The Game of Phishing
A game theory inspired solution to Phishing attacks.

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Abstract Phishing attacks occur because of a failure of computer users to authenticate Bob. The computer user’s role, her job, is to authenticate Bob. Nobody else can carry out this task. I researched the ability of browsers to counterfeit the behaviour of installed software. The objective was to find a signalling strategy which would protect against counterfeiting i.e. phishing attacks. The research indicates that a user-browser shared secret cannot be counterfeited because Mallory cannot counterfeit what Mallory does not know. After your browser has verified a TLS certificate’s digital signature the browser should create a two page login wizard. The first page should display a random educational message, to inform and educate users about the process. The second page will show the user (1) the user-browser shared secret, (2) the verified identity credentials from the TLS certificate and (3) the input fields for the user to enter her login credentials. The shared secret prevents counterfeiting, prevents phishing. Computer users can now authenticate Bob by examining the TLS certificate’s identity credentials. The educational messages will communicate to the user, the issues and pitfalls involved. On accepting Bob, as Bob, the user can enter her login credentials and login.

Keywords Phishing attacks · game theory · applied cryptography · authentication & secret sharing · security protocols · human factors

Mathematics Subject Classification (2010) 91A28 · 94A62

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1 Introduction

Originally it was game theory research, seeking screening strategies to prevent the counterfeiting of websites i.e. phishing attacks. Various ways for websites to counterfeit installed software behaviour were studied. In full screen mode, it was found that, browsers can counterfeit almost anything, including blue screens of death and formatting the hard drive. This is discussed in Section 2.

From an academic point of view, full screen counterfeiting eliminates several categories of installed software behaviour, as possible anti-counterfeiting solutions. One category of installed software behaviour was resistant to counterfeiting. In Section 3 I present an explanation of this category from the discipline of cryptography and another explanation from the discipline of game theory. Every solution, in that category, was found to be a user-browser shared secret. Basically Mallory cannot counterfeit what Mallory does not know. The user-browser shared secret is not known by either Bob or Mallory.

This means a user-browser shared secret can be used to extend TLS to seek further authentication of Bob by the computer user. On successful verification of a TLS certificate’s digital signature, the browser presents a dialogue, Fig. 1. Mallory cannot counterfeit this dialogue without hacking in, to steal the shared secret. The computer user now authenticates (1) her browser dialogue and (2) Bob, by accepting the shared secret and Bob’s identity credentials which came from the TLS certificate. Acceptance of these two ‘proofs of identity’ is communicated by the user entering her login credentials.
In Section 4 the possibility of Bob authenticating Alice was studied. My research found that the absence of Trent in this process means that Alice must authenticate Bob first, during account setup. This makes Alice authenticating Bob more important than the other way around. At this point I returned to researching Alice’s authentication of Bob.

Our total dependence on Alice authenticating Bob requires us to make this act as straightforward as possible. The final solution proposed is a mixed strategy of (1) a user-browser shared secret to facilitate extending TLS, for Alice to authenticate Bob, (2) standardisation of the login process via a browser created login window, (3) using central banks as Trent for financial institutions and (4) utilisation of common knowledge and education to guide Alice through the process i.e. to prevent phishing attacks Alice must fulfil her role and authenticate Bob.

2 Concerning The Capacity of Browsers To Counterfeit Installed Software Behaviour

The idea is that a phishing attack is a game of incomplete information. That the user does not even know that a phishing attack is taking place. It is the successful counterfeiting of the website that does this. If we can devise a signalling strategy which cannot be counterfeited then the computer user will know when a phishing attack is taking place. They will back away from the phishing website causing the phishing attack to fail.

The idea was to add information, specifically an anti-counterfeiting signalling strategy which would be triggered after the browser has verified the digital signature on Bob’s TLS certificate. I listed behaviour that installed software is capable of but websites are not capable of. The idea was your browser is installed software so it has this advantage over websites trying to counterfeit its behaviour. The following categories were proposed for research:

1. Drawing outside the browser canvas area.
2. Creation of Modal Windows.
3. File manipulation e.g. file creation, copying, renaming etc. this includes the possibility of formatting the hard disk, though we can’t use that as evidence either.
4. Access to local data and operating system identifiers e.g. your username, your account login picture or whether or not you have accessed this website before.
5. Microsoft, User Account Control behaviour.
6. Existing best practice i.e. inspection of the TLS Certificate being used by your browser.

