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Designing an Intelligent User Interface for Preventing Phishing Attacks

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Abstract. Most phishing sites are simply copies of real sites with slight features distorted or in some cases masqueraded. This property of phishing sites has made them difficult for humans and various anti-phishing techniques to detect. Also, the attacker community has proved itself able to quickly adapt to anti-phishing measures, mainly warning messages to help limit the effectiveness of phishing attacks and protect unsuspecting users. Despite the notable advances made in the last years by the active warning messages for phishing, this attack remains one of the most effective. In this paper we propose an intelligent warning message mechanism, that might limit the effectiveness of phishing attacks and that might increase the user awareness about related risks. It implements an intelligent behavior that, besides warning the users that a phishing attack is occurring, explains why the specific suspect site can be fraudulent.

Keywords: Usable Security, Intelligent User Interfaces, Cybersecurity.

1 Introduction

Phishing is a form of social engineering in which an attacker attempts to fraudulently acquire sensitive information from a victim by impersonating a trustworthy third party [1]. Today these attacks typically employ generalized "lures." For instance, a common phishing attack is (for a phisher) to obtain a victim's authentication information corresponding to one website that is mimicked by the attacker and then uses this at another site. This is a successful attack given that many users reuse passwords – whether in verbatim or with only slight changes. This attack is typically carried out by e-mail or instant messaging, and often directs users to enter details at a fake website [2]. A common example is "we need you to confirm your account details or we must shut your account down". The reason why an individual falls prey to this type of trap is that the message, which appears as the victim expects, and therefore legitimate, directs the user to visit fake webpages whose look and feel is similar or identical to the legitimate one.

This phishing modality is also known as context-aware attack and is becoming increasingly common. **Fig. 1** shows an example of a phishing attack sent to a user by email. The email appears genuine from a trusted sender, i.e. "uniba.it" which is the email service provider of the user. However, visualizing the details of the sender's identity reveals that it was masquerading to get the user to fill a form.

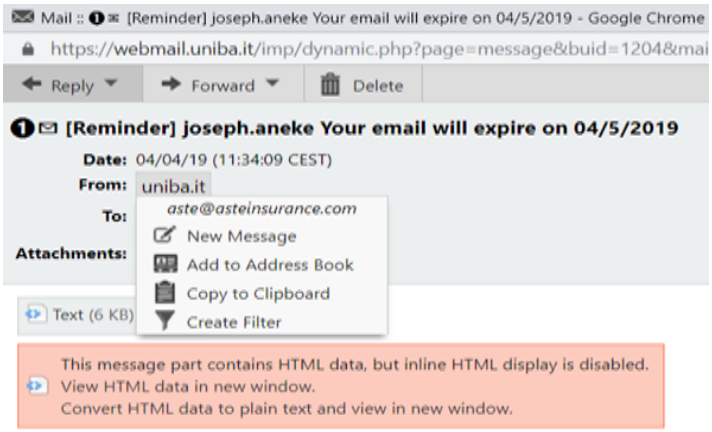

Fig. 1. Example of a phishing attack sent by email.

The effectiveness of phishing techniques, and more in general of cyber-attacks is not only related to the obsolescence of software and hardware. Federal Computer Week reports that almost 59% of security incidents that involve human errors are the result of simple mistakes as opposed to intentional malicious actions [3]. Hosteler found that human error is one of the first cause of cyberattacks (37%) [4]. Furthermore, the simplest and fastest way to start an attack is by means of phishing and social engineering attacks, where 91% of all cyberattacks starts with some kind of phishing email that manipulates users to provide sensitive information via various methods of social engineering [5].

Because of the risks associated with cyberattacks, it is crucial for Internet users to be aware of when they are being attacked and to be successfully informed on how to combat them. The recent demography results by Anti-Phishing Working Group 4th quarter report shows that around 45,794 phishing reports have been chronicled [2]. There is no single way that can prevent all types of phishing. But different methods applied at different stages of a phishing attack can abort the attempt and properly applied technology can significantly reduce the risk of identity theft [6]. Different approaches are already proposed to automatically detect phishing websites [7-9]. These methods and algorithms determine the likelihood that a website can be suspect but without absolute certainty. When the resulting likelihood exceeds a critical threshold, typically the users are informed about the potential risk of phishing attacks. This is done through a visual warning message that should help users in deciding to access or not the suspect website. Despite the significant advances of current warning messages, this

attack remains very effective since the users often are not able to make the right decision.

