

An Investigation into the “Beautification” of Security Ceremonies

Giampaolo Bella¹, Karen Renaud^{2,3}, Diego Sempreboni⁴ and Luca Viganò⁴

¹*Dipartimento di Informatica, Università di Catania, Italy*

²*Division of Cybersecurity, University of Abertay Dundee, U.K.*

³*University of South Africa, South Africa*

⁴*Department of Informatics, King’s College London, U.K.*

giamp@dmi.unict.it, k.renaud@abertay.ac.uk, {diego.sempreboni, luca.vigano}@kcl.ac.uk

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Abstract: “*Beautiful Security*” is a paradigm that requires security ceremonies to contribute to the ‘beauty’ of a user experience. The underlying assumption is that people are likely to be willing to engage with more beautiful security ceremonies. It is hoped that such ceremonies will minimise human deviations from the prescribed interaction, and that security will be improved as a consequence. In this paper, we explain how we went about deriving beautification principles, and how we tested the efficacy of these by applying them to specific security ceremonies. As a first step, we deployed a crowd-sourced platform, using both explicit and metaphorical questions, to extract general aspects associated with the perception of the beauty of real-world security mechanisms. This resulted in the identification of four beautification design guidelines. We used these to beautify the following existing security ceremonies: Italian voting, user-to-laptop authentication, password setup and EU premises access. To test the efficacy of our guidelines, we again leveraged crowd-sourcing to determine whether our “beautified” ceremonies were indeed perceived to be more beautiful than the original ones. The results of this initial foray into the beautification of security ceremonies delivered promising results, but must be interpreted carefully.

1 INTRODUCTION

Security measures can trigger unintended and unanticipated side effects if users consider them unattractive. By unattractive, we mean difficult, arduous, inconvenient and generally a nuisance. If people perceive their interactions with security systems negatively, instead of something that is there to protect them and their data, they might try to bypass or game them (for instance, by using weak passwords). People will dread an encounter with a system they consider unattractive. Yet “beauty” is likely to be in the mind of the beholder, and it is not necessarily obvious how to beautify security systems.

Bella and Viganò introduced the *beautiful security approach* (Bella and Viganò, 2015), postulating that security should:

1. become a primary, inherent feature of the system; *at the same time,*
2. not be disjoint from the system functionalities; *at the same time,*
3. contribute to the very positive experience that the

user has of the system, ultimately making that experience beautiful.

While the first two are dealt with elsewhere, the third is the one that this paper is concerned with: how can security ceremonies *contribute to* the positive experience that a user has of a secured system, ultimately triggering a perception of beauty?

Because users are an essential and integral part of the greater socio-technical system, they have to engage with *security ceremonies* (Ellison, 2007), which are added to systems in order to secure them.

An example of a ceremony is an access control system that restricts access to authorised users by requiring the user to identify and authenticate themselves.

Users engage in a kind of ‘ritual’ with security ceremonies, with predetermined actions being actioned by the two parties in a prescribed order when they interact with the ceremony. The result may be that interaction with the security ceremony is far from straightforward. The need to ensure the security of systems may unintentionally make interaction with security ceremonies complex (and possibly unattractive).

A number of approaches have been developed to inform the design and analysis of secure ceremonies, e.g., (Bella and Coles-Kemp, 2012; Radke et al., 2011; Karlof et al., 2009; Martina et al., 2015), but these seem to neglect the notion of beauty. We coin the term “*beautification*” to refer to the process of making security ceremonies (more) beautiful. We know that beautifying existing ceremonies by merely simplifying them has sometimes led to the deployment of insecure ceremonies. Such ceremonies contain vulnerabilities that could be exploited by an attacker. A prime example is the use of fallback questions to allow people to recover from forgotten passwords, but which often serve as a convenient back door for attackers (Schechter et al., 2009). In sum, it is known that security ceremonies have functional goals that guarantee requisite security properties. For example, a password recovery ceremony must ensure confidentiality of the replacement password.

This need motivates the need for a methodology that makes beautiful security practically applicable. Such a methodology is the main contribution of this paper. We leveraged crowdsourcing to help us to orient security ceremony design towards greater beauty. The methodology was applied, as a proof of concept, to four real-world security ceremonies aimed, respectively, at voting, logging into a computer, setting up a password and entering physical premises. Our findings are promising but require careful interpretation, as we shall explain.