In my original research I dismissed or counterfeited every Category except number 4. Every solution in Category 4 is actually a secret shared between the computer user and their web browser. Category 4 is discussed below in Section 3.
Originally I dismissed Category 3 believing it to be unworkable. However references [3] and SiteKey [5] both use cookies to trigger their solutions. Cookies actually fit Category 3. This is discussed further in Section 4.

A key component of this research was the study of screening strategies. While it was not my intention Mallory, the counterfeiters, never wanted screening strategies to work. Effectively I was researching an arms race where Mallory would keep changing her behaviour to prevent my screening strategies from working. Section 6 outlines one interpretation of that arms race. The actual path that I followed was to study the categories listed above. There is no point in me documenting that research here because it is quite similar to discussions of screening strategies found in [1] and [2].

One phishing attack website that I stumbled upon requested a username and password. Even though the genuine website was open access. This type of phishing is more social engineering than counterfeiting. During my research the most versatile type of phishing I stumbled upon was full screen counterfeiting.

2.1 Full Screen Counterfeiting

About ten years ago browsers stopped the JavaScript function ‘window.open()’ from creating completely undecorated popup windows. The function still works, however an address bar is added to the window, as shown in Fig. 2. Without this it would be easy to counterfeit browser controls and 'inspection of the TLS certificate'.

![Fig. 2](image)

Fig. 2 This is a recent attempt to create an undecorated window with the JavaScript function ‘window.open()’. The arrow points to an address bar which browsers now add to prevent counterfeiting of browser controls.

Within the past few years a Fullscreen API has been added to HTML 5 / JavaScript. It's still in development so browser specific function names exist like `mozRequestFullscreen()` and `webkitRequestFullscreen()`. Once a user performs an action which results in this function call, the browser switches into full screen mode. The transition to full screen happens whether or not the user has been warned in advance. Yes the browser will show a warning, after the transition. However each browser has its own warning windows and websites can query your browser and deliver the appropriate counterfeit. Fig. 3 shows a Firefox warning.
The thing about social engineering is that almost anything goes. Consider a criminal harassing a user with warnings, like that shown in Fig. 4. Once the user is accustomed to hitting ’Allow’, the criminals can request full screen mode and hope the user falls for it. After that they can counterfeit the entire computer desktop, blue screens of death etc.

For example, Fig. 5 shows six bitmap images. They are deliberately drawn to look fake. When assembled correctly they mimic a desktop. Fig. 6 shows a computer desktop just before a full screen counterfeiting attack. Once the user clicks on a button which executes JavaScript. The `requestFullscreen()` function is called, along with code which alters the webpage to show the fake browser, and desktop, controls. This turns Fig. 6 into Fig. 7. Note the substitution of the bitmaps from Fig. 5 for the genuine browser and desktop.
**Fig. 5** Six bitmap pictures are shown on a grey background. The grey background is to help the reader see the size and shape of the bitmaps. The top three are to counterfeit browser controls while the bottom three show a counterfeit 'Windows start button', counterfeit taskbar with an application icon and clock. They are deliberately made to look fake, like crayon drawings. This is to help the reader see the difference between Fig. 6 and Fig. 8. The crayon like fake is made to look like the original NCSA Mosaic browser.

**Fig. 6** Screenshot of desktop before full screen counterfeiting attempt.

If the user does not notice that the warning message is different they may click on 'Allow'. There are a number of differences between the harassment window and the genuine warning window. Along with the message being different the harassment window cannot grey the entire desktop, nor can it be drawn at the top centre of the screen.
Fig. 7 Screenshot of transition to full screen. If the user has been harassed by similar looking warnings then they may select 'Allow' without noticing that it's a different warning window. See Fig. 4. Note, the fake browser and O.S. controls have already been substituted.

Fig. 8 Screenshot after full screen counterfeiting attack.
If the bitmaps used in Fig. 5 were realistic then Fig. 6 and Fig. 8 would be almost identical. Furthermore Fig. 7 would only appear odd/unusual because the greyed area extended beyond the perceived canvas area and because the warning window appeared outside of the perceived canvas area. These are very weak indicators of counterfeiting.

