AUTOMATED BORDER CONTROL: A COMPARATIVE USABILITY STUDY AT TWO EUROPEAN AIRPORTS

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ABSTRACT

Throughout Europe airports are increasingly installing automated border control (ABC) technologies as they are expected to improve security, streamline the traveling process, and facilitate better passenger experience. Although these e-gates have been in use for years, they are still underutilized by travellers. This might be partly due to problems with the systems' usability. This paper presents a usability analysis of ABC e-gates at two large North-European international airports and compares their ease of use. Our study shows that there is scope for a better designed, standardized system with a more intuitive interface.

KEYWORDS

Automated Border Control, e-gates, usability, passengers, biometrics.

1. INTRODUCTION

European countries have been including biometric data (digital photographs and fingerprints) in their passports since 2004. It is likely that soon every European traveller will encounter biometric systems at some stage of their travel (Sasse, 2007). Airport operators are installing Automated Border Control (ABC) systems with biometrics to improve passenger clearance without increasing staff costs (efficiency), to make the process easier for passengers (convenience), and to enhance precautions at airports (security).

Self-service technologies such as ABCs are defined as technological interfaces that enable customers to produce a service independent of direct service employee involvement" (Meuter et al., 2000). As with any other self-service system, e-gates need to have user-friendly, intuitive interfaces, be easy to remember, give full guidance for the users, and provide universal access. Sasse notes: "We can assess usability in terms of three criteria: task performance, user satisfaction, and user cost" (2007: 78). Task performance is related to the effectiveness and efficiency of the user's interaction with the ABC gate. The interaction is *effective* when users can achieve their goal and complete the task of getting their passport scanned and their facial image captured successfully. The interaction with the gate is *efficient* if they can go through the e-gate within an acceptable time period. User's (subjective) satisfaction can depend on the level of physical or mental workload and other criteria. Finally, user cost considers the impact of the interaction on user's health and safety.

E-gates consist of many components: physical barriers (glass doors), a document reader, biometric capture devices, user interfaces (monitors, LED signals, monitoring stations), and surveillance cameras or sensors (CCTV, left luggage detection). There are different systems currently in use: one-step processes, integrated two-step processes with single or double door e-gates, and segregated two-step processes. The design of e-gates must provide both convenience and performance. A positive user experience is usually based on convenience (time-savings or a reduction in physical or mental work), confidence that the system is functioning correctly, and its perceived utility. With everyday self-service systems such as ATMs and ticket machines, highly practiced (frequent) users can overcome some of their usability problems. However,

contrary to many other self-service technologies, a large proportion of users will interact with e-gates very infrequently. According to a report from the British Department of Transport (2010) just under half (47%) of UK adults had flown at least once in the last 12 months. A fifth (20%) of adults had made just one flight, 11% two flights, 6% had made three flights; and a further 10% had made four or more flights. Training and regular use will improve the user's interaction with the system (learning curve) and will also increase the user's confidence and satisfaction in the system. Therefore, an infrequently used system must be *especially* easy to use for untrained and non-habitual users with no technological background.

In order to enhance the usability of e-gates they must adapt to the user as much as possible rather than asking the user to adapt to the system. Automated border gates need to accommodate a population with different characteristics (e.g. height, ages, and impairments). Results from the 2005 UK Passport Service Enrollment Trial show for instance that face recognition systems have higher failure rates for users with dark skin and eyes: "very dark skin absorbs light to a degree that a face's underlying topology doesn't stand out enough" (Sasse, 2007: 79). It is also necessary to accommodate 'non-perfect' users. Travellers are often stressed, tired, and in unfamiliar surroundings. This will bear on their interaction with a self-service system. The choice of the ABC solution will impact on the ergonomics, comfort, speed and performance of the passengers.

Because European airports will see an increase in passengers (Teyssier, 210; Boeing, 2013; Airbus, 2013) a move to automated border control systems seems inevitable. Although e-gates have been in use for years, they are still underutilized by travellers (UK Home Office, 2013). This might be partly due to problems with the systems' usability. This paper presents a usability analysis of ABC e-gates at two large North-European international airports and compares their ease of use.

