Video-Passwords: Advertising While Authenticating

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ABSTRACT

We introduce a new class of authentication schemes called "video-passwords", which require the user to watch and remember parts of a given video (e.g., a sequence of scenes, movements, and/or sounds). We propose four different video-password schemes, describe their prototypes, and analyze their security. Under certain parameters, the security of some of these schemes appears to be theoretically comparable to traditional text passwords. Video-passwords provide more than potentially better security; they also present a unique opportunity for businesses to consider – advertising through the rich multimedia used in the login task. We suggest that the adoption of new schemes, such as video-passwords may be more likely in the presence of monetary incentives provided through advertising; we also discuss some ethical issues that may arise from such incentives.

Categories and Subject Descriptors

K.6.5 [**Management of Computing and Information Systems**]: Security and Protection—*Authentication*; H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems—*Video*

General Terms

Security, Human Factors, Economics

Keywords

Video-Passwords, Passwords, Video, Advertisement, User Authentication, Security

1. INTRODUCTION

Traditional text passwords have well-known shortcomings, such as vulnerability to being guessed by attackers [36] and memorability issues [1] that lead to password re-use across accounts [18]. Password policies continue to become more strict, leading to other usability issues [20]. These weaknesses have motivated many new alternatives to passwords, with the goal of improved security and usability. Of these, some biometrics [21] and physical tokens [30] appear to have very good security and usability properties, but for various reasons, including the cost of deployment, text passwords remain much more popular [19]. When cost is a reason that keeps organizations from adopting an alternative scheme to replace text passwords, we suggest that the adoption of a new scheme may be more likely in the presence of monetary incentives. At first glance, this seems unlikely, as who will pay such incentives? However, what if there were a reasonably secure and usable new alternative to text passwords that is not only cheap to implement, but also provides the benefits of advertising and/or making revenue? We propose video-passwords that are, to the best of our knowledge, a novel alternative to text passwords that have this potential.

In this paper, we propose and analyze video-passwords, which use rich multimedia in the authentication process. The goal is to make use of the rich information of multimedia to provide stronger "cues" for the user's memory, which we hope will in turn help users create strong passwords. Human memory has been shown to have stronger performance when aided by "cues" such as images and words [34]; we hypothesize that richer multimedia cues such as video scenes, video movement, and audio sounds will help similarly. This motivates us to propose video-passwords.

Video-passwords require a user to select parts of a video as his or her password. The scenes, movement, and sounds in a video work as cues for particular parts of a video. For example, a video-based password scheme could require the user to remember a sequence of *times* on a particular video, cued by particular audio sounds or visual scenes that occur at those times. These times could be used alone (see Section 4.2), or combined with other types of information. Examples of other types of information that can be used in video-passwords include visual-spatial (see Section 4.3) and textual (see Section 4.4). In all cases, the distinguishing elements of a video-password from any other knowledge-based authentication method is that video-passwords present a video to the user, from which audio and visual cues are used upon setting a "video-password". Upon subsequent logins, these cues are involved in helping the user recall his or her "video-password". In a video-password scheme, the video itself is an integral part of the login process. For example, a login page that simply contains a password field with a video playing beside it would not be considered a video-password. We provide a formal definition of video-passwords in Section 2.

We propose four different video-password schemes in Section 4. The specifics of what is stored and checked as a video-password is highly dependent upon the scheme; e.g., one of our schemes (*Timeline Video-Passwords*) use only a set of times recorded (i.e., timestamps) along a timeline as the password, another (*Click-Based Video-Passwords*) includes selecting visual (x, y) coordinates on a user's chosen scene in a video, and another two (*Tagged Video-Passwords* and *Tagged-Click Video-Passwords*) involve "tagging" a part of the video at a user-chosen timestamp. We discuss these schemes in further detail in Section 4.

We analyze our proposed video-password schemes in terms of their theoretical security and also attempt to provide some more reasonable security estimates. Two of our proposed schemes (*Click-Based Video-Passwords* and *Tagged-Click Video-Passwords*) have sufficient theoretical security under reasonable parameters to offer a possible replacement for traditional text passwords; *Timeline Video-Passwords* appears to have the potential to be a replacement for PIN numbers. We provide more reasonable estimates of their security where possible, but user studies will be required to show the effective security they would realistically offer in practice.

Our Contributions. To the best of our knowledge, this paper introduces video-passwords for the first time. We also propose four specific video-password schemes, discuss some relevant usability challenges, analyze the theoretical security (and also some more reasonable estimates), and consider practical issues to consider in deployment. Additionally, this paper introduces a new idea of advertising while authenticating using schemes that involve rich multimedia. While this possibility is exciting in that it may offer incentives for organizations to adopt video-password schemes, advertising while authenticating is an idea that may have ethical implications; we encourage open discussion of any such issues and begin this discussion herein.

The proposals, ideas, and theoretical analyses we present in this paper point towards a number of interesting directions for further exploration, each of which will require a thorough investigation. These directions include evaluating the usability of each video-password scheme and the security impact of "hot-scenes" (video scenes that are more popular than others); these evaluations will provide context regarding appropriate parameters and environments for video-password schemes (for further discussion, see Section 8). These directions also include investigating how to best design video advertisements (or other videos) that do not weaken the security or usability of the system. Of course, video-passwords could be used with other types of videos that might be useful for other purposes (e.g., for educational purposes).

The remainder of this paper is organized as follows. We define video-passwords more precisely in Section 2 and discuss related work in Section 3. In Section 4, we discuss four video-password schemes that we call *Timeline Video-passwords* (Section 4.2), *Click-Based Video-passwords* (Section 4.3), *Tagged Video-passwords* (Section 4.4), and *Tagged-Click Video-passwords* (Section 4.5). We analyze the security of these four schemes in Section 5 and discuss some implementation challenges in Section 6. We begin the broader discussion of advertising while authenticating in Section 7. We discuss our plans for evaluating the usability, security, and user perception of video-password schemes in Section 8, and end with concluding remarks in Section 9.

2. DEFINING VIDEO-PASSWORDS

Video-passwords are a new class of knowledge-based authentication mechanisms that require a user u to watch a video v_u and remember parts of a video. There are many possible video-password schemes that belong to this class, which use different types of information (e.g., timestamps, text, click-points, and drawings) as part of a user's authentication secret. In other words, a particular video-password scheme (e.g., *Click-Based Video-Passwords*) requires a user u to remember some specific types of information (e.g., timestamps and click-points) cued by video v_u. In this Section, we first review these types of information, and then use these types to define video-passwords. The types of information that can be used in video-passwords, include:

- **Timestamp information.** If we view a video as a timeline, there are many possible timestamps t along this timeline at which different scenes, sounds, and movements occur. Each timestamp can be chosen as a part of the user's secret. More precisely, each timestamp $t \in T$, where T is the set of all possible timestamps. This information type is required for a scheme to be considered a video-password scheme; all others explained below are optional.