We commence with a brief review of the relevant literature (§2) and continue by presenting our methodology. The first step was to consult crowdsourcing platform participants using questions aimed at gathering their views on what makes cyber security beautiful (§3). The second step was to leverage such views to formulate beautifying guidelines to inform the design of more beautiful ceremonies (§4). The third step applied the guidelines to existing ceremonies, attempting to make them more beautiful (§5). The fourth and final step returns to the crowdsourcing platform participants to determine whether the intended beautification of the ceremonies was successful (§6). We draw conclusions and discuss future work in §7.

2 BEAUTY IN SECURITY

Beauty is traditionally thought of as something visual, but it has also been applied to music (Portanova, 1975), mathematics (Erickson, 2011; Russell, 1956), truth (Nass et al., 2000) and design (Gelernter, 1998).

Carritt (Carritt, 1932) claims that beauty is not simply related to the agreeableness or usefulness of

an item or experience. He says that beauty has more to do with a contemplation of a feeling experienced during, or remembered after, an encounter with a particular artefact. Hence, beauty is interwoven with a person’s experiences.

What characteristics of this experience might contribute to beauty? The literature suggests the following: ease of use (fluency) (Reber et al., 2004), a sense of pleasure (Tatarkiewicz, 2006), simplicity (Chen et al., 2005; Karvonen, 2000; Glynn, 2010), aptness (Gelernter, 1998), elegance (Gelernter, 1998), the value of the system in a given context (goodness) (Hassenzahl and Monk, 2010) and responsiveness (Pancake, 2001). This review suggests that beauty will be attributed to an artefact if it elicits positive feelings, based on prior user experiences.

Let us now consider the idea of *beautiful* security software. This is especially important because its non-use or, worse, a negative experience of an unattractive ceremony, will compromise security and leave holes open for hackers to exploit. Current experiences of common security software appear to confirm their general unattractiveness (Cranor and Garfinkel, 2005; Sheng et al., 2006; Clark et al., 2011). The consequence is that users might act to circumvent the ritual (Blythe et al., 2013). Awareness and training programmes are the standard organisational response to this (Yildirim, 2016), but the effectiveness of such drives is patchy (Banfield, 2016; Kennedy and Kennedy, 2016). Training does not work because it can not overcome a reluctance that stems from previous negative experiences with unattractive software.

What we are proposing is to *beautify* security ceremonies so that people will *want* to use them because the beauty thereof results in positive feelings. What we seek to discover is exactly how to achieve this. In summary, we want to build security ceremonies that users will want to engage with because doing so has been a positive experience. This might mean that the software displays one or more of the general characteristics listed above. It could also be that beautiful security ceremonies have their own set of characteristics: identifying these is the topic of this paper.

3 CROWDSOURCING FOR THE CONCEPT OF BEAUTIFUL SECURITY

Bella and Viganò (Bella and Viganò, 2015) asked a fundamental question: what constitutes a beautiful user experience of a security ceremony? Answer-

ing this question is far from trivial both because of the vastness of the spectrum of possible answers and because, as researchers working in security, our own point of view is likely to be biased. For these reasons, we decided to source an answer to this question from a heterogeneous global crowd of people by means of a questionnaire.

Our questionnaire aimed to gain an understanding of how the users of security ceremonies perceive and describe them by means of a scale of “*emotional*” values, leaving them free to express as many values as they desired. In other words, we designed the questionnaire to explore a correlation between security ceremonies and how their beauty is sensed. The questionnaire consisted of the following four questions:

- Q1 Think about when you log into your bank account, and you use one of those little devices the bank sends you that displays a number for you to enter as your password. Do you consider this process to be: *Fun, Beautiful, Excessive, Annoying, Engaging, Essential, Reassuring, Appealing*?
- Q2 When you were a child, did you ever read a book about a group of children having a secret club, with meetings where people were allowed in when they knew the secret password? In this case, how would you rate the security of this process in terms of: *Fun, Beautiful, Excessive, Annoying, Engaging, Essential, Reassuring, Appealing*?
- Q3 Think about a web-based system that requires you to provide a password that meets certain rules (e.g., upper case, lower case, digit, special character, minimum length). In this case, how would you rate the security in terms of: *Fun, Beautiful, Excessive, Annoying, Engaging, Essential, Reassuring, Appealing*?
- Q4 Think about old-fashioned burglar alarms that used to go off every time a bird landed on the roof, or lightning struck nearby. The only way to correct a false alarm was to get home as quickly as possible to enter the PIN to shut it up. Modern systems are different. They are often controlled from your smartphone. Now you can keep an eye on them from wherever you are in the world, and even see if everything at home is in order, by linking to cameras in your home. False alarms can quickly and easily be dealt with, without annoying your neighbours for hours on end. This is an example of how physical security has become more engaging. *Can you think of a way that cyber security could improve in the same way?*

The first three questions were closed-ended, allowing people to respond with multiple preferences (and thus allowing us to gain insights into their feel-

ings, where these could not be represented by only one choice). The final question was open-ended. The rationale behind the questions is as follows.