There is a direct need for us to design such a remedy which can address the above problem and stand out from the traditional warning messages available. In this paper, we report on an ongoing work about an intelligent warning message that might limit the effectiveness of phishing attacks and that might increase the user awareness about the related risks. The proposed solution implements an intelligent behavior that explains why the specific suspect site can be fraudulent. It is well-known that explaining the reasons about a fact helps the user being aware of the danger and taking more conscious and adequate decisions [10].

2 Literature Review

Successful security depends on systems, technology and people (including users) collaborating to identify threats, weaknesses, and solutions. However, many initiatives today focus on systems and technology, without addressing well-known user-related issues. In fact, users have been identified as one of the major security weaknesses in today's technologies, as they may be unaware that their behavior while interacting with a system may have security consequences. The user interface is where human users interact with computer systems. It is where the user's intention transforms into the system operation. It is where the semantic gap arises [11]. And this is the aspect that needs more attention to further limit the effectiveness of cyberattacks.

One typical anti-phishing approach is to use visual indicators, for example an informative toolbar, to differentiate legitimate messages from phishing messages [12]. This approach tries to bridge the semantic gap by unveiling to human users the system model and expects them to make a wise decision under phishing attacks. User studies in [13] show that the tested anti-phishing toolbars fail to effectively prevent high-quality phishing attacks. Many subjects failed to constantly pay attention to the toolbar's messages; others disregarded the warnings shown in the toolbar if the web page content looked legitimate. The studies also found that many subjects did not understand phishing attacks or realize how sophisticated such attacks can be.

Emigh provided an overview of several studies regarding phishing and usability of browser security clues [14]. It emerged that phishing is a threat because users are unable to verify the authenticity of a website asking for their credentials. He questioned the ability of users to avoid phishing sites based on security and identification indicators suggesting that the solutions were still inadequate. Varshney et al. proposed Dynamic Security Skins, a browser extension that allows websites to display a secret image and customizes the browser chrome [15]. Anecdotal evidence suggests that some users may still fall victim of those phishing websites which, in order to cheat about their different appearance (e.g., logo not displayed), claim that the image database is down for maintenance or simply do not provide any explanation about this, since logo absence might not trigger users' attention.

In [16], the authors sought to determine if user's education was a possible solution to prevent phishing attacks. They explored the impact of both specific users' characteristics (age, gender, education, knowledge about phishing) and of their Internet usage habits on their ability to correctly identify e-mail messages. Quantitative data was collected by showing to participants e-mail messages and quizzing their ability to correctly categorize them. The results show the variables listed above did influence the participant's ability to correctly identify email messages. Although educational efforts are unlikely to solve the phishing problem on its own, vigilant users form an important part of the defensive strategy. Both research efforts and public education campaigns are still not enough.

A study to determine the impact that communicating to users different security policies has on mitigating phishing attacks is discussed in [9]. The research results reveal that a security policy that contains an explanation of the impact of an attack or a statement indicating an evaluation for non-compliance or a statement from a direct authority provides no significant impact on mitigating phishing attacks [17]. The use of online games to teach users good habits to help them avoid phishing attacks is investigated in [18]. The authors explore the relationship between demographics and phishing susceptibilities, and the effectiveness of several anti-phishing educational materials. Results suggest that women are more susceptible to phishing than men and participants between the ages of 18 and 25 are more likely to be a victim of a phishing attack than other age groups.