- **Text information.** Typed text information can be used in a video-password scheme, e.g., by "tagging" parts of the video with one or two words or sentences. Each tag s is a string that contains one or more words, and the number of words used will likely be related to the policies of the particular scheme using this information type. We denote the set of all possible tags by S. This information type is analogous to a password or passphrase [23].

- **Click-point information.** Click-points are (x, y) coordinates within the video screen that a user clicks on with a mouse, or touches on a touch-screen. The number of possible (x, y) coordinates is related to the resolution of the video (i.e., the width × length of the video display screen in pixels). We denote the set of all possible click-points by C. This information type has also been used in click-based graphical password schemes (e.g., PassPoints [37] and PCCP [13]).

- **Drawing/gesture information.** Drawings (sometimes referred to as gestures [32]) can be added as yet another information type. Drawings could be made on a part of a paused video, using a grid overlaid on the still image. Thus, this information type will be recorded as the sequence of grid cells that the drawing passes through. We denote the set of all possible drawings by D. Using drawing information for authentication has also been proposed on a background grid for an earlier scheme called Draw-A-Secret [22] and on a background image in another scheme called Background Draw-A-Secret [17].

We classify a video-password scheme by the types of information it uses. The one information type that must be present in order for a scheme to be considered a video-password scheme is the timestamp information. Let $\mathcal{I}$ represent the Cartesian product of the sets of information types used by a particular video-password scheme. For example, $\mathcal{I} = T \times C$ for a video-password scheme that uses both timestamps and click-points and $\mathcal{I} = T \times S \times C$ for a video-password scheme that uses timestamps, tags, and click-points. Similarly, when the video-password only uses timestamps, $\mathcal{I} = T$.

Definition of video-passwords. We define a video-password $P = (\omega_1, \cdots, \omega_n)$ which is a sequence of n pieces of video-related information ω_i where $\omega_i \in \mathcal{I}$ for all $1 \leq i \leq n$.

For example, in a video-password scheme that uses both timestamps and click-points, $\omega_i \in \mathcal{I} = T \times C$. So $\omega_i = (t_i, (x_i, y_i))$ and $P = ((t_1, (x_1, y_1), \cdots, (t_n, (x_n, y_n))$.

2.1 General Video-Password Usage Scenario

Here we describe two phases of video-password selection and login for video-passwords, in general terms. As mentioned earlier, in all video-password schemes, the timeline information is the one required information type; all other information types can be used with the timeline information in different combinations to produce different schemes.

Video-password selection. A video-password is set by a user u watching a video v_u, which they have the ability to navigate through, pause, play, and re-play as they wish. While watching the video v_u, the user u is asked to select a set of times, which is recorded as a set of timestamps $\{t_1, t_2, \ldots, t_n\}$. These timestamps can be selected and remembered based on the scene, movement, and/or sound events that occur in v_u at that time. Depending on the scheme, the user may also be asked to select a set of other additional information (e.g., click-points, tags, drawings) at each time t_i which together form a piece of video-related information ω_i. We denote the resulting video-password that is stored and recorded as $P = (\omega_1, \ldots, \omega_n)$. For example, if the user was asked to pick a click-point and tag a word in each timestamp, we have $\omega_i = (t_i, s_i, (x_i, y_i))$ and can write the video-password as

$$P = \Big(\big(t_1, s_1, (x_1, y_1)\big), \ldots, \big(t_n, s_n, (x_n, y_n)\big) \Big)$$

where s_i and (x_i, y_i) represent the selected (and recorded) tag and click-point at timestamp t_i respectively.

Video-password login. To login, a user u must watch the same video v_u again, and input P', which the user can remember based on the events that occur in v_u at that time. If P' is approximately equal to P, the video-password will be accepted by the system. By "approximately equal", we are referring to the need for error tolerance, denoted by τ, on the timestamps that the user selects during video-password selection. More specifically, if we denote the i^{th} timestamp in input $P^{'}$ by t_i', then $t_i^{'}$ is acceptable by satisfying $|t_i^{'} - t_i| \leq \tau$. Based on our own preliminary testing with a video-password implementation (described in Section 4.2), we suggest $\tau = 0.5$. E.g., if the first timestamp $t_1 = 4.005$, it would be acceptable if the user re-entered $t_1^{'}$ between times 3.505 and 4.505. Of course, it is possible that the specific error tolerance may need to be adjusted after formal user studies with the system.

In order to accomplish an error tolerance of τ, and still be able to hash the password for secure storage, some form of discretization will be necessary to encode a user's timestamps. Timestamps can be discretized using a method of discretization used in another context: click-based graphical passwords [12], where instead of using a set of a 2-dimensional grids (where each grid is composed of grid cells) we are using a set of 1-dimensional timelines (where each timeline is composed of time slots).

If ω_i has some other additional information besides t_i in P, they must also be checked to determine that P' is approximately equal to P. We propose using the same checking methods as the authentication mechanisms that inspired these additional elements: for text information, an exact match can be performed (as in traditional text passwords), for click-point information, robust discretization [7] or centered discretization [12] can be performed (as in click-based graphical passwords), and for drawing information, a grid overlay can be used (as in Draw-A-Secret [22] and Background Draw-A-Secret [17]).

3. RELATED WORK

All variations of video-passwords are a form of knowledge-based authentication, meaning that they are based solely on "what the user knows". Traditional text based passwords are, of course, the most popular form of knowledge-based authentication. It has been well-known for many years that there are problems with text-based passwords relating to their memorability and vulnerability to being guessed by an adversary [39]. Other work has recently demonstrated that the problems with text-based passwords are even worse than previously believed, in terms of vulnerability to guessing attacks [36, 8], and there is an increasing burden being placed on users by unusable password policies [20]. These continued findings of problems in traditional text-based passwords motivate our work on alternative authentication schemes such as video-passwords.

Many other alternatives to traditional text-based passwords have been proposed over the last 10-15 years. Graphical passwords is the most closely related; they make use of a single medium (images) in the authentication process, as opposed to the rich multimedia used in video-passwords. There have been many variants of graphical passwords proposed; see Biddle et al. [5] for a comprehensive survey. Although graphical passwords do not offer the same potential for advertising through authentication, we review them by some general categories and some representative schemes, drawing relationships to video-passwords where applicable and possible.