3.1 Q1 — Token Device

The first question concerns the technology that people use to confirm their identity upon login to their own online bank accounts. Originally, when a customer activated the e-banking functionalities on their bank account the bank would supply them with a plastic card or a sheet of paper with several *one-time passwords (OTPs)* to enable them to carry out two-factor authentication¹, in this case using their username-password pair as well as a OTP. More recently, banks started handing out small electronic devices to their customers that are capable of generating an OTP on the fly, instead of their having to consult a pre-printed list of fixed OTPs. Nowadays, these devices are very common².

We devised the first question to explore reactions to OTPs as a mechanism that is widely used to prevent bank-account hacking but that is sometimes not as usable as it should be (Subashini and Sumithra, 2014). OTP devices are intended to help users to handle a situation in which security ought to be the first goal, even though the way it achieves this might not be ideal. We wanted to find out what respondents thought about needing to possess such a physical device to generate OTPs. This question allowed us to gather evidence to understand whether current two-factor authentication ceremonies are in line with our ideas or whether we ought to start thinking about alternative approaches.

3.2 Q2 — Secret Club

The second question is about using an episode of the British pre-school animated television series “Peppa Pig” (Bella and Viganò, 2015). In this episode, titled “The Secret Club”, Peppa’s friend Suzy Sheep is

¹Two-factor authentication asks the user who wishes to be authenticated to provide two different secrets: something the user knows (e.g., a password), something the user has (e.g., a device), something the user is (e.g., unique biometric features such as fingerprints or the patterns on a person’s retina blood vessels). This can be straightforwardly extended to multi-factor authentication, where the user has to provide multiple different authentication factors.

²In fact, mobile applications have been developed to enable users to generate OTPs on their smartphones, thus replacing also these small electronic devices. However, given that these mobile applications are not yet widespread (only some countries and some banks have adopted them so far), we decided not to include this option in our questionnaire.

building a secret club whose membership is identified by wearing a mask. Joining the club demands uttering a one-time password, as shown by the following excerpt:

Peppa: Hello, Suzy.
 Suzy: Hello, Peppa.
 Peppa: Why have you got that mask on your face?
 Suzy: So people don't know it's me. I'm in a secret club.
 Peppa: Wow! Can I be in your secret club?
 Suzy: Shh! It's not easy to get into. You have to say the secret word.
 Peppa: What word?
 Suzy: Blaba double!
 Peppa: Blaba double!
 Suzy: Right, you're in.

Later on Suzy will comment that the password changes all the time to keep it secret! It would appear that anything related to secrecy is perceived to be an enjoyable game, even before the rules are set, and Bella and Viganò use this to propose that a user's experience of a security ceremony could be appealing and beautiful as is demonstrated by the childish enthusiasm with which Peppa reacts in this episode.

What would our respondents think of a similar situation? Even though it could seem a fairly childish example, we devised the second question to help the respondents connect with similar experiences from their own childhoods, thereby allowing us to determine whether the respondents agreed with Bella and Viganò's assessment of the attractiveness of this example. Thus, this second question aimed to give us a reference point for the kind of user experience that we would like to achieve when security is seen in terms of beauty and attractiveness.

3.3 Q3 — Password Creation

Given that the second question considered passwords in a childish context, we devised the subsequent question to ask about passwords in a more adult context, thus also allowing us to check whether the answers obtained would be in line with those given in response to Q2. More specifically, Q3 considers a thorny situation that users have to face at least once a day. A cloud service, an email account, a favourite e-commerce website, or maybe a laptop account, all require the user to enter a secret password correctly to gain access. Nowadays, this usually requires a strong password that respects certain criteria (such as a minimum length, different characters, special characters) and is also semantically different from the user's sensitive information (such as name or birth date). We asked respondents to express how they felt about engaging

with this particular security ceremony. We expected to obtain results that would reflect the users' frustration with current password management systems.