From a researchers point of view many types of installed software behaviour can be counterfeited. Including browser addons, inspection of TLS certificates, and Microsoft User Account Control behaviour. As such categories 5 and 6 must be eliminated as suitable anti-counterfeiting solutions. Furthermore we now need to be concerned with counterfeiting of blue screens of death, hackers/criminals blackmailing people with the threat of formatting their hard drives etc.

The purpose here is to demonstrate these mechanisms. No user testing has been performed. The academic exercise of demonstrating that this is possible is sufficient to eliminate categories 5 and 6. There is anecdotal evidence in [7] that these tactics will work.

In the short term best practice can be changed to (1) hit escape to exit full screen, (2) click on the padlock symbol and (3) read the TLS certificate details window, to ensure you are connected to the correct website. Also we can roll back the full screen API, just like the undecorated window functionality.

3 Alice Authenticating Bob, Game Theory or Cryptography?

I believe the system has been mistakenly identified as a two actor system. When, in fact, a third actor is present. The failure of TLS to force proper authentication of Bob allows Mallory to masquerade as Bob, to counterfeit his identity i.e. phishing attack.

You might argue that the two actor model is incorrect, that users check for the presence of the padlock symbol. If they did then phishing attacks would not exist, or the conflict would escalate as outlined in Section 6.

Fig. 9 shows a schematic of the existing two actor model and my three actor model. To distinguish between the actors in the two models I have given them different names, as shown.

In the existing system Alice-Browser verifies the digital signature on Bob’s TLS certificate. On success Alice-Browser and Bob proceed to implement TLS. In my model HAL-Browser verifies the digital signature on Bob’s TLS certificate. On success HAL-Browser turns to Alice-Human and invites her to further authenticate Bob. He does this by displaying a window like that shown in Fig. 10. The problem is: this act is vulnerable to counterfeiting. In this context counterfeiting is referred to as a phishing attack.

Shown in Fig. 10 is a picture of a turtle which is a shared secret between Alice-Human and HAL-Browser. Neither Bob nor Mallory know this secret. As such Mallory cannot counterfeit Fig. 10 without hacking into HAL-Browser to steal the secret. Hacking into thousands of computers to steal these secrets is an entirely different endeavour to tricking people into going to a fake website.
Fig. 9 In the existing system two machines do some math but no human being actually examines the identity credentials output by that math. The presence of a padlock symbol is not an accepted method of authentication documented in cryptography textbooks.

Fig. 10 Example of the authentication window shown by HAL-Browser to Alice-Human, to force the completion of Bob’s authentication. The picture of a turtle is a shared secret between Alice-Human and HAL-Browser. It protects this dialog from being counterfeited since Mallory would need to hack into hundreds of user’s computers to steal each user’s secret. The names used for Bob, Trent etc. all come from the TLS certificate.
Once you correctly model the system as a three actor system. Cryptographers know how to appropriately authenticate the three participants. As such Fig. 10 is a relatively obvious step for cryptographers. Dhamija et al also use a user-display shared secret. They use it to protect a dedicated login window from counterfeiting. They do not appear to go beyond that and use it to present Bob’s identity credentials [4]. With my solution, by entering her login credentials Alice-Human is accepting Bob’s identity credentials and her browser’s shared secret. She is authenticating both Bob and her web browser. HAL-Browser then proceeds to implement TLS. Hence Fig. 10 extends TLS to ensure proper authentication of Bob by Alice-Human.

Alice-Human now knows she is looking at a dialogue created by her web browser i.e. it is not a counterfeit, a phishing attack. She can now examine the identity credentials presented and complete Bob’s authentication.

I was approaching this as a game theorist seeking screening strategies to prevent counterfeiting. Here follows an outline of the game theory interpretation.

3.1 Shared Secret Authentication as a Screening Strategy

Anti-counterfeiting technologies and the screening strategy that accompany them go together like a lock and key pair. The research involved the study of each category, from section 2, to find screening strategies which would prevent phishing attacks.

The definition of a screening strategy, from [2] is given since its language is used to frame the discussion that follows. From [2]: A screening strategy is a strategy used by a less informed player to elicit information from a more informed player.