We use the graphical password schemes categorization of Biddle et al. [5]: recall-based, recognition-based, and cued-recall. These categories are sometimes called other names; De Angeli et al. [2] called these categories by the following names: drawmetric, cognometric, and locometric respectively.

Recognition-based graphical password schemes generally require the user to recognize one or more images from a larger set. This category includes PassFaces [29, 11], which requires users to recognize a set of human faces from a larger set presented. Other recognition-based schemes include Déjà Vu [16], which requires the user to recognize a set of random art from a larger set presented, and Story [15], which requires the user to recognize a set of images (of people, food, and objects) from a larger set presented. Our Timeline and Tagged Video-password schemes may be considered as containing recognition-based tasks that are similar to recognition-based graphical passwords; if the user is using visual cues in scenes (instead of audio cues), they are effectively using visual recognition to cue the timeline points entered. Recognizing a sound as a cue can also be considered a type of recognition-based task.

Cued-recall based graphical passwords are sometimes called "click-based" graphical passwords, as they often present the user with one or more background images, on which they click a sequence of (x, y) points. One of the first such schemes was PassPoints [37], whereby the user was presented with a single background image and asked to remember on a sequence of 5 points. Cued-recall graphical passwords have appeared commercially by PassLogix [28]. Other variants have been proposed such as PCCP [13], whereby the user clicks on each of a sequence of background images and is persuaded to choose more secure points through user interface enhancements. Our Click-Based Video-password scheme has similarities to click-based graphical passwords, in that a user is asked to click on a scene in a video, which is similar to the task of clicking on an image; however clicking on a video scene records the video scene's timestamp as well as the click-point coordinate. In both video-password and graphical password cases, the user is cued by a background image (in the video-password however, there will also be a number of cues leading up the scene, which may also provide additional cues to aid the user's recall).

Drawing-based graphical passwords ask the user to create a drawing as his or her authentication secret. Examples of a drawing-based graphical password schemes include Draw-A-Secret [22] and Pass-Go [33], which ask users to draw a password on a background grid. A variation of this idea called Background Draw-A-Secret [17] displays the background grid over a still image, which appears to offer security and usability advantages. GridWord [4] is a related scheme in that it displays a grid to the user and they have the option of selecting a few grid cells as their password (it also provides the option of entering a few text-based words if the user prefers). Other drawing-based password schemes include Android phones' password pattern [3], and a variation that has appeared as an option in Windows 8 [32], which is similar to Background Draw-A-Secret (BDAS) [17] in that it asks the user to draw on the background image. As discussed in Section 2, a video-password scheme could incorporate drawings into its design, such that a user draws on a paused scene, similar to the user drawing on a background image in BDAS; however, the timestamp of the scene will also be recorded in a video-password, which theoretically adds more security.

Another alternative to passwords is *OBPwd* [6], which requires a user to remember the location of a digital object (e.g., a file on the local computer or on the web); the ObPwd application hashes the object and converts it to a text password for the user to copy and use. This scheme is very interesting, but quite different than the video-passwords we propose, as even if a user decides to choose a video file as his or her OBPwd, the user does not watch the video as part of the OBPwd login process. If the user does not watch the video as part of the login process, there is no opportunity for advertising.

More loosely related work, which does not focus on authenticating individual users, includes video CAPTCHAs that aim to distinguish humans from computers. One video CAPTCHA scheme involves the user viewing a video and typing a few words that describe its content [25]. Other CAPTCHA schemes involve the user watching a video with a word moving across it, and then typing the moving word [38]. If a user performs these tasks accurately (which are difficult for computers to do), they are considered human and allowed to proceed with e.g., account creation.

4. SOME VIDEO-PASSWORD SCHEMES

As discussed in Section 2, video-passwords are a class of authentication schemes that present a video to a user, which is used by the user to recall their login information. In this section, we discuss a few initial video-password schemes. These schemes have some common usability considerations; we discuss these in Section 4.1. The first scheme we consider is the simplest form of video-passwords; it only uses timestamp information (e.g., a sequence of distinct times on the video) and thus we call it *Timeline Video-passwords* (Section 4.2). The second scheme we consider uses the timestamp information combined with spatial information from the visual scenes (as in click-based forms of graphical passwords); we call this variant *Click-Based Video-passwords* (Section 4.3). The third scheme uses the timestamp information and additionally uses a text information to tag one or more distinct times on the video timeline; we call this variant *Tagged Video-passwords* (Section 4.4), and the fourth scheme uses text information to tag one or more distinct click-points on the video; we call this variant *Tagged-Click Video-passwords* (Section 4.5). We discuss our prototype of these schemes, describe our initial designs, and discuss some usability considerations.

4.1 General Usability Considerations

Video-passwords have a few general usability considerations, regardless of the details of the particular scheme. Each of the video-password schemes we consider have some common user interface elements, all related to the general viewing and navigation of a video. We believe the following considerations are required for a successful user experience in any video-password scheme (see the following elements numbered also on Figure 1):

1. **Time display.** The user should be able to see how many seconds have lapsed in the video's play. For example, if the user knows that they chose all of their timestamps after the 20-second mark, they should be able to navigate to that time (through the fast timeline scroll feature described further below) and see that they have successfully navigated to the desired time.

2. **Play/pause button.** Videos can be fast-paced, so the user should be able to control viewing the video, and have the ability to pause it if needed. For example, if the user begins watching the video v to login, and must attend to something else for a moment, he or she should be able to pause the video and play it again when ready.

3. **Fast timeline scroll, with an automatic visual update.** The user should be able to quickly focus on a particular part of the video that he or she knows its approximate point in the timeline. For example, if the user knows his or her first timestamp is just after the middle of the video, this feature will allow an initial quick jump to the middle of the video.

4. **Rewind button (with fine-grained control).** If the user wishes to watch a particular part of the video again, they should be able to do so. For example, if the user recognizes the scene that corresponds to timestamp t_2 before inputting t_1, he or she knows that the first point was missed and should be able to rewind.

5. **Fast-forward button (with fine-grained control).** If the user wishes to focus on scenes of the video they know occur at a later time, they should be able to fast-forward through irrelevant scenes. For example, if the user recognizes that the video was rewound too far, he or she can fast-forward to the desired scene.