3.4 Q4 — Cyber Security Improvement

We chose to conclude with an open question to capture the respondents' different points of view. Cyber security will continue to evolve and we believe that this evolution could take many different directions. We devised the final question to collect a wide variety of suggestions about the different ways of making security ceremonies more attractive, and thus of pursuing beauty. By using an analogy with an old-fashioned burglar alarm, we asked respondents to assess the attractiveness of modern solutions and to propose improvements related to cyber security.

3.5 Findings

We administered the questionnaire to one hundred respondents. We used the CrowdFlower platform and did not constrain respondents in terms of language or geography. CrowdFlower workers span the globe so we were assured of a heterogeneous sample. The results for the first three questions are summarised in Figure 1, whereas Table 1 shows the results of the answers to Q4.

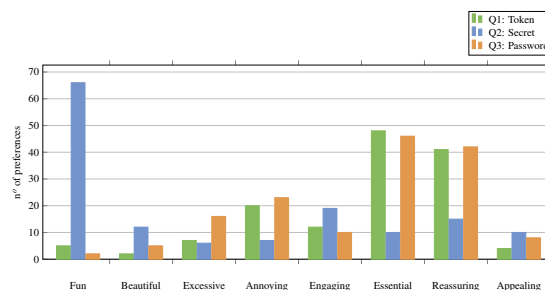


Figure 1: The answers to questions Q1, Q2 and Q3.

3.5.1 Findings from Q1, Q2 and Q3

The answers to Q1 show that users most often perceive these kinds of ceremonies to be *Essential* (48) and *Reassuring* (41). The third most popular reaction is that engaging with the ceremony is *Annoying* (20), confirming that users find it frustrating. The least chosen options are: *Fun* (5), *Appealing* (4) and *Beautiful* (2). This reinforces our initial assertions about the unattractiveness of current security ceremonies.

In Q2, users largely chose *Fun* (66), followed by *Engaging* (19) and *Beautiful* (12), and finally *Annoying* (7) and *Excessive* (6). This could mean that the users see that the situation is less serious but also that

they perceive this to be less burdensome than rigorous security ceremonies. This is so even though the secret mentioned in the cartoon is very similar to an actual password.

In Q3, we can observe similar responses to Q1. We obtained a high number of preferences for *Essential* (46) and *Reassuring*(42), reflecting the fact that users sense the importance of a tangible feeling of reassurance. Similar to Q1, the third most voted response is *Annoying* (23) followed by *Excessive* (16). Very few respondents considered the password management to be *Fun* (2) or *Beautiful* (5).

What we can understand from the responses is that the respondents seem to grasp the *Essential* nature of security ceremonies, and they also feel *Reassured* by security measures such as passwords and mobile tokens. However, they undoubtedly feel annoyed and consider the security measures *Excessive*, especially for password-like ceremonies. The burden of having external devices such as token generators or complicated passwords could be responsible for the number of *Annoying* responses. In designing more beautiful security ceremonies we have to take this into account.

If we focus on the *Fun* and *Beautiful* aspects, we can see that a majority of the users believe that having a secret code in a childish context is funny but also beautiful and *Engaging*, as compared to the other two contexts. In Q2, we did not mention details like the complexity of the secret but, even so, the perceived positivity of this Peppa Pig experience reveals the negativity of existing real-life security measures.

If we return to what Carritt (Carritt, 1932) says, these negative experiences and perceptions will lead to users not considering the engagement with security ceremonies to be “beautiful”.

3.5.2 Findings from Q4

In Q4, we analysed the 100 open-ended question responses. From an open-ended question we expected several possible kinds of answer, which we had not only to check but also to classify. In questions like this, some respondents just provide a random answer as they are not interested, or are too lazy, to think and provide a meaningful answer. Our analysis approach was the following. First of all, we skimmed the list for yes/no/I-don't-know answers, removing 27 answers. After that, we removed 32 answers that we deemed to be out of context (e.g., due to apparent misunderstandings). We classified and grouped the 41 remaining answers based on the general idea or suggestions that they communicated.