2. METHODOLOGY

In June and July 2013 we were granted permission to observe travellers using the automated border gates at two North-European airports with each between 50 and 60 million passengers per year. After having been given security clearance and receiving temporary airport ID-cards, we could observe people in the secure area of the airport. We watched intently how travellers used ABCs in practice, taking notes of how they scanned their passports and went through the facial recognition system. We paid attention to the following issues: How do they approach the e-gates (e.g. confident, hesitant)? Do they use the provided information leaflets? How easy or difficult do they find it to scan their passport? Do they know where to look to have their face scanned? Do they remove glasses and hats? How much luggage do they carry with them? Which part of the system causes problems? How often does the system reject people? Is help needed to get through the ABCs, and if so, who provides it (e.g. other passengers, border guards, airport personnel)?

Besides observing the actual use of the e-gates, we carried out 155 face-to-face surveys with passengers about their experience with ABCs and biometric systems. Finally, we conducted in-depth expert interviews with border guards and border management. The interviews were recorded and transcribed for analysis. Verbatim quotes from these interviews are represented in italics in this paper. The fieldwork locations are described next.

2.1 Airport A: two-step mantrap design

Airport A has implemented a pilot two-step, double-door ABC system: the traveller scans his passport *before* being admitted via an entry gate into a mantrap, where facial matching takes place before being released via an exit gate. To use the e-gate system the passengers have to place their passport firmly on the scanner, ensuring the photograph is face down. If the passport is in a cover, this needs to be removed beforehand. If the passport validation is successful, the first set of glass doors will open. When indicated, the passengers have to remove the e-passport and step forward into the booth, positioning themselves at a certain distance to the camera in the exit door (there are markings on the floor). They look straight at the camera, and the booth will match their face to the photograph held in the chip in their passport. They can exit through the second set of glass doors when the biometric process was successful. If the system rejects the passengers, they are requested by the system to see a border officer for a manual check.

2.2 Airport B: one-step mantrap design

Airport B currently provides 36 self-service ABC gates. The main motivations to implement automated border control were to improve border management, to embrace new technology and be innovative, and to handle the growing number of passengers with the same number of border guards: "*Globalization of the economy, more business traffic, more people going on vacation. Previously you went round Europe by car on holiday and now more and more families go by plane, flights are cheaper"*. The system involves using electronic gates equipped with facial recognition to compare passengers' identity with the digital photographs in their e-passports. To reduce passage time in the gates, the passport validation and facial recognition are done simultaneously within the mantrap. If the information does not match, the passenger is referred to an immigration officer who will undertake a traditional manual check. The system can also identify forged passports and persons who may be on an authority's 'watch' list. The ABC team at Airport B places a lot of emphasis on the usability of the gates. Their ongoing work on user experience is contributing to a better understanding of how to use the gates, thus saving precious seconds in the overall process and providing greater satisfaction to both passengers and border guards.

3. RESULTS

3.1 Visibility and Communication

In an interesting article that analyses the usability challenges in border control for disabled people Pirelli (2009) explains that *all* people have difficulty to access and retain information. He points out that passengers should be provided with many channels of information such as pamphlets, a short video-clip, information via loudspeakers, and information on a screen, via radio or television. He argues that people often miss a part of each channel of information and therefore redundancy may provide the missing pieces of information in a different format as well as on a different moment: "In stations or airports, in noisy situations, in different languages, it is difficult to understand the full information from loudspeakers. The information on the screens is more detailed and available for longer time". From both the observations and the surveys we have seen that few people (only a quarter of the non-users) are aware of the existence of e-gates. Of the actual users 25 per cent would have welcomed more information, better signage, or help from airport personnel. This indicates that not enough information channels have been used to inform people about Automated Border Control.

