Poster: User Centered Design and Evaluation of an Eye Movement-based Biometric Authentication System

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1. INTRODUCTION

Biometric authentication systems offer advantages over knowledge-based and token-based systems because they do not require users to remember anything or carry a physical object. However, usability and acceptability issues have often been neglected in favor of optimizing technical performance. We present work-in-progress on the design and development of a novel biometric authentication system. The system uses eye tracking to generate a "gaze print" that reflects unique physical properties of the user's eye and surrounding muscle. Our development process focuses equally on technical performance and usability. This poster describes the first stage of an iterative process of designing the the user interface for this system, and outlines initial findings from a usability study employing low fidelity prototypes.

2. BACKGROUND

Interest in usability problems associated with biometric security systems has increased in recent years [3]. Usability problems, if left unaddressed, can make the security system more vulnerable to attack. Despite this, these concerns have often been a low priority in development process for biometric systems.

Studies investigating the viability of using eye tracking data for authentication [1, 2, 4] report experiments in which users were shown a visual stimulus while their eye movements are recorded using an eye tracking system. Various features were extracted from the movement data, and the classification accuracy achieved by several different algorithms was compared.

The system we are developing builds on a technique explained in greater detail in earlier publications [5]. Instead of feeding features extracted from the eye movement directly into classification algorithms, our system fits a mathematical model of the oculomotor plant to the user's eye movement data. The oculomotor plant is the collection of muscles surrounding the eye, and it is hypothesized that the properties of these muscles are unique for each person. In our previous work, we achieved a False Acceptance Rate of 5.4% and a False Rejection Rate of 56.6% with this method. We are continuing to improve the technical performance of the security system in parallel to the work presented in this poster.

3. METHODOLOGY

We are using a user-centered design process for developing the gaze print system. We began by conducting usability tests with a series of low fidelity prototypes, made from paper and cardboard, to learn about the most significant usability issues without yet engaging in the costly development of working prototypes.

In order to present users with a complete security system and to enable them to focus on realistic usability issues, we selected a specific, common context: authenticating bank customers prior to an ATM transaction. ATMs are both high security and widely used. Most study participants would be familiar with using an ATM, and might see value in implementing a secure system in that context. We developed a set of prototype ATM authentication systems and conducted usability evaluations, described below.

3.1 Prototype Development

We developed three prototypes for this study, all of which share a common workflow. They differ only in the step where a visual stimulus is presented to the user and the eye movement data would be recorded, which we term the *verification step*. Each prototype begins with a welcome screen, where the participant's name is shown. Following this is a *calibration step* where the participant advances through a simulated 9-dot calibration routine. Next the verification step is presented, where the user completes a simple task using their eyes to control the interface. Finally, the simulated ATM shows the user a screen where they select a financial transaction.

The verification step is the most significant part of each prototype. We generated a large set of interface ideas, from which we selected three core designs for the verification step. We sought to capture some of the breadth of the design space, so we chose designs that are quite different from one another. Below we briefly describe the verification step for each of the prototypes.

3.1.1 Onscreen Keyboard

This prototype displays a standard QWERTY keyboard, and prompts the user to "eye-type" his or her first name. When the user dwells on each letter, it is added to a text box on the screen.

3.1.2 Ribbon

The ribbon prototype, like the onscreen keyboard, prompts the user to enter the letters of his or her first name. However, the user must select each letter, in order, using a vertically scrolling ribbon. The ribbon is marked with the letters of the alphabet.

3.1.3 Letter Selector

The letter selector prototype displays a blank screen on which each letter of the participant's first name appears. The letters appear one-at-a-time and in order. As the participant dwells on each letter, it disappears and the next letter is displayed. Once all of the letters have been eliminated, the verification step is complete.

3.2 Evaluation

Once we had created the three prototypes, we recruited participants using email announcements and flyers posted in campus buildings. A total of nine people (six female, three male) with a wide range of ages (three in their 20s, four in their 30s, and two in their 50s and 60s) participated in the study. All used ATMs regularly, most about once a month. Only two had any prior experience using eye tracking systems, and most had little or no experience with biometric security.