6. **Feedback.** It is helpful for the user to have some sort of feedback that each timestamp t_i has been selected and registered with the system (at least during video-password selection). We use three methods to accomplish this: (a) The "traffic lights" feature at the lower-right corner of the screen – for each t_i that is recorded, a circle is filled-in and (b) we pause the video for 2 seconds to allow the user to have a moment to commit the scene to memory. Other feedback mechanisms can be added that are specific to the other elements in ω_i that are used in each scheme (e.g., see Section 4.3 for an example when ω_i contains a click-point).

7. **Playback.** To help the user recall his or her password P, we incorporated a video-password playback feature that occurs immediately after password selection. This will replay the video, with the feedback mechanisms specified above added-in to indicate when each timestamp t_i was selected. Additional scheme-specific feedback mechanisms are also replayed in the playback feature.

Figure 1: A video-password interface. The number on each user interface element indicates the point that details it in Section 4.1. The video shown is a UOIT advertisement [35].

Usability considerations that are specific to a particular scheme are discussed within its subsection.

4.2 Scheme 1: Timeline Video-Passwords

Timeline Video-Passwords are the most basic form of video-password in that it only makes use of the video's timeline information. As we will discuss in Section 5, the security it affords under reasonable parameters is comparable to that of PIN numbers.

In this scheme, the user's task is to watch a short video, and choose a set of timestamps $\{t_1, t_2, \ldots, t_n\}$ on the video timeline (i.e., $\omega_i = t_i$). The user is cued by the audio sounds and video scenes/movement that occur during those times, and presses a button (or the spacebar) to input those times to the system. One can view the video as a mnemonic to help the user to recall a set of times along a timeline. See Figure 2 for an example. The user's video-password is recorded as the set of timestamps $P = \{t_1, t_2, \cdots, t_n\}$.

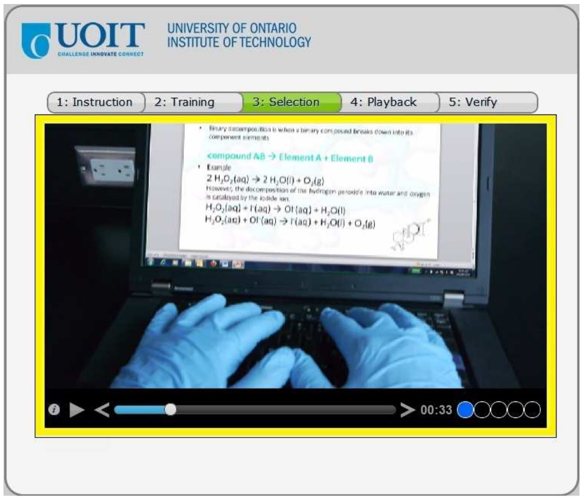


Figure 2: Example of *Timeline Video-passwords*, where the user is entering $\omega_1 = t_1$. The border around the video screen is the spacebar press indicator. The border is yellow when viewed in color. The video shown is a UOIT advertisement [35].

Parameters. In order to be comparable in terms of login time to other alternatives to text passwords (e.g., click-based graphical passwords [37, 13]), we suggest a video duration of 30 seconds. The other parameter is the number of timestamps that the user must remember along the timeline; these are distinct pieces of information, thus the more timestamps we ask a user to recall, the more difficult it should be for them to remember the password. We suggest a maximum of $n = 4$ timestamps that a user recalls in a video-password.

Specific usability consideration: spacebar press indicator. It is helpful for the user to have some sort of additional feedback that their time has been selected and registered with the system. We use one additional method (on top of the general traffic light and pausing methods specified in Section 4.1 to accomplish this: we place a yellow border around the screen while it is paused to frame the scene (see Figure 2).

4.3 Scheme 2: Click-Based Video-Passwords

In Click-Based Video-passwords, the user clicks (or touches, if the user has a touch screen), a point (x_i, y_i) in a particular scene at time t_i. In this scheme, $\omega_i = (t_i, (x_i, y_i))$, so the video-password is $P = \{(t_1, (x_1, y_1)), \ldots, (t_n, (x_n, y_n))\}$. This scheme requires a number of additional user interface considerations to make the system more usable.

1. **Multi-coloured mouse cursor.** We observed that a regular mouse cursor does not stand out enough over a fast-paced video, and that some changes greatly increased its visibility. We modified it to be yellow, round, and slightly larger than a traditional mouse cursor. To allow it to still stand out in areas where the background is yellow (or close to yellow) we set the center of the cursor to be black (see Figure 3).

2. **Click-indicator.** The click indicator provides feedback to the user regarding which point was registered by the system. We kept the feedback mechanism of pausing the video for 2 seconds, and added a "ripple-like" click-indicator, which grows like a ripple when a rock is thrown in water, but then shrinks back down after reaching its maximum size. See Figure 3 for a diagram showing the different phases of the click-indicator.

3. **User recommendations.** We observed that in our own preliminary use of Click-Based Video-passwords, the usability was strongly affected by the video used. For slow-paced videos, it was easy to create a password; however, when the video is fast-paced (i.e., containing many rapidly changing scenes), we needed to pause the video to select a time t before selecting an (x, y) click-point. For any fast-paced video, we suggest recommending this sequence of actions to the users of the system. To facilitate this recommendation, we made pausing the video easier; pressing the spacebar is a shortcut to pause the video (note that this could be any action such as the first tap on the interface in a touch-screen environment), and the video will resume once the user has selected a click-point.

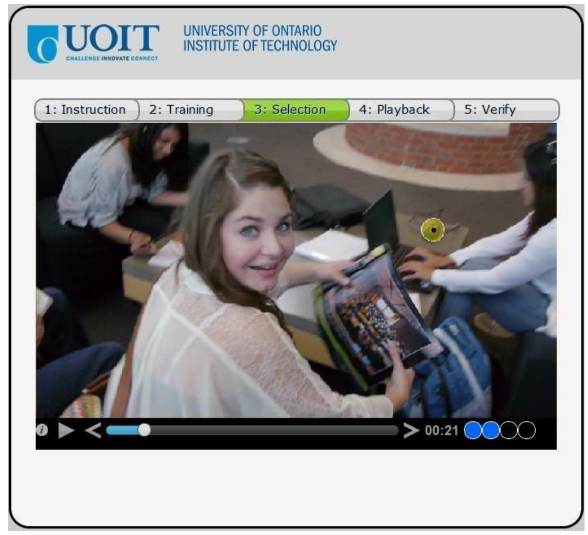
Figure 3: The click-indicator and mouse cursor features for Click-Based Video-passwords. The yellow halo expands like a ripple when a rock is thrown in water, then shrinks back after reaching its maximum size. The mouse cursor looks like the click indicator at its smallest phase.