At Airport A signage to the e-gates was not very clear. People had to first walk past the traditional manned booths to get to the e-gates. Thus, people might not have been aware of the possibility to use a self-service system and instead queued up to be manually checked. Although pamphlets were provided at the e-gates, none of the passengers picked one up. One of the reasons could be that the stand with the pamphlets was possibly obscured by other people in the queue. Or maybe travelling makes one too tired and weary to notice things like leaflets. An earlier version of the e-gate system used to make a sound when the border control procedure was successful. This would alert other passengers who were waiting in the queue for the manned booths to the fact that they could use the e-gate system instead. Since the update of the system (end 2012) the gates no longer make a sound, which has caused a sharp decline in the number of passengers using the ABC system.

At Airport B signage is quite clear and at busy times floorwalkers employed by the airport direct eligible passengers in the right direction. The floorwalker is someone who checks passenger passports to determine whether they are over 18 years of age, and have an e-passport. Once one passenger uses the gates, others will follow: *"You can see the 'herd behaviour' in that you just need to guide the first passengers and then the people following think 'Hmm, we can go through that too'. If the normal desks are busy and no one sends them to the e-gates, people do just not see them or they are afraid of them, I do not know, but they do not present themselves spontaneously. However, if you do send a few people to it, then the rest follows as a herd. People like to join the end of a queue. A large part of the passenger traffic travels just once a year. The business traffic that travels more often just goes straight through. That difference is obvious."*

3.2 Passport Scanning

E-gate systems use the passport holder's personal and biometric data stored on the electronic chip integrated in the e-passport: *"When we started we still had a lot of the public using non-e-passports"*. Most European citizens will be in possession of a passport with biometrics. However, in some countries passports are valid for 10 years and therefore until 2016 some Europeans will still be using non-e-passports.

At Airport A 58 percent of passengers had problems with the passport scanner. Of these, 20 percent were not able to solve the problems by themselves, instead they had to go and see a border officer to provide a manual check. The other passengers were able to go through the system in the end, either through sheer perseverance, by looking at other passengers, or by asking for help from the researchers doing the observations.

The instruction screen at the e-gate showed 5 different instructions on a loop. The first picture showed two passports: one without an e-passport logo and one with the e-passport logo. This indicates that you need to have a passport with an electronic chip integrated in order to proceed with the process. The second picture re-enforced this instruction by showing the passport plus chip picture again. The third screen instructed passengers to open their passport (Figure 1), while the 4th and 5th screen showed them how to place their passports on the scanner and press it down. Because these instruction screens were on a constant loop, people approaching the e-gate would not necessarily be greeted by the first instruction screen. The order in which the screens were seen by the passengers had a great impact on their understanding of the process. If the system happened to be showing instruction number 2 when the passenger walked up, they would be under the impression that they had to place their passport closed onto the scanner. If they were shown the third instruction: "open your passport", as their first screen (Figure 1), they would assume that this was how they were supposed to position the passport on the scanner. However, this side-ways position was NOT how the passport should be placed. This confused many passengers. Only one passenger took the time to look at all the instruction screens before placing her passport correctly on the scanner. All other passengers immediately started to place their passports onto the scanner in the way they thought was appropriate. Sometimes they would hold it up to the instructions screen, other times they would place their passport closed on the scanner, or on top of the scanning system. The less experienced users often looked at passengers standing at the next gate to see how to place the passport. The lesson we learn from this is that the instructions shown to the users need to be fully synchronized with the different steps of the process.

Figure 1. The instruction screen showing that the passport needs to be opened.

Airport B operates a one-step, double-door mantrap device. The passenger walks through the first set of (open) doors and puts his passport on the reader. The first set of doors will then close and not open until the passenger has gone through the whole procedure. A big issue with the passport reader was that initially people had to place their passports on the scanner and keep it there. A lot of people would remove their passport before the chip was read by the system. Several alterations of the original system improved the

ease of use of the passport scanner*: "First we used the classic route where passengers had to open their passport and really press it down; then we had one with a clip where you slide it in and the clip will hold it down. But a lot of documents don't fit under the clip so then it would break off or damage the passport, so that didn't work. Then we built something with brushes to keep the passport down, that didn't work properly either. Now we have a kind of bankcard reader: you put your passport down on the plate and then it is drawn inside and correctly pressed down. And only when the process is finished is your passport returned"*.