Human Interactive Proofs (CAPTCHA), Turning tests and anti-counterfeiting technologies are all specific types of screening strategy. Here too authentication, through the confirmation of a shared secret, constitutes a screening strategy. The less informed player is eliciting the identity of the more informed player. They are not eliciting the secret because they already know it. They want to know ‘do you know what the secret is?’ This is why it’s just a point of view that this is cryptography. As a game theorist I see a screening strategy. It elicits their identity, as the individual who knows the secret or someone else.

Furthermore, the fact that this works while other approaches fail indicates phishing attacks involve the counterfeiting of an identity, not a website. This is significant because it allows us to prevent any type of counterfeiting. It recasts counterfeiting as theft of intellectual property, patents, copyright, Trademarks, designs etc. accompanied by identity theft. The purpose of the identity theft is to undermine law enforcement attempts which would otherwise prevent the intellectual property theft. This means authentication based solutions can be developed for any type of counterfeiting including manufactured goods like pharmaceutical drugs and currencies.
4 Bob Authenticating Alice

References [3] and SiteKey [5] both utilise cookies to trigger mutual authentication. In both cases, the cookie is used to authenticate HAL-Browser to Bob. Bob then presents his shared secret, seeking authentication from Alice-Human. This behaviour resides outside of the shared secret category of solutions, just discussed. It’s subtle, but this is a new category of behaviour which is resistant to counterfeiting. As a machine HAL-Browser can discern the difference between identical websites. He can then treat these websites differently, even if we humans can’t see the difference. All solutions in this new category involve the web browser differentiating between websites and then responding in an installed software manner, which is not vulnerable to counterfeiting. Here follow our two examples:

1. Browsers correctly returning cookies to the websites that created them.
2. Browsers correctly volunteering saved passwords for the websites they belong to.

For the solution presented in Fig. 10 our browser responds with installed software behaviour which is not vulnerable to counterfeiting. However that response is not specific to each website.

Both cookies and saved passwords require the browser to distinguish between websites and provide a response which is specific to that website.

To develop a mechanism for Bob to authenticate Alice, consider the following thought experiments.

4.1 Using The Saved Password Facility

On account setup a bank can create a login page which will trigger the browser save password facility. Now the bank specifies both the username and password. The password should be very high entropy, impossible to remember by Alice-Human. The idea is that the browser will remember it.

Since the browser can distinguish between websites it will never enter the data into a phishing website.

4.2 Cookies

Create a cookie with a high entropy code stored inside it. This is equivalent to the password idea, just described i.e. the browser only hands over cookies to the websites that created them. The cookie could be created with multi factor authentication e.g. a code could be sent to Alice-Human’s mobile phone.

4.3 So What’s the Problem?

Both solutions are equivalent and they are both vulnerable to the same kinds of attack. I refer to this as ‘cookie as certificate’ since these solutions use
cookies as a poor man’s certificate. To identify HAL-Browser to Bob. Both [3]
and SiteKey utilise cookies as certificates.

The thing is, they don’t have a secret private key and they don’t have
a digital signature. Basically they are a number, a password. All they have
going for them is that the browser will only hand them over to the website
that created them.

Mallory simply attacks the cookie creation process. While various solutions
can be presented they tend to look like an arms race e.g. Mallory could try
a brute force attack generating lots of cookies. Bob will respond in the usual
ways.

On closer inspection, the asymmetric nature of TLS makes it easier for
Alice-Human to authenticate Bob, than the other way around. Alice-Human
can trust Trent and proceed accordingly. In Bob’s interactions with Alice-
Human no third party (Trent) is vouching for anyone. For Bob to use a cookie,
he must create that cookie as part of an account registration process.

Whatever process is used, it will always be vulnerable to attack by Mal-
lory unless Alice-Human correctly authenticates Bob during that account reg-
istration. Basically, without Trent, Bob can never authenticate Alice-Human
without her authenticating him first. The cookie creation process will always
involve Alice-Human authenticating Bob or it will be vulnerable to MITM.
Hence Bob cannot authenticate Alice-Human without her authenticating him
first.

This makes Bob authenticating Alice-Human less important than the other
way around. This is because TLS is asymmetric. Alice-Human can enjoy the
use of TLS certificates. The user-browser secret combined with the TLS cer-
tificate is Fig. 10. That’s all Alice-Human needs.