4.4 Scheme 3: Tagged Video-Passwords

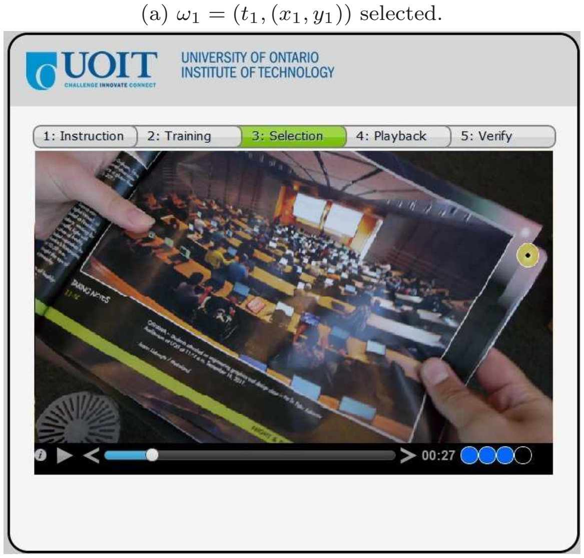
Tagged Video-passwords extend Timeline Video-passwords, such that when a user presses the spacebar, he or she types s_i (a word or pair of words) to "tag" the scene. In this scheme, $\omega_i = (t_i, s_i)$ and the video-password is recorded as $P = \{(t_1, s_1), \ldots, (t_n, s_n)\}$. See Figure 5 for an example.

The only additional user interface feature is a pop-up box in the center of the screen where the user's word(s) are entered. On login, this is replaced by circles as in a traditional text-based password scheme.

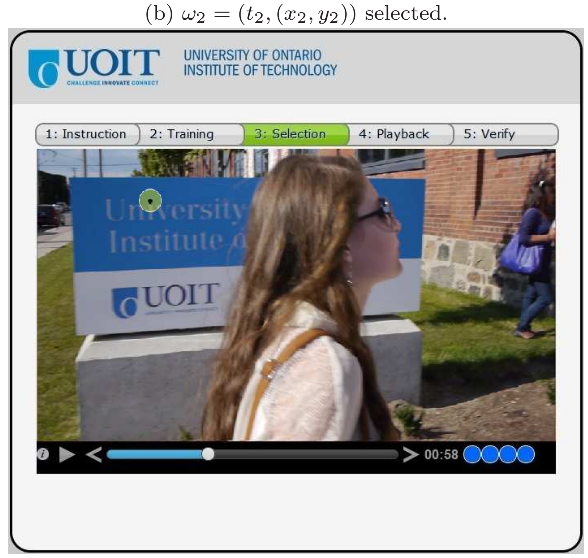
(a) $\omega_1 = (t_1, (x_1, y_1))$ selected.



(b) $\omega_2 = (t_2, (x_2, y_2))$ selected.



(c) $\omega_3 = (t_3, (x_3, y_3))$ selected.



(d) $\omega_4 = (t_4, (x_4, y_4))$ selected.

Figure 4: Example of a password created using *Click-Based Video-passwords*. In this scheme, the password shown is $P = \{(t_1, (x_1, y_1)), (t_2, (x_2, y_2)), (t_3, (x_3, y_3)), (t_4, (x_4, y_4))\}$. The yellow halos of the click-indicator were manually circled in white to make them more visible for print. These halos show the click indicator (see Figure 3) at its largest phase. The video shown is a UOIT advertisement [35].

Figure 5: Example using *Tagged Video-passwords*, where the user is entering $\omega_1 = (t_1, s_1)$. The video shown is a UOIT advertisement [35].

4.5 Scheme 4: Tagged-Click Video-Passwords

Tagged-Click Video-passwords combine tags with Click-Based Video-passwords, such that when a user enters a click-point, he or she types s_i (a word or pair of words) to "tag" the click-point. In this scheme, $\omega_i = (t_i, (x_i, y_i), s_i)$ and the video-password is $P = \{(t_1, (x_1, y_1), s_1), \ldots, (t_n, (x_n, y_n), s_n)\}$. This scheme uses the combined user interface features of Tagged Video-passwords and Click-Based Video-passwords.

5. SECURITY ANALYSES

Here we analyze the theoretical size of the password space of each of the video-password schemes we present in this paper. We also analyze how different parameters will affect the security that it can offer. We show that, under certain parameters, Timeline Video-passwords is comparable to PIN numbers. We also show that Click-Based Video-passwords and Tagged-Click Video-passwords, under certain parameters and assumptions are comparable to traditional text passwords. Note that all of our analyses assume that users will not be allowed to choose any ω_i that overlap with each other on the video timeline; the effect is a slight underestimate of the security for video-password systems that allow overlapping ω_i.

5.1 Timeline Video-Passwords

To estimate the theoretical space of video-passwords created with Timeline Video-passwords, we first consider whether it is possible for a short video to contain a sufficient number of events that can be used as a cue for a particular time in the video. To this end, we counted the number of distinct events (audio and visual) that we could detect from 4 different videos. We detail our counting results below in Table 1. In Table 2 we show our results for different values for n (the number of timestamps in T), where $n \leq 4$, for the number of events we could detect from each of the 4 videos.

We use the number of counted events to determine what could be the maximum theoretical number of Timeline Video-passwords on each of these videos. We calculate this based on m (the number of counted cues) in each video, and n (the number of times the user selects). The resulting number of possible passwords is shown in Table 2, calculated by the number of combinations $C(m, n) = \binom{m}{n}$.

From Table 2, we can see that the maximum number of possible passwords we can expect is 720720 (when $m = 66$ and $n = 4$). This is much more secure than a PIN number, but still not sufficiently secure to be a replacement for passwords.

We must also consider the security impact of allowing an error tolerance τ, which is a necessity for the scheme's usability. In Table 3, we show the theoretical maximum number of distinct timeline points that can be provided when the error tolerance is 0.5 seconds (before and after each point). In a production system, the error tolerance can be achieved using timeline discretization, as discussed in Section 4.2.

In Table 3, we consider different video durations and assume a 0.5-second error tolerance (i.e., $\tau = 0.5$) to obtain a maximum number of possible cues. To obtain an upper-bound on the security that this scheme can provide, we consider that each second (on the half-second) could be selected as a distinct (non-overlapping with any other) timestamp (i.e., $\{0.5, 1.5, 2.5, \ldots \ell - 0.5\}$ seconds, where ℓ is the duration of the video in seconds).

