency and type A errors.

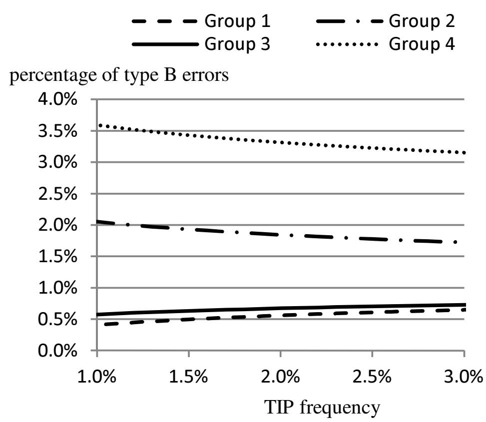

Fig. 4. Relation between the TIP frequency and type B errors.

The graphs in Figures 3 and 4 show the results for the usable range of TIP frequencies, i.e. from 1% to 3%. Some interesting regularities can be observed:

- Screeners committing a small number of type A errors (group 1 and 2) are characterized by an increase in the number of errors with increasing TIP frequency. For those who commit a large number of type A errors (group 3 and 4), this relation is reversed: the higher the TIP frequency the lower the number of errors.
- Screeners committing a small number of type B errors (group 1 and 3) are characterized by an increase in the frequency of errors with increasing TIP frequency. Similarly, screeners with a high number of type B errors (group 2 and 4), record its' decrease with increasing TIP frequency.

Psychological analysis of the reasons of such screeners' behaviour goes beyond the scope of this work. The conclusion of this analysis is that in the general case neither very low nor very high TIP frequency is appropriate. Most preferred is the intermediate TIP frequency, about 2%. Only when we know to which of the four identified groups the screener belongs, we can select individual TIP frequency to him/her.

6. The overall assessment of the effectiveness of detecting prohibited items

The study (Wells, Bradley 2012) presents a method of SSc assessment consisting of analysis of the relationship between the probability of prohibited articles detection (dependent on type A errors) on the frequency of false alarms (type B errors). This method assumes that measurements of prohibited items detection rate are performed in laboratory conditions. In our work, we used this method, but in real conditions. The most important difference is that in real conditions the number of bags containing a TIP in its image is much lower than in the laboratory. In addition the screeners work under tension and stress, which can affect their performance. From the effectiveness of detection point of view, the above mentioned relation for a small number of type B errors is the most important. The results of the analysis, based on measurements performed in Katowice-Pyrzowice Airport from January to April 2012 is shown in Figure 5.

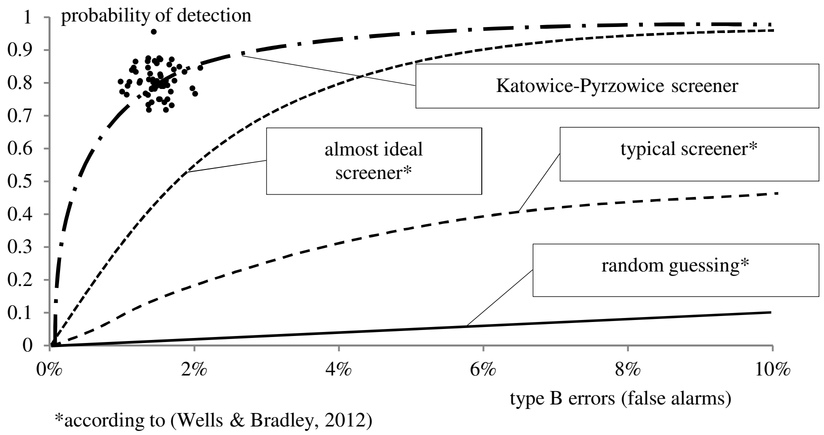

Fig. 5. Comparison of typical levels of SSc work effectiveness.

As one can see SSc in Katowice–Pyrzowice make a small number of false alarms and have an excellent level of prohibited items detection, comparable to the theoretical values, those obtained in laboratory conditions. It can be assumed that a large role in this excellent result is played by the SSc awareness as to the role that baggage screening plays to air transport safety (Mearns et al. 2013). It is worth noting that in real conditions only this most important part of the relationship presented in Figure 5 can be measured.

7. Conclusions

1. The paper presents an analysis of the dependence of the number and types of errors made by the security screeners on their experience and the frequency of the stimulus, represented by an image of a prohibited object. The basic data for analysis are measurements of errors committed by the screeners. They were recorded in real conditions, using the Threat Image Projection (TIP) telematic support system. We conclude that the TIP system is a great source of knowledge about the security screeners work, while also allowing for continuous improvement of their skills.
2. One of the main results of the research is finding the relation between the screeners' experience and the number of errors they commit. This allowed for an indication that after about 5 months a screener reaches such a level of experience which may entitle him/her to work independently on baggage image analysis. We can also conclude that the screener, which has about nine months of experience, reaches the operating parameters which allow one to qualify him/her to fully experienced.

3. The second result was to determine the relation between the TIP frequency and the number of type A and type B errors. This dependence on a general level does not exist. However, the identification of four groups of screeners, characterized respectively by low and high number of errors of type A and B, allows observing some interesting relations. This makes it possible to say that neither very low nor very high TIP frequency is appropriate in the general case. However, with the knowledge how effective the screener's work is (i.e. to which of the four groups he/she belongs) it is possible to select TIP frequency best for him/her.
4. Screener's response time differs substantially when type A and type B errors are committed. The decision to qualify a bag as secure is usually taken quickly. When the image analysis takes longer it is more likely that a type B error appears.
5. The dependence of the response time during a type A error on the experience is consistent with the dependence on type A errors number. However, the increase of the experience does not affect the response time during type B errors.

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