The results are shown in Table 1. The general categories that emerged from the analysis are: *SMS*, *Geolocation*, *Biometric*, *Alert* and *Password*. *SMS*

suggests to use text messages to warn the users that something is happening. *Geolocation* suggests to use the GPS position or Wi-Fi location to prove that some operations are allowed from the place where they are executed. *Biometric* suggests the use of fingerprint or face recognition, or other biometric-recognition technology to authenticate the users. *Alert* suggests the use of some kind of notification (e.g., push notifications) to alert the users. *Password* suggests that passwords be used, but that they be improved in different ways (e.g., reducing the number of characters, relaxing some of the constraints on character type, or the “distance” from the previous password).

Table 1: Categories for the answers to question Q4.

SMS	Location	Biometric	Alert	Passwd
7	2	17	8	7

Biometric technology was suggested by 17 respondents as a viable way to beautify the security experience, thanks in particular to the recent spread of fingerprint and face recognition facilitated by smartphone manufacturers. 8 respondents expressed the will to improve cyber security by using some kind of alerting system through notifications, as long as this is integrated into a two-factor or multi-factor authentication solution with multiple devices enabled to receive warnings.

New methods based on passwords and SMS-enabled technology were indicated by seven respondents. Finally, two respondents suggested using geolocation as a method that checks the position of devices to authorise certain operations.

4 OPERATIONALISING THE FINDINGS

The idea behind the questionnaire was to understand how people characterise the beauty of security ceremonies in such a way that we could formulate general guidelines to inform the design of beautiful security ceremonies, or of beautified versions of existing security ceremonies. The previous Section presented the answers to our questionnaire and reported the insights we gained. Such insights can be generalised as a variety of guidelines. Here we report the four that we deem most relevant. They derive from the four questions seen above, respectively.

- G1. Feel unencumbered: you do not need to carry anything along.
- G2. Leverage the sense of the group.
- G3. Simplify the rules, even though they seem essential.

G4. Use biometrics techniques.

G1 enhances the sense of freedom and it comes from the the insights originated from Q1. At some point, security analysts ruled that “possessing” something enables us to pursue security through what we hold. This changed the pre-existing password approach due to the perception that holding something is easier than remembering complicated password. Unfortunately, this is not always true. Human nature makes us prone to forgetting seldom-used objects and we also easily lose small objects. Cards and one-time token generators are good examples of objects that are easily lost or mislaid.

However, a ceremony that asks a user to prove that they hold an object might not be the best solution to the perceived unattractiveness of existing security ceremonies. The need to possess an essential security ceremony object could easily be considered burdensome. It can lead to frustration each time a user cannot engage with it. This is why we advance guideline G1 as a solution to this burden every time a person needs to demonstrate ownership of a physical object.

G2, which derives from the insights for Q2, is oriented at a ceremony design that makes the user feel part of a group. This situation is well represented in the Peppa Pig episode (Peppa, 2010) where having a secret word implies being part of a secret club. This view was supported by the responses that we obtained in the questionnaire because the situation we described was perceived as being *Fun* by most respondents. Although it would seem unusual to achieve this level of agreement in a such diverse context, we want to strive towards exciting that same feeling of enthusiasm when people interact with systems securely.

G3, stemming from Q3, is a reasonable assumption based on the fact that having simpler ceremony rules improves the user’s experience while preserving security. What G3 advances is an approach that urges a return to simpler rules, thereby freeing the users from any extra burdens in the execution of essential security ceremonies. Einstein famously said that things should be “*made as simple as possible, but no simpler*”. This applies admirably to our security context.

G4 suggests using “something you are” in security ceremonies. The answers to Q1 and Q3 revealed that users considered “something you know”, such as a password, as well as “something you have” burdensome. An alternative approach that might be more acceptable could be the use of biometrics, as highlighted in the responses to Q4. Although the use of biometrics is not exempt from critique as many users (and some developers of security solutions) are con-

cerned about their privacy ramifications, a variety of different biometrics are available and they do appear to represent a reasonable compromise, also conveying a sense of play and of being “cool and modern” in achieving security.

If we are able to introduce G4 in ceremonies, we will likely obtain a positive response from the users.