Video duration	# cues⋆	$n = 2$	$n = 3$	$n = 4$
30-second video	30	8.76	11.99	14.74
60-second video	60	10.79	15.06	18.9
90-second video	90	11.97	16.84	21.28
120-second video	120	12.8	18.1	22.97
150-second video	150	13.45	19.07	24.27

Table 3: Theoretical size of password space, accounting for error tolerance, for Timeline Video-passwords. ⋆ These calculations assume an error tolerance of 0.5 seconds, and that events are uniformly distributed in all possible times in the entire video. All values provided are log_2 of the cardinality of the password space under the specified parameters.

As we can see from Table 3, if we want the scheme to be more secure than a PIN number, and we choose to keep our video at a 30-second duration, we must ask users to choose $n = 4$ times on the video timeline. Reducing n can provide enough security if the video duration is longer, e.g., a 60-second video with $n = 3$. For $n = 2$, the video duration must be approximately two and a half minutes before it is comparable with a PIN number. We consider video durations that are longer than 30 seconds as it may still be usable if users make use of the fast-timeline scrollbar to quickly jump to different parts of the video.

In this analysis, we do not consider the effect of "hot-

Source	Total number of cues	Number of audio cues	Number of visual cues
Sampled Video 1: New York Subway Yard	40	17	23
Sampled Video 2: Kitchen Junk Drawer	66	24	42
Sampled Video 3: Book Shelf	65	25	40
Sampled Video 4: Hot Air Balloons	36	5	31

Table 1: Counting results from 4 videos that use different camera techniques: static camera with moving objects, panning camera with static objects, and panning camera with moving objects.

Source	m (number of counted cues)	$n = 2$	$n = 3$	$n = 4$
Sampled Video 1: New York Subway Yard	40	780	9880	91930
Sampled Video 2: Kitchen Junk Drawer	66	2145	45760	720720
Sampled Video 3: Book Shelf	65	2080	43680	677040
Sampled Video 4: Hot Air Balloons	36	630	7140	58905

Table 2: Size of password space for Timeline Video-passwords. All calculations use the manually counted number of possible cues.

scenes" (i.e., scenes that are more popular choices than others). The effect of hot-scenes may reduce the estimates we provide in this section, but their effect should be compared to the effective security of PIN numbers when considering patterns in user choice [10]. In future work, we plan to analyze the effect of hot-scenes by conducting a user study.

5.2 Click-Based Video-Passwords

Here we analyze the security impact of adding an (x_i, y_i) click-point to each t_i. The theoretical security that this will offer is related to the number of possible points at each time that the user is likely to choose. A video's scenes can be constantly changing, and at best, the scene will completely change each second; at worst, it will only slightly change each second. The reality is highly dependent upon the video, so here we consider a fast-paced video with many scene changes for a high estimate and a static image for a low estimate.

High Estimate

To create a realistic "upper bound" set of assumptions, we observed the first 30 seconds of a fast-paced music video [26] to determine how often the scene completely changes; we observed scene durations ranging from 0.5-2 seconds, with the majority lasting approximately 1 second, and an average scene length of 1.2 seconds. We use the simplifying assumption that no visual changes are happening in each scene (although in reality, there are a number of things changing such as people or objects moving, so this simplifying assumption should provide an underestimate regarding the number of distinct places a person may choose and recall based on an event).

We assume a video resolution of 451×331 and an error tolerance of 10 pixels in any horizontal or vertical direction, for comparison to previous studies on click-based graphical passwords [27]. We note that in our own informal testing of the system, this error tolerance of 10 pixels worked well, but we may find in our planned user studies that this parameter should be relaxed to be more generous for usability reasons. Using these parameters, there are theoretically 395 distinct points that a user can choose, but there are likely some areas that are more popular than others (i.e., "hot-spots"). We use the estimate provided by a click-based graphical password study [27] of 111 as a more realistic number of spots on an image that a user might click.

Low Estimate

To create a lower-bound set of assumptions, when a very slow-paced video is used for Click-Based Video-passwords (i.e., a video with very few audio or video cues – we assume only one of either type of cue every 6 seconds), we use the same estimate of 111 spots on an image from a click-based graphical password study [27] that used a single background image.

# points	# scenes	$n = 1$	$n = 2$	$n = 3$	$n = 4$
414	30	13.6	26.2	38.22	49.82
111	27	11.55	22.10	32.06	41.61
111	5	9.12	17.23	24.76	31.86
30	15	8.81	16.62	23.85	30.65
10	27	8.08	15.15	21.63	27.69

Table 4: Size of password space for Click-Based Video-passwords. The first row is the theoretical size, and the remaining rows are estimates. All values provided are log_2 of the cardinality of the password space under the specified parameters.

Table 4 shows the results (log_2) for considering high and low estimates for the number of scenes and number of distinct (x,y) points that a user can click in any given scene. The theoretical maximum is shown in the first row, showing that it can produce at most $2^{49.82}$ passwords with the assumed reasonable parameters of a 30-second duration video with a 431×331 resolution, a 10 pixel error tolerance (for each x_i and y_i) (this result is lower but still comparable to the $2^{52.5}$ possible 8-character passwords with special characters, numbers, and uppercase characters). Our more reasonable estimates show a range between $2^{41.6}$ passwords (for 111 possible distinct (x_i, y_i) points and 27 distinct scenes) and $2^{27.69}$ passwords (for the worst-case scene detail of only 10 possible distinct (x_i, y_i) points but 27 distinct scenes). We include the other values to show that even if we assume very few points on each scene will be chosen, with a reasonable amount of scene variation or audio cues in the video, we can still have a system with a password space of 2^{30} possible passwords. With recent estimates of the effective security offered by text passwords (when accounting for the effect of user choice) is actually only around 20 bits [8], even under lower parameters this scheme may prove to be promising in comparison.

Our analyses herein do not consider the probability of any given time and/or (x,y) location on a video being selected by a user, as we do not have empirical estimates of such probabilities yet. We plan to study the effect of such higher-probability "hot-spots" and "hot-scenes" in our future work.

5.3 Tagged Video-Passwords

In this section, we analyze the security impact of using text information with timestamp information. The theoretical security that this will likely offer is related to the number of possible words at each time that the user may choose. We use the same assumptions regarding the number of possible cues that each video can have. We further assume that all tags will contain one or two lower-case dictionary words. For our estimate, we consider only the top 10% most popular dictionary words as defined in the British National Corpus (BNC) word frequency list [24]. This works out to be approximately 94000 words. In Table 5, we show results for the user choosing either one or two timestamps (i.e., $n = 1$ or $n = 2$) and either one or two words in each tag.