A new anti-phishing approach which uses training intervention for phishing web sites detection is discussed in [19]. The results of this work show that technical ability has minimal effect whereas phishing knowledge has a positive effect on phishing web site detection. A system called PhishGuru incorporating an embedded training methodology and learning science principles is proposed in [20]. The author evaluates the proposed methodology through laboratory and field studies. Results show that people trained with the proposed system retain knowledge even after 28 days. A major drawback is that the system will need to be trained and updated regularly. Robert W et al [21] found that web browser warnings should help protect people from malware, phishing, and network attacks. Adhering to these warnings keeps people safer online. They further demonstrated that recent improvements in warning designs have raised adherence rates, but they could still be higher. And prior work suggests many people still do not understand them. Thus, two challenges remain: increasing both comprehension and adherence rates. The authors in [21] suggested that further improvements to warnings will require solving a range of smaller contextual misunderstandings.

Most phishing sites are simply copies of real sites with the above-mentioned feature slightly distorted or in some cases masqueraded [22]. This property of phishing sites has made them difficult for humans to detect, but fortunately, easier for computers. However, the attacker community has proved itself able to quickly adapt to anti-phishing measures mainly warning messages. Different warning messages have been already evaluated during controlled experiments [21, 23]. Besides evaluating the efficacy of different solutions, these experiments provided useful indications on how to design and evaluate phishing warning messages. Despite the notable advances made in the last years by the active warning messages for phishing [21, 23], this attack remains one the

most effective. Indeed, algorithms for detecting phishing attacks are only able to determine the likelihood with which a website can be suspect but without absolute certainty. When the likelihood exceeds a critical threshold the warning messages alert the users about a possible risk and the users have to decide to access or not the website. However, current warning messages have large room for improvement, as shown by the high success rate of phishing attacks reported in [24]. One of the first problems is the click-through effect [25]: the users tend to skip these alerts because they appear always in the same way, thus pushing most users in neglecting these messages. The second problem is the wrong design of the warning messages in term of colors, words, interaction, as underlined by [21, 23]. Lastly, the users are not experts in cybersecurity, they do not know what a phishing attack is and what are the risks they are exposed to [21].

In order to overcome these limitations, in the following section, we propose an intelligent warning message mechanism that might limit the effectiveness of phishing attacks and that might increase the user awareness about related risks. It implements an intelligent behavior that, besides warning the users that a phishing attack is occurring, explains why the specific suspect site can be fraudulent.

3 A Polymorphic User Interface to Warn Users about Phishing Attacks

An example of polymorphic user interface to warn users about phishing attacks is reported in **Fig. 2**. In addition to addressing the design guidelines and lesson learned proposed in [21, 23], this prototype shows three panels that explain the reasons why the target website can be a fake. In this example, the first panel specifies that the URL of the target website (www.paypaI.com) looks similar to the original one but the l has been replaced by capital I, thus confusing the users. The second panel reports that the suspect website was created three weeks ago, an age typical of phishing websites. The last box reports information about the HTTPS certificate of the suspect website, explaining that even if the users see safe navigation in the browser toolbar, with a self-signed certificate they are not guaranteed that the site behavior is legitimate.

It is worth remarking that the three panels show different information according to the suspect website, thus different reasons would be reported with different phishing websites. Thank to this intelligent warning message, we address three important goals, i.e.:

1. *Prevent user habituation*: a polymorphic message decreases the clickthrough effect caused by the user habituation [25];
2. *Provide an explanation about the attack*: useful information about the causes of the phishing attacks support the users in deciding if the website is (or not) a phishing attack[26];
3. *Educate the users on cyberattacks and related risks*: a long-term training of the users on phishing attacks is performed since they understand the reasons for this attack [19, 27].