5 APPLYING BEAUTIFYING GUIDELINES

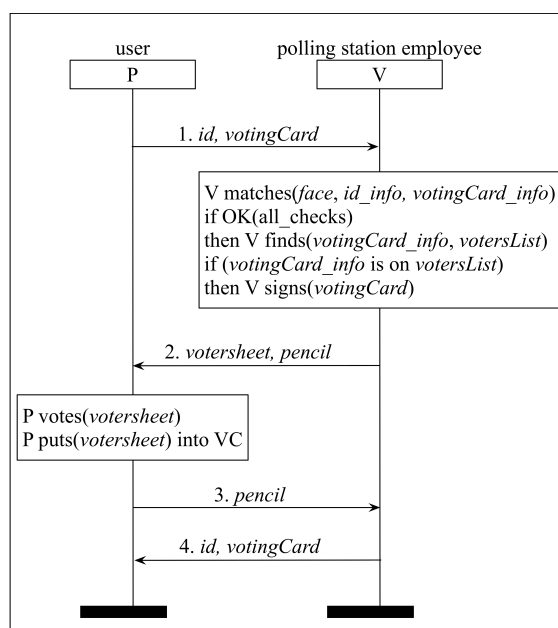


Figure 2: The current Italian voting ceremony.

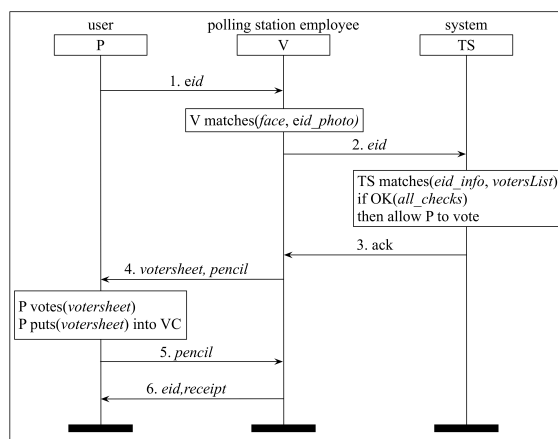


Figure 3: Potentially beautified Italian voting ceremony.

Bella and Viganò (Bella and Viganò, 2015) highlighted the crucial aspects of security ceremonies to acknowledge the value of beautifying ceremonies.

Developers can avoid their ceremony becoming ineffective when people bypass it due to its unattractiveness. However, achieving cyber security requires systems to interact with many other pre-existing systems' ceremonies. Some of these are so part-and-parcel of others' systems that it might be difficult to replace them with more beautiful ceremonies built following our guidelines. We are concerned with the possibility of improving an existing security system with as little effort as possible. Our intention is (i) to take a system that does not reflect the beautiful security approach (Bella and Viganò, 2015) yet it is secure in the (often) optimistic assumption that the users will use it precisely as intended by the system designers, and (ii) to beautify the system following our guidelines so that this assumption becomes less optimistic and more realistic.

We consider four ceremonies that are, we believe, in dire need of beautification:

1. the Italian voting ceremony,
2. the Laptop login ceremony,
3. the Password setup ceremony, and
4. the EU Premises access ceremony.

We discuss ways to make such ceremonies more beautiful and for each of them we present a specific beautified version that we have devised, with the exception of the improved Laptop login ceremony that has already been developed by Apple.

The beautification changes that we propose reflect the guidelines we identified in the previous Section (and also reflect the authors' combined experience of designing *Socio-Technical Systems*). In the following Section, we will then report on the second questionnaire that we issued to assess whether the new versions of the security ceremonies that we present here are indeed perceived to have been beautified.

5.1 Italian Voting Ceremony

Figure 2 shows the voting ceremony currently used in elections in Italy. Here, and in the following, we represent security ceremonies by means of *Message Sequence Charts (MSCs)*, which show the messages exchanged by the principals (agents) participating in the ceremony, as well as the internal computation that is performed by the principals. The MSCs that we consider in this paper are, hopefully, quite self-explanatory.

In the Italian ceremony in Figure 2, there are only two principals: a user (the voter) and an employee of the polling station (the voting officer). This ceremony could be considered outdated in comparison with the voting ceremonies adopted in other countries. The



Figure 4: *votingCard* currently used in Italian elections.

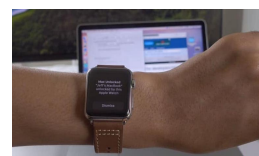


Figure 5: A successful MacBook login by Apple Watch.

outdated part of the ceremony would be represented by the need of the voter to have two different documents:

1. a national ID card (or any other identification document such as a passport or a driving licence) and
2. a *votingCard*, issued by the city hall to record that a voter has cast a vote in this election.