We consider longer-duration videos as they may prove to still be usable if users make use of the fast-timeline scroll to quickly jump to known times in the video. We highlight that the results in Table 5 assume that there are 94000 possible words that people would use in their tags. In practice, this may be an underestimate (as there are many more possible words that people could choose or create), or an overestimate (due to likely patterns in the words people choose).

The results from Table 5 indicate that security gains are obtained by adding a tag, and mostly so when each tag contains two words – in this case, the number of possible passwords with two tags (under our assumptions and using a 3-minute long video) is $2^{47.02}$. With a 30-second video, and two tags (each containing two words), this number is $2^{41.81}$. In general, we believe that using a longer video might be possible if we train users to use the fast-scroll bar, but as with all variations we discuss in this paper, usability studies would be necessary.

5.4 Tagged-Click Video-Passwords

As discussed in Section 4.5, we could also combine tagging with Click-Based Video-passwords. We consider this using the same assumptions as in the security analysis of Click-Based Video-passwords from Section 5.2. Our results are shown in Table 6.

The results from Table 6's rows two and three indicate that a password space between $2^{45} - 2^{55}$ is feasible even with a reduced video duration of 30 seconds; a password space of this size is feasible when we set the same tagging conditions of $n = 2$ and two words per tag and incorporate the click-points. Under these parameters, this video-password scheme would be comparable to the theoretical security of traditional 8-character text passwords. We note that when we compare against the theoretical security of text passwords, we are comparing against the best case for text passwords; our estimates only consider 94000 possible tags. That said, we expect patterns to exist in the words that users choose/create for their tags. In the future, we plan to estimate the effective security based on user study data.

6. IMPLEMENTATION CHALLENGES

The use of video opens up new possibilities for what can be done during authentication (both from a security and user interface perspective, and an advertising perspective). We note that there will be some challenges in implementing such schemes in practice (see Section 6.1) and also some policy implementation challenges (see Section 6.2).

6.1 Technical Implementation Challenges

Suitable video selection will be dependent on the particular scheme's task. In order for the user to make use of the timestamp information provided in the video, it must have a sufficient (and well-distributed) number of distinct events (e.g., actions, sounds, or visual changes). This is a consideration that would ideally be solved by filtering videos for suitability, which will require user studies and research into automated video-processing and video complexity analysis.

Video storage and transmission. Businesses that employ video-passwords will ideally need to store a different video for each user to complicate "human-seeded attacks" [27]. This will require additional storage space on the part of the business, who will also need to send or stream this video to the user. We suggest that this can be accomplished most efficiently by having the video sent to the user's machine once, and cached by the user's system. It may also be possible to stream the video from a third-party service to reduce overhead for individual businesses.

6.2 Policy Implementation Challenges

Most of the parameters that we discussed within this paper should be incorporated into video-password policies. We review them below:

- **Video duration.** There is a tension between a "more secure" video that is longer, and one that does not demand too much of a user's time. Selecting a reasonable video duration may depend on how much security the system would like to have, and how well users are educated to understand that they can quickly navigate to a certain point in the video for login.

Video duration	# distinct events	n=1, one word	n=1, two words	n=2, one word	n=2, two words
30-second video	30	21.43	37.95	25.29	41.81
60-second video	60	22.43	38.95	27.31	43.83
90-second video	90	23.01	39.53	28.49	45.01
120-second video	120	23.43	39.95	29.32	45.84
150-second video	150	23.75	40.27	29.97	46.49
180-second video	180	24.01	40.53	30.5	47.02

Table 5: Estimated password space (log_2) of Tagged Video-passwords. ⋆ These calculations assume an error tolerance of 0.5 seconds (before and after), and that events are evenly distributed in all possible times in the entire video. It also assumes that at each t_i, the user will add a tag consisting of one or two words from a space of 94000 possible words.

# (x, y) points	# scenes	$n = 1$, one word	$n = 1$, two words	$n = 2$, one word	$n = 2$, two words
414	30	30.12	46.64	42.72	59.24
111	27	28.07	44.59	38.62	55.14
111	5	25.64	42.16	33.75	50.27
30	15	25.33	41.85	33.14	49.67
10	27	24.6	41.12	31.67	48.19

Table 6: Theoretical security analysis of Tagged-Click Video-passwords. All values provided are log_2. These calculations assume a 30-second video duration and that the tags consist of one or two words from a space of 94000 possible words.

- **Setting an appropriate value for n.** A higher value of n should theoretically make the system more secure, but also puts more strain on the user's memory. Thus, we suggest a maximum of $n = 4$, as there is evidence that the number four is considered to be a limit on the capacity of human memory [14].
- **Ensuring that system owners (and advertisers) create "good" videos.** If a video has very few events of interest, it seems unlikely that a user will be able to use it to produce a strong video-password. Defining what makes a "good" video for use in a video-password will likely be dependent on the actual design of the scheme.
- **Proactive video-password checking.** It is possible that some video-passwords might be common choices (e.g., having all timestamps near the start of the video); this must be determined through user studies. If such common video-passwords exist, they can be disallowed through proactive video-password checking.

6.3 Limitations

As with many other forms of authentication (e.g., graphical passwords), video-passwords will have some accessibility limitations. E.g., for people with visual impairments, the Click-Based Video-passwords scheme will not be sensible; however, the Timeline scheme could be useful, provided the video has a set of detailed and varied audio events. Similarly, people with hearing impairments would not be able to make use of the audio events in a video, but they would be able to make use of the visual scenes.

7. DISCUSSION OF ADVERTISING WHILE AUTHENTICATING

We realized that video-passwords can also be used for advertising when we were experimenting with different videos on our video-password implementations. We observed that some of the videos that were the most enjoyable to create passwords on were actually commercials, movie trailers and music videos. This lead us to realize the potential for this type of authentication to be used as a conduit for advertisement and revenue making. The real advantage of advertising while authenticating from a security perspective is that this additional revenue may help encourage organizations to adopt a video-password scheme, as opposed to the more comfortable option of sticking with traditional text passwords. The rationale is that by providing a monetary incentive, the cost and effort associated with adopting a new scheme will be worthwhile from a business perspective.

A product or service can be advertised to user u through a video v_u, which is presented to u during authentication. This presents a possible solution to one of the challenges in advertising – to successfully draw people's attention and awareness to the advertisement of a product, service, or person. Some surveys have indicated that most users ignore the places on web pages that they have learned contain advertisements [31]. In contrast, in our proposed video-password schemes user u actually needs to pay attention to all of v_u at least once (during password selection), and at least some parts of v_u during subsequent logins. This provides a unique opportunity for businesses to place advertisements in videos that are suitable for video-password authentication.