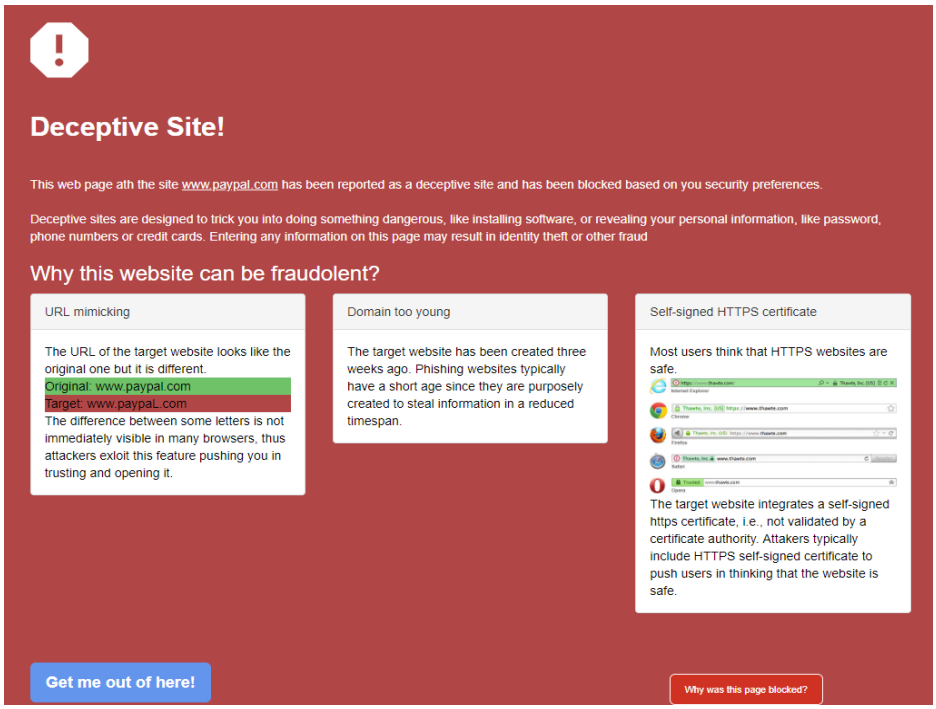

Fig. 2. A prototype of intelligent warning message for phishing attacks.

In our work we are not interested to classify phishing websites [7-9]. We start from the assumption that the browser can detect the phishing website through its internal algorithm, or that we use an API to detect malicious sites[1]. Regardless of which of the two solutions we adopt, when a phishing website is detected, instead of displaying the traditional warning messages implemented in the browser, we show the intelligent UI proposed in this paper (see **Fig. 2**).

To provide users with information that explain the reasons of the phishing attacks, our approach consists of two main steps, i.e., 1) the computation of a set of indicators that can reveal phishing websites and 2) the use of machine learning approaches to select the most important indicators. The three most important indicators will be shown and explained to the user, as shown in the example above.

According to our goal and a literature review [7-9, 28], we are considering indicators for the suspect web sites like:

- *URL*: phishing sites typically have URLs containing more than 2/3 number of digits or "-". In addition, they often try to mimic the original URL changing character that looks similar, for example, "l" with "I";
- *Server location*: phishing websites are often hosted by a web server located in countries where there are no strict laws against cyberattacks;

[1] https://safebrowsing.google.com

- *Alexa or search engine rank*: phishing website typically appear after the first 1 million Alexa top results, or in the last positions of search engines like Google Search;
- *Timelife:* this cyber-attack is usually concentrated in a limited time span, thus the suspect website is typically created few days/weeks before the attack;
- *Top-level domain*: attackers typically use free domains to host phishing web sites; one of the most popular is freenom.com, thus domains like ".cf", ".gq", ".ml", ".tk" and ".ga" are common among phishing web sites;
- *Name length:* Attackers may create domains using a specific template, such as random strings of a given length;
- *Archived domain:* a domain archived on the "Wayback Machine" is more likely to be legitimately owned, and vice versa;
- *Self-signed https certificate*: the suspect websites often integrate a self-signed https certificate, i.e., not validated by a certification authority. Including this certificate, attackers confuse users who see safe navigation in the browser toolbar, but without any guarantee about the web site behaviour.

We defined different metrics to calculate each indicator for the suspect website. For example, Alexa rank can be obtained through its API; the Wayback Machine APIs are used to get information about website archiving; SSL certificate is inspected to see if a trustable certification authority signed it. Those indicators, resulting in a numeric value, are normalized in a 0-1 interval using a min-max function, with min and max values obtained calculating each indicator on all the phishing websites available in the *PhishTank* database and selecting for each indicator the min and max value.