Once the passport reader sees that the passenger is eligible to use the system the door closes behind him and he is temporarily trapped in the gate. Then the EPR performs a number of checks on the passport to see if that has not been tampered with, simultaneously capturing the electronic facial image. The camera captures a live image of the travellers' face and uses facial comparison to check that it is similar to the picture on the RFID chip. It ensures that the passport is genuine and that the person presenting it is actually the rightful holder. It also checks if it is a living person. If all that is checked the system opens the exit door and the passenger can leave the gate. Finally, the system checks that no baggage is left behind, only then opening the entrance door for the next user. The interface information adapts to the passport. The first message 'put your passport here' is in English, but once the system has read the chip it can determine what country a passenger comes from and switches to the language of the country - only in the case of multilingual countries does it use English.

The e-gate team at Airport B is very focused on usability issues but the interviews made clear that it remains difficult to design e-gate systems that are user-friendly, intuitive and give enough guidance. One respondent remarked: *"Even if the [instruction] video is very clear on how you should enter the document, it clearly states "This part goes in first", still people will put it either like this or like this. Some people will put the passport up to the camera"*. Another respondent elaborates: *"The video display is linked to the steps of the process. It simply is synchronized. But still a large proportion of the errors are really user errors. No matter how clear or well you instruct someone, there are always people ... The stress of traveling, of course, uncertain, ignorant of new technology. A lot of mistakes we see are purely down to the user. But, the system is still not user-friendly enough. We have informed the supplier and consequently the adaptation of the passport reader was done. We just look at the total percentage of errors and user errors are anticipated and if that is too much, it is up to the supplier to amend and adapt the system"*.

Because the system is still in an operational testing phase, the team can implement any improvements. Continuous usage of the e-gates by real passengers helps to point at problems that seasoned testers do not pick up on. It is real use that makes the system better: *"You see, as a tester, we know at some point, of course, how that system works and then you go through there smoothly. You come across the most common errors when you have thousands of passengers through at the same time. Then you really see the human behaviour. About 3000 passengers per day use it"*. The continuous testing also benefits the suppliers as they can implement the findings of usability testing into their new products*: "And this design is indeed significantly better than what they used to have, so they also benefited from our testing period*".

3.3 Facial Recognition

Facial recognition (or face recognition) is a type of biometric software application that can identify a specific individual in a digital image by analyzing and comparing patterns. The Automated Border Control system uses facial recognition technology to compare the travellers' face to the photograph recorded on the 'chip' in the passport. Once the checks are made, the gates will open automatically for the passenger to go through. There are three major factors influencing performance of the automatic face recognition: 1) the quality of the facial image digitally stored on the passport (the reference image), 2) the quality of the live recorded facial image by the gate (the probe image), and 3) the quality of the face recognition algorithm used (Spreeuwers et al., 2012).

One of our interviewees noted that there are some quality issues with the digital photographs in certain European passports: "*As you know, the quality of pictures in e-passports differs from country to country, and from picture to picture*". Research by Spreeuwers, Hendrikse and Gerritsen (2012) confirms that this is indeed the case, with 5% of passport images containing serious deficiencies. According to the authors, major issues include: poor contrast (i.e. over exposure or too dark images), compression artifacts, dust and hairs on photographs, cracks, bad scan lines, non-frontal pose, colour smudges or stains, blurred images (due

to motion), distorted aspect ratio (i.e. the face is vertically stretched or compressed), or wrong eye colour due to compression or red eye correction.