If Alice-Human will always authenticate Bob first then its academic how
Bob authenticates her. Codes, pictures, mobile phone, email, it’s all the same.
He might as well just ask for a username and password. It’s up to her not to
type her credentials into a phishing website. The responsibility always falls on
her to properly authenticate Bob first. After that it’s academic if he accepts
a username and password or some convoluted dance.

Effectively this breaks the use of cookies as an anti-counterfeiting mecha-
nism. Yes they are an effective solution. However they are dependent upon TLS
and Fig. 10. We’re actually going in the wrong direction. Instead of worrying
about Bob authenticating Alice-Human. We should focus more on actually
getting Alice-Human to authenticate Bob.

4.4 The Now Abandoned Idea

The original idea was quite similar to [3] and SiteKey, however it was aban-
donned, as outlined above. Basically an ‘out of band’, multi-factor authentica-
tion technique could be used to create a cookie e.g. send a text message to
Alice-Human’s phone. Fig. 12 would need to be used to create the cookie, just
to ensure TLS is actually being used. Even then it would still fail i.e. this
system is vulnerable to all the attacks that work against SiteKey and users would only see Fig, 12 once every three, or four, years.

The reason why its a nice solution, why it’s included here, is that Mallory would not be able to get the login screen up without the cookie. So even if Mallory has successfully harvested correct usernames and passwords, she would still need to create the cookie to get the login screen up. Its possible this solution will still be implemented, however, computer users still need to authenticate Bob. There is no getting away from this.

This is the 'cookie as username' idea. Fig. 11 shows Fig. 10 with this additional solution implemented.

![Fig. 11](image)

Fig. 11 Shown is Fig. 10 altered for the 'cookie as username' idea. It seems like a nice idea but it is vulnerable to all the attacks that work on SiteKey and [3]. Hence Fig. 12. Note the shared secret is now a photo of a ruler which looks like a giraffe.

5 Krugman, Common Knowledge and Education

Before I dismissed cookies I tried to overcome their shortcomings. Fig. 12 is a mock-up of a browser created dialogue for the creation of a cookie. SiteKey, [3] and the 'cookie as username' idea all require Fig. 12 to ensure a MITM attack is not used.

Since Alice-Human will only see this dialogue once every three or four years, this solution will fail. To overcome this problem we need Alice-Human to be educated in the art. Since it’s not practical to force people to take lessons we need another way.
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To create cookies safely Alice-Human must not fall victim to a MITM attack. Problem is, Alice-Human will only see a dialogue like this once every three or four years. She won't remember that this dialogue is needed, so this won't work. Phishers will just ask for the email, or mobile phone, code on a regular webpage.

The counterfeiting of currencies is hindered through common knowledge i.e. people use genuine bank notes every day. When they encounter a new note their everyday knowledge will aid them in evaluating that note’s authenticity. In the same way Fig. 10 will become common knowledge. Effectively Krugman’s Theory of Passive Learning [8] Clearly passive learning and low involvement consumer behaviour are beyond the scope of this paper. The ideas outlined here need to be combined with user studies like [7][9] and academic work in the field of education and passive learning.

To educate Alice-Human, in the art, we can make Fig. 10 the second page, in a login wizard. The first page can be used to present messages which will slowly educate the user e.g. Fig. 13 and Fig. 14. Effectively this passive learning approach will make the required knowledge, common knowledge. The idea is to meet users 'half way’ i.e. we should adjust our authentication solution to make it more accessible. And we should aid users in its use. Where flaws appear the solution can be assessed to ascertain why the system failed. If the authentication mechanism is flawed we can alter TLS, if users are being tricked by some aspect of the system, we can adjust both the educational messages and the login process till they can discern genuine from counterfeit.

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1 Passive learning focuses on what is ‘caught’ rather than ‘taught’ e.g. company slogans and 'sound marks’. These are sound versions of trademarks. Often the public learn them passively from television advertisements. Google ‘uspto Trademark Sound Mark Examples’.
Dhamija et al found that some users did not know this type of fraud was possible. Some users accepted websites which contained professional looking images and distrusted websites which were plain i.e. few links and few images. Some distrusted webpages which did not originate from the bank’s main homepage [7]. Misconceptions like this can be addressed with informational messages on wizard page one.

Informing and educating does not mean annoying, so a 'I know this' check box could be added to remove educational messages that the user already knows. Eventually just the login page will appear or questions during setup could also remove it.