We asked each participant, during a private video-recorded session in our lab, to withdraw cash using each of the three simulated ATM interfaces. We employed a think-aloud protocol to elicit the participant's reactions to each prototype. After the task was completed with each prototype, we asked participants for additional comments, as well as to compare, contrast, and rank the prototypes after they had completed all three tests. This took about 25 minutes for each participant.

4. FINDINGS

We uncovered a variety of usability problems in our low fidelity prototypes. These will help to guide the next phase of system design, which will involve higher fidelity prototypes using an actual eye tracker.

4.1 Speed of authentication

Several participants reported that the gaze print authentication process took much longer than the PIN-based systems most commonly used by ATMs. For some participants this was the most significant problem. One participant said "I'm kind of focusing on the drawback of the speed of it, since it now adds about six steps or so, as opposed to one screen with four buttons."

4.2 Clear verification step

Some of the participants were confused about which step was which in the prototypes. For example, for those that experienced the Letter Chooser prototype first, the apparent similarity to the calibration step was confusing. Others were confused by the fact that the prototypes asked users to enter the letters of their first names. Because in the most familiar authentication systems (usernames and passwords), the name is not the secure element of the system, participants did not associate entering their name with authentication. Perhaps it would be better to instruct users to enter some other string of characters, or to emphasize authentication in the instructions, for example: "Enter *digital signature* by eye-typing your name." The verification step should be clearly identifiable to encourage users to feel safe and secure while using the system.

4.3 Gaze control problems

Some participants mentioned concerns about how well they would be able to control the interface using their eyes. Some of these issues were inevitable given that almost all participants were completely unfamiliar with eye tracking. One participant said "I'd be concerned if with a real functional one if I'll often get distracted and make glances elsewhere, so I'm worried about an accidental error from staring at something else." For the Ribbon prototype, a participant commented "I'd be worried about it yo-yoing back and forth to get it to select something." Careful attention must be paid to tuning gaze-based interaction to ensure that the user feels in control of the interface.

4.4 Transitions from touch to gaze

The prototype ATM interface began with a touch-controlled interface, as is typical for modern ATMs. The verification step, however, was gaze controlled. We indicated this transition using a labeled icon in a corner of the screen. However, we found that most participants either did not notice or did not understand this indicator. One participant suggested dedicating one part of the screen to the touch controls, while reserving another part for gaze-controlled elements. Indicators for which type of interaction is currently active should be clear and impossible to miss.

4.5 Visual simplicity

We found that even with this low fidelity prototype, participants were concerned about the interfaces being too complex to be controlled by gaze. For example, the Onscreen Keyboard and Ribbon prototypes were perceived as much more complex than the Letter Chooser. For this reason, the Letter Chooser was preferred by several participants. It presents only one interface element at a time, making it relatively easy for users to control with their eyes. We will stress visual simplicity in future designs of these interfaces.

4.6 Supporting predictability

For the Letter Chooser, as well as for the calibration interface, one issue that surfaced for several participants was the pattern in which targets appeared. For the 9-dot calibration, dots appeared in a left-to-right, top-to-bottom order. For the Letter Chooser, the letters of the participant's name appeared from top-to-bottom, then right-to-left. Several participants noticed this difference and found it confusing. Other participants were not sure whether the order was supposed to be random, or whether there was a pattern. For future prototypes we will consistently use left-to-right then top-to-bottom order for these interfaces.

5. CONCLUSION

While others have investigated eye movement-based security systems, no prior work that we are aware of has studied their usability or integrated user feedback into the design process, which is essential to developing successful biometric security systems. We have described our implementation of a user centered design process for developing a novel user authentication system based on eye movement, and presented initial findings from our usability tests with low fidelity prototypes.

6. ACKNOWLEDGMENTS

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