But even when the photos on the passports are of a good quality, the system will need an equally good quality live recorded facial image to make a comparison: *"What you really need is a good image with a good image to make a decent comparison. And so with my own passport and my own face just doing stupid things in front of the camera: shaking your head, jumping up and down, covering parts and stuff like that, I can change my score from 99 to 11. And even if you do the most obscure things sometimes you will pass. It has nothing to do with my face anymore".* The score is compared to a threshold. If the live image and the digital passport image are from different people and the score is still above the threshold then it is known as a False Accept. When a person shows his genuine passport but the score falls below the threshold, it is known as a False Rejection. This can for instance happen when somebody is wearing glasses: *"Unfortunately if people are wearing glasses in real life and in the passport they are not wearing glasses they will get the same kind of low scores because the frame will distort the scoring rate a lot."* Or when somebody is passing through the gate with a James Dean or Bob Marley t-shirt: *"This was a passenger – a real Rastafarian, so a lot of dreadlocks in front of his face. The camera didn't see a face here but it saw a face on the shirt [of Bob Marley]. So it was checking the passport photograph against Bob Marley and of course it wasn't Bob Marley so the guy was stopped. It just shows you how sometimes the system is not doing what you have trained the system to do".* False rejections will negatively affect the satisfaction of the e-gate users as they are unable to successfully achieve their goal.

At Airport A the face recognition system worked well (13% experienced some problems), and was more intuitive and user-friendly than the passport scanner. The system makes use of a so-called 'digital mirror' in front of the camera, i.e. passengers see their own image when looking into the camera. This helps to position the users correctly and make them look into the camera as the system needs them to. It is a very natural way to get passengers looking straight into the capturing device. Common problems with the facial recognition system were people either standing too close or too far away from the camera.

The facial recognition camera moves up and down depending on the height of the passenger. It is not a static camera that people have to look up to, although some travellers did this. This is an indication that harmonisation throughout Europe would increase the usability as people will not be confronted with different methods of facial scanning. People with glasses or wearing a hat seldom took those off. This did not cause any problems with the facial recognition. At Airport B performance data shows that people wearing glasses score worse. The system does not tell passengers *in advance* that they should take their glasses off. By design, the system only displays an icon or text with 'Please look into the camera without glasses' if it struggles to capture/compare the face picture. Fewer difficulties are encountered with hats and caps: *"We had a Muslim woman wearing a headscarf, and she just came through because the system just looks at a particular part of the face".*

The camera at Airport B is activated the moment a traveller walks into the gate. The camera goes up and down, looking for the right height of the passenger. It can provide extra illumination if this is needed. When two people enter the gate the system will detect two faces and display a "only one person" message. The scanning of the passport and the facial recognition happens simultaneously. A problem with one of the first versions of the system was that the moment the camera took the picture of the traveller, he was just being handed back his passport by the feeder. So a lot of the live images showed people looking down at the passport scanner instead of straight into the scanner. By altering the timings, this was solved. But then another problem occurred: people did not look straight into the camera. The system does not have a 'digital mirror' so people are not really aware where the camera is. To draw their attention to the camera a waving hand was projected in front of the lens. But this caused another (unexpected) problem: *"Because people didn't look in the camera the right way, we used this waving hand, but they are waving back to the camera. So now I don't see a face because there is a hand in front of the face, and I don't get a good picture. Stupid things like… I mean you try to improve the system and actually you're deteriorating the system".*

3.4 Speed of the Process

The speed with which people are able to go through e-gate systems is variable. A border guard explains: *"You see some people walk right through. Especially young people, they are used to it and go straight through. The elderly have a little more difficulty - some do not understand at all that you have to put your*

passport on the reader – you see them holding it up to the camera". According to our respondents approximately 15 to 20% of passengers have problems with the system and require intervention. This might be because a passenger is in the wrong queue, two people get into the gate at the same time, or the passport is malfunctioning. Work is still ongoing to reduce the number of interventions.

When the e-gates work, and the passengers know exactly what to do, the system is fast, taking about 15-20 seconds to let a passenger through. However, when people have problems understanding the system, it can take anything up to 5 minutes. In comparison, it takes a border guard 10 seconds to process a person. Although the system takes longer than that, there are five or six gates doing the work of one border guard. During the observations we noticed that all circumstances being equal (no queues at the e-gate - no queues at the manual check), passengers who were headed towards the e-gates, would decide to go through manual border control instead.