![Login Wizard Page 1 of 2](image)

**Fig. 13** While the second page of the login wizard will always be Fig. 10. The first page can be chosen randomly from a number of educational pages. Here the shared secret has been changed. The image would be the same on both pages of the login wizard.

The existing system is unhelpful for many reasons. Users must remember to click on the padlock to examine the TLS certificate. Even then, they don’t really know if www.BobsOnlineBanking.com should be used rather than www.BobsOnlineBanking.ie. Trent should be an actual trusted third party. The public probably don’t even know the name of any certificate authorities. Identities presented in TLS certificates are de facto worldwide trademarks. They are these businesses’ shopfront. Yet we put all of these brand names behind a picture of a padlock.
5.1 Central Banks as Trent

On inspecting Fig. 10 Alice-Human needs to remember three things, her user-browser shared secret, Trent and Bob. Her secret will be easy because it’s the same for every website. Once the phishers start attacking browser weaknesses associated with TLS, Alice-Human will need to remember Trent. So why not make it easy for her?

If central banks sell TLS certificates to banks that operate within their regulation domain then those certificates can state that central bank’s name as Trent. Hence European Central Bank, Federal Reserve, Bank of England, Bank of Japan etc. will all appear as Trent in their respective countries. Now Alice-Human has less to remember.

Regular ecommerce sites can continue as usual with TLS certificates bought on the open market. Also the central banks can outsource the certificate creation process. So the certificate authorities will not be out of pocket, they just won’t have their name in lights on Fig. 10.

Effectively this is an extension of the existing Extended Validation Certificates idea. The central banks would end up authenticating the identity of these banks. This is precisely Trent’s role.
6 Phishing Attacks Arms Race

6.1 Current Situation

Tell users to search for the padlock.

6.2 Criminals Now Use Their Own TLS Certificates

With either commercially purchased TLS certificates, or certificates they created themselves, the criminals can now display a padlock symbol.

Users are now told to click on the padlock and examine the TLS certificate details to verify Bob’s identity.

6.3 Full Screen Counterfeiting

Life is a lot more difficult for the phishers because they now need to trick users into full screen mode. However, once there, they can counterfeit anything. This gives them more options for theft/crime.

6.4 Introduction of Browser-User Shared Secrets

Authentication windows like Fig. 10 are introduced and users are directed to only enter their login credentials into these login windows. HAL-Browser only displays the authentication window Fig. 10 on successful verification of a TLS certificate’s digital signature. Hence Mallory cannot persuade HAL-Browser to display the window without her own TLS certificate. The criminals are likely to attack TLS and browser weaknesses associated with TLS certificates.

6.5 Meeting Alice Half Way

Anti-Virus, private keys, shared secrets all have a role to play. Alice-Human’s job is to complete Bob’s authentication. A mixed strategy of educating Alice, making details of the process common knowledge and altering the authentication process can be used to bring Alice-Human into the process. At the end of the day, only Alice-Human can authenticate Bob.

7 Conclusion

Phishing attacks are not the counterfeiting of a website but the counterfeiting of an identity. The research found the system to be responsive to strategies which protect the website creator’s identity, whereas website content could not
be protected. In fact, the research found that web browsers can counterfeiting almost anything.

The asymmetric nature of TLS makes Alice-Human authenticating Bob more important than vice versa. Without Trent, Bob authenticating Alice-Human will always require her to authenticate him first, during account setup. Otherwise a MITM attack will occur. This requirement undermines solutions like SiteKey.

The conclusion is that a mixed strategy is called for. A user-browser shared secret allows TLS to be extended so Alice-Human can complete Bob’s authentication. The shared secret protects this act from counterfeiting, from phishing, since Mallory cannot counterfeit what Mallory does not know.

The login process should be standardised into a predictable login window. This makes details of the interaction common knowledge, guiding Alice-Human through the process. Furthermore educational messages displayed in a login wizard will educate the public by making this knowledge common knowledge. This includes the possibility of central banks taking over the role of Trent for financial institutions. The mixed strategy means “meeting users half way”. Alice-Human must fulfill her role and authenticate Bob. We must make this task as easy as possible. Protecting the authentication process from counterfeiting, through the use of a user-browser shared secret, using central banks for Trent, standardising the login window, informing and educating users all bring us closer to Alice fulfilling her role.

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