In videos, advertisement can be covert or overt. Overt advertising is the advertising we are normally aware of, where the purpose of the video is clearly to advertise a product or service (e.g., a commercial). Covert advertising is a different method for promoting products and services that is becoming more popular. In covert advertising, the advertisement is hidden and embedded in the media such that it is not the focal point. One of the most common covert advertising methods is placing product or brand names within videos, where the video contains some visual references to a particular product or service. For example, the use of Nokia cell phones in the movies titled "The Matrix" and "Minority Report".

We here explain different types of advertisement videos which can be used in video-password schemes:

- **Commercials.** Video commercials are produced by an organization/company to overtly market a product or service. These commercials sometimes feature a song that listeners, after repeated exposure, will soon relate to the product. Commercials are usually designed to be short in length and are intended to be broadcast during television programs to increase the audience size. Commercial videos are attractive and short in length, making commercials well-suited for video-password schemes.

- **Movie Trailers.** A trailer is an advertisement for a movie that is short and attractive, containing diverse scenes from the movie; these features make them suitable to be used in video-password schemes. Note that trailers can serve to advertise the movie and can also include covert advertising.

- **Music Videos.** A music video is short video featuring a song and/or singer, which is intended to market a music recording. Music videos directly advertise the song and/or singer, and can also be used for covert advertising.

7.1 Ethical Issues

From a business perspective, advertising while authenticating seems like a fantastic opportunity. When users log on to a web site, the site has an opportunity to advertise their brand, or the brands of others who pay them to use their videos instead. However, there are some considerations that we as a community must discuss. As a starting point for such discussion, we present a few ethical considerations in this section.

First, how do we make sure what a business' first priority is when they are using a video-password scheme? Security or advertising? Is the video-password (including its video selection) done in a way that will create a secure password for the end-user? We believe it is possible for video-passwords to achieve reasonable security, but how users actually choose such passwords must be studied for a particular scheme to be accepted as truly secure. Even once a scheme is found to have good usability and security properties, there are a number of important parameters that should be considered carefully (e.g., length of video, number of memorable events and detail in the video, and number of times that the user must choose). If these parameters align with good parameters for advertising, there is no conflict; but if they don't always align, there is a chance that good security parameters are not used. Ideally, we can determine a set of parameters where they do align, allowing us to create metrics and guidelines that all adopters of video-passwords should use.

Second, will advertising during authentication be acceptable to users? To be acceptable, we expect it is something that must be implemented delicately, and without additional cost to the user's time and effort. Usability studies will be critical to ensuring that advertising during authentication does not annoy users.

Third, if advertising during authentication becomes an option for businesses, it does not mean that it is a system they must adopt. Even if they choose to adopt video-passwords, they do not need to use videos that advertise anything. However, if the majority of businesses do adopt a form of advertising during authentication, what would this mean to the businesses who choose not to? Would they be losing an important advertising edge and thus feel pressure to adopt it too?

We acknowledge that there are likely further ethical considerations, and encourage their open debate.

8. DISCUSSION AND FUTURE WORK

We plan to conduct formal user studies on our prototype video-password schemes. At the time of writing this paper, we have obtained approval from UOIT's Research Ethics Board for studying some video-password schemes we present in Section 4. We plan to study and collect user data regarding the security, usability, and user perception of these schemes.

For security, we plan to examine whether "hot-scenes" occur, i.e., particular scenes in the video that are more popular than others. We expect to see some number of "hot-scenes", but the relevant question is whether their impact would render any of the given schemes insecure. For Click-based and Tagged-Click Video-passwords, we plan to analyze whether there are "hot-spots", both dependent and independent of the scenes. We also plan to study the effect of different videos (in terms of their pace, amount of audio, and amount of visual detail and complexity).

For the usability of each scheme, we plan to examine its memorability, how long it takes for users to enter their passwords given different video durations, optimal values for n, and whether one scheme is more usable than others. We also plan to evaluate acceptability of different video-password parameters and video types (e.g., movie trailers, music videos, and commercials). We also plan to study the usability of Timeline Video-passwords in mobile environments.

The results of future usability evaluations will provide context regarding appropriate parameters and environments for video-password schemes. For example, if studies show that under some parameters a video-password scheme has reasonable usability, memorability, and security, it could be useful as a primary login method for many systems. Alternatively, if studies show that a video-password scheme is less usable in some aspects than text passwords (e.g., having a longer login duration), it could be useful in the following environments: a password recovery scheme in place of commonly used personal knowledge questions, which appear to have questionable security [9], or a primary login method for infrequently used websites (e.g., for which users login once per week). We note that there may be other reasons for some users to find a video-password scheme useful; for example, Timeline Video-passwords may be easier to input for users who are not proficient typists, who use touch screens, or who have visual impairments (if they make use of the audio cues).

9. CONCLUSION

We introduce video-passwords, a new class of authentication schemes that require the user to watch and remember parts of a given video (e.g., a sequence of scenes, movements, and/or sounds). We propose four different video-password schemes, describe prototypes for these schemes, and analyze their security. Alongside its potential security, video-passwords provide a new opportunity for businesses to consider – advertising through the rich multimedia used in the login task.

Our security analyses indicate that video-passwords have the potential to be a promising new class of knowledge-based authentication schemes. The schemes we presented and analyzed all showed differing levels of security, and required different information for a user to recall. For videos with a 30-second duration, the scheme with the strongest theoretical security was Tagged-Click Video-passwords, which had a theoretical password space of 2^{59}. Security estimates using more reasonable assumptions about the video and user choice would still produce between 2^{45} to 2^{55} possible passwords. For videos with a 30-second duration, the Click-Based Video-password scheme also had a theoretical password space ranging from 2^{13} (when one click-point is used) to 2^{49} (when four click-points are used). The Timeline Video-password scheme can offer over 2^{14} possible passwords on videos with a 30-second duration when four timestamps are selected. We have developed prototypes and plan to study the usability and effective security that these video-password schemes offer.

Video-passwords present a unique opportunity to explore the feasibility of advertising while authenticating. The monetary incentives that advertising can have may help encourage organizations and businesses to adopt video-passwords as an alternative to traditional authentication schemes, if video-password schemes are found to have reasonable security and usability in practice. Given the existing barriers of cost to adopt a new form of authentication (at least in terms of training and password resets), such incentives can play an important role. However, we believe that advertising while authenticating is a delicate subject that may have unintended consequences if it is not deployed with care. There are at least some ethical issues for advertising while authenticating; we hope to begin an open discussion of such issues through this paper.

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