This *votingCard*, which is shown in Figure 4, represents the ceremony's main sticking point for two primary reasons. Firstly, *votingCards* are stamped at each election, and they fill up. If this happens, there are no more spaces for the voting officer to stamp the *votingCard* to register the voter's presence. A second problem occurs when a voter loses their *votingCard*. In both cases, the voter will first need to obtain a new *votingCard* from official sources at the city hall in order to be able to vote in this election (and some of the following ones, until the new *votingCard* is full).

During electoral rounds in the last years, these two issues have created particularly obvious difficulties, with long queues snaking out of city hall offices across Italy, populated by voters needing to obtain new copies of their *votingCards*.

The complication comes from the use of a single document (the *votingCard*) for two different purposes: (1) a voting register and (2) an eligibility proof. Voters experience frustration, especially if the *votingCard*'s spaces have been filled up, in which case the *votingCard* only satisfies one of its two purposes: eligibility. Recrafting this ceremony offers us a clear-cut opportunity for improvement.

The new ceremony in Figure 3 applies what we have suggested with G1 and G3, essentially simplifying the actual ceremony. We suggest replacing the "what you hold" object (the *votingCard* in this case).

The simplest way to replace the *votingCard* would be to use a system that needs the voter only to present their national ID card (or identification document), in its electronic form. The polling station employee would check the voter's eligibility and record their presence in a centralised database, by interacting online with a third principal in the ceremony (the "system"). The voter would no longer need to "hold" the *votingCard* that causes all the problems stated earlier.

5.2 Laptop Login Ceremony

Every day, users have to enter multiple passwords into their laptops (and computers). These passwords are becoming longer and more complex over time due to the security requirements enforced by operating systems. Figure 6 shows “password entry”, the login ceremony currently enforced by most laptop models. We can of course all agree that passwords are essential, but our questionnaire respondents confirmed our personal intuition (and our personal experience) that users increasingly dread this ceremony.

To simplify the login, Apple has developed a new way to login on its latest laptops by means of its Apple Watch product.³ It is coherent with our guideline G2 if we see the Apple Watch as a distinctive feature of a group. This authentication method is incorporated in the beautified ceremony shown in Figure 7. Every time the user needs to wake up her MacBook, she just needs to press a key on the keyboard or touch the trackpad; after that, the system looks for a paired Apple Watch and if it finds one, the MacBook unlocks itself without requesting any other actions. A successful outcome is demonstrated in Figure 5. Similar ceremonies using one or more small portable/wearable devices have also been proposed (Stajano, 2011).

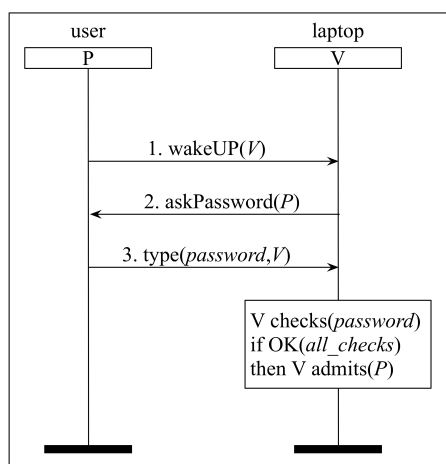


Figure 6: The widespread Laptop login ceremony.

5.3 Password Setup Ceremony

In 2003, the National Institute of Standards and Technology, published the NIST Special Publication 800-63 (Burr et al., 2004), where they suggested that users protect their accounts by inventing “awkward”, new

³Google and Microsoft are similarly planning to remove passwords using the protocol Fido in conjunction with Android phones or physical tokens, respectively.

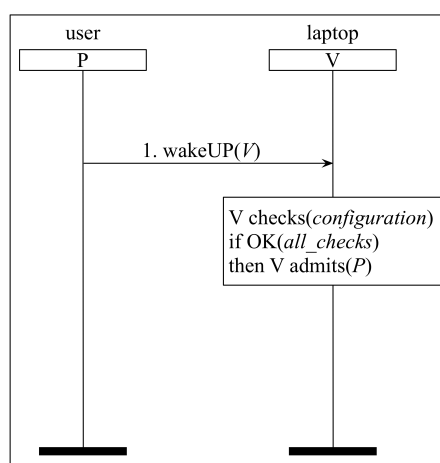


Figure 7: A potentially beautified Laptop login ceremony (by Apple Watch).

passwords that include uppercase and lowercase letters, numbers and special characters, and by changing their password regularly. Such passwords aim to be less guessable (e.g., more resistant to dictionary attacks). Nowadays, this is common practice, with websites and services forcing users to craft passwords respecting these constraints. Figure 8 shows a ceremony that reflects this practice.

In 2017, Bill Burr, the person who originally proposed the rules, declared that he regretted publishing those strict rules (McMillan, 2017). In fact, the new NIST document published in June 2017 (Grassi et al., 2017, Section 5.1.1.1) contains the following novel guidelines:

“...memorized secrets shall be at least 8 characters in length if chosen by the subscriber. Memorized secrets chosen randomly by the Credential Service Provider (CSP) or verifier shall be at least 6 characters in length and may be entirely numeric. If the CSP or verifier disallows a chosen memorized secret based on its appearance on a blacklist of compromised values, the subscriber shall be required to choose a different memorized secret. No other complexity requirements for memorized secrets should be imposed.”

Applying these guidelines, it is possible to propose a new ceremony that allows users to choose whatever password they want, morphing the security component into a check on the number of times a password is typed incorrectly. By doing so, we simplify the rules imposed by the ceremony as suggested by G3. Figure 9 shows the new “Password setup” ceremony that we propose.

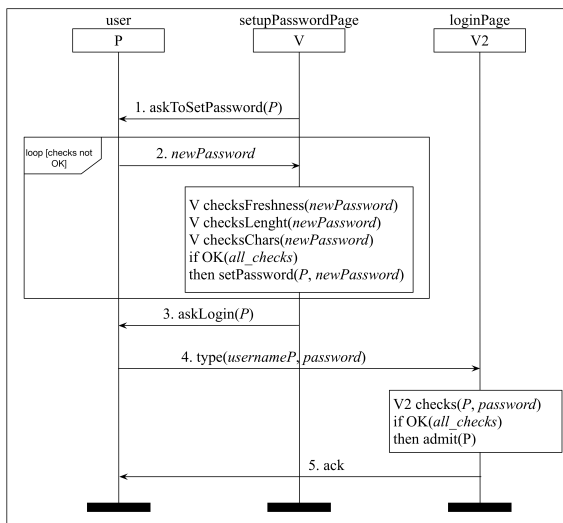


Figure 8: The current Password setup ceremony (using NIST 2003 rules).

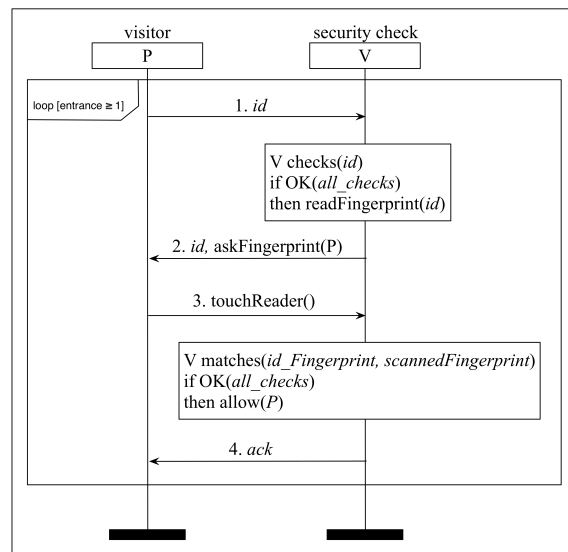


Figure 10: The current EU premises access ceremony.

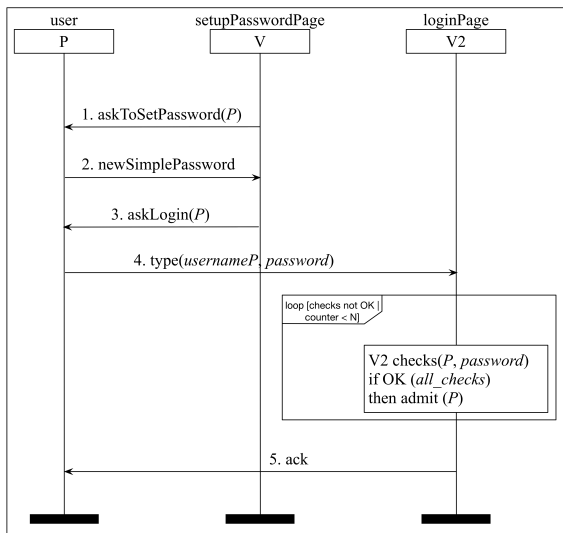


Figure 9: A potentially beautified Password setup ceremony (using the new NIST rules).