4. CONCLUSION

Throughout Europe airports are increasingly installing Automated Border Control technologies as they are expected to improve security, streamline the traveling process, and facilitate better passenger experience. In this paper we have focused on the passenger experience with ABC systems. We investigated the e-gates at two European airports and compared their usability.

Although the first ABC systems have been in use since the beginning of this century, there is no standardization of the main components, with user interfaces still being under development. Overall we can state that the e-gate system at Airport A did not perform well. A total of 60% of the passengers experienced problems. The main issues detected were with the scanning of the passports. This was in general not a technical failure, but a problem with the incomprehensible user interface. What we saw is that when the users know *exactly* what to do, the system is fast, taking only 15 to 20 seconds to let a passenger through. Unfortunately, the problem with the system lies with the word 'exactly' as very few people know how to use e-gates. The current pilot ABC system at Airport A is not user-friendly, with instructions that seem to make little sense to first-time users. This resulted in over half of the passengers having problems scanning their passports. It was unclear to them where and how they were supposed to place their passport. Sometimes they would hold it up to the instructions screen, other times they would place their passport closed on the scanner. People would get confused and irritated, causing delays and frustration in the queue behind them.

The facial recognition system caused fewer problems, with the digital mirror being a particularly user-friendly and intuitive way of getting passengers to pose correctly for the facial capture. People occasionally stood too close or too far away from the camera, but would soon become aware of this and change their position. Although the system refers people to the border guards for a manual check after a couple of failed attempts, some of the more persistent passengers would take anything up to 5 minutes in front of the e-gate before either succeeding or acknowledging defeat. Obviously this is not ideal for a system that is supposed to speed up the border control process and increase passenger satisfaction.

In comparison to Airport A, the ABC technology at Airport B is a lot more intuitive and user-friendly. The feedback to the users is synchronized with the different process steps. The passport reader has been repeatedly adapted until it is now functioning as a feeder which takes the passport in to read the chip. This prevents people from not putting enough pressure on the document and also from taking the passport away too soon. However, not having a digital mirror in front of the camera is a missed opportunity. Without such a device the passengers are unsure where to look to have their facial image captured.

Social Informatics and HCI researchers have identified the exclusion of people who will be using a system from the design process as one major cause of system failures. Many designers develop tacit scenarios of the ways they imagine people will use systems that often differ significantly from actual conditions and uses (Oostveen et al. 2013). To investigate users' motivations and to understand their needs, desires, and fears it is recommended that designers and engineers involve users continuously throughout the development process. End-users are increasingly active participants, not just passive recipients of new technologies. Only through identification of the user requirements of both the passengers and the border guards, will it be possible to achieve the user satisfaction that leads to the success of any new system.

Looking at the two automated border control systems we see that the man-machine interface of e-gates is still under development. One important lesson to learn is that continued usability testing with real

users AFTER implementation is very important and will further enhance the system. The emphasis at Airport B on usability and its ongoing testing means that the current system is continuously being improved. As one respondent remarked: *"What we could not test of course, was the passenger behaviour. You only notice it when you're operating the gates. Things come up which we have not thought of, or that we see 'that could be better'"*.

User acceptance requires that the users perceive a real need for the e-gates (e.g. convenience) and that the system is easy to use. This is particularly true when the users need to interact with new technologies infrequently or in unusual complex situations, such as travelling in an unknown context, under stress and fatigue (Pirelli, 2009). Currently, major component differences make it difficult for users to know how to interact with unfamiliar and dissimilar e-gates. Standardization will be key to improve the usability for travellers and will raise user confidence. Positive experiences of users are vital as they lead to repeated use, and can have a favourable impact on the uptake of the technology by current non-users through word-of-mouth endorsement. Our study has shown that there is clearly scope for a better designed system with a more intuitive interface, which will enhance the usability and increase the overall appeal of e-gates for passengers.

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