After the computation of the indicators, we use a decision tree model to select the most important indicators. In particular, we adopted the C4.5 algorithm to generate our decision tree. This algorithm was developed by Ross Quinlan [29] and it is an extension of Quinlan's earlier ID3 algorithm. The decision trees generated by C4.5 can be used for classification, and in our case to classify the suspect website. However, we are not interested to understand if it is a phishing site, since we already know it. We only exploit this tree to select those three nodes that positively contribute to determining it as phishing. In other words, we use it to filter the indicators that are more influential in the classification process.

After the selection of the three most important indicators, we dynamically create three panels that are visualized in the warning message and properly adapted if necessary. For example, if a panel has to report the information on the URL, it is customized with the URL of the suspect website and the URL of the Website that is mimicked.

4 Future work

Based on feedback received during the IFIP WG 13.2 & WG 13.5 Workshop on "Handling Security, Usability, User Experience and Reliability in User-Centered Development Processes" held in conjunction with INTERACT 2019, we are revising our proposal of intelligent warning interface.

A first suggestion we received is related to the graphical aspect of the interface, that should be able to attract user attention and communicate that it contains an alert. Actually, the interface shown at the workshop and reported in **Fig. 2** is an early prototype and we are working to change its aspect.

We are also investigating how effective warning messages are constituted in terms of structure, aspect, content, and language. We started from the work in [25, 30], whose authors examined various aspects of warning design and how they affect subjective evaluations, memory, comprehension, and behavioural compliance. In fact, there is at least some involvement of perceptual and cognitive processes when making decisions with respect to warnings (e.g., the level of risk involved, whether to comply). In particular, the Communication-Human Information Processing Model (C-HIP) model [30] is widely adopted in warning design. It accounts for cognitive-affective processes, such as attitudes and motivation, which are influenced by experience as well as characteristics of the source and the channel. Based on this model, the following requirements must be considered in designing warning messages:

- *Salience*: the warning must be noticeable. It should be conspicuous enough to draw user's attention to it. In [31-34] the authors showed that salient or conspicuous warnings increase the likelihood of reading, recall, comprehension and compliance.
- *Wordings*: the warning must be formulated according to four components: (1) signal word to attract attention, (2) identification of the hazard, (3) explanation of consequences if exposed to hazard, (4) directives to return to safety/avoiding the hazard.
- *Layout*: it is used to describe the internal characteristics of a warning label. Presenting warning text as bullets in outline form is preferred to continuous flowing text.
- *Technical Jargon*: it should be avoided as much as possible. Except if your audience is technically savvy, it is good practice to avoid technical terms. It may be hard to totally avoid some of these terms entirely, but when you *do* use them, explain what they mean in the simplest way.
- *Transparency*: when there *is a* chance of attack, communicate the potential risk, but be transparent about the uncertainty. Thus, use words like "suspect", "potential", "attackers could", etc.

We are designing a **user study** that will involve around 50 participants, representative of a large community of Internet users, both adult male and female with basic literacy level (i.e., able to use the Internet, read/write emails and perform other simple tasks with a computer). The study aims to evaluate the effectiveness of the proposed approach by comparing our intelligent warning messages to conventional phishing warning messages available in the current web browsers. As the attack has to be plausible. we plan to simulate a spear-phishing attack, which involves personalized emails or emails sent to a specifically targeted group, such as employees of a particular organization. In our case users, we will involve Internet users holding an uniba.it email account, namely people with an institutional account of the University of Bari.

5 Conclusion

In this paper, we discussed our early work on addressing phishing attack from an HCI perspective. The aim is proposing a mechanism that is able, more the currently available solutions, to attract the users' attention when they are going to fall in the attacker's trap. Our proposal has also the goal of educating the users to more safe interaction behaviors, making them able to recognize the signs of the threat and aware of the risks. Indeed, we agree with [21] that users need to understand and use systems warnings correctly in order to guarantee the efficacy of any security strategy that has been implemented. AS reported in the future work section, we are currently working at the design of an improved version of the intelligent user interface that will be tested with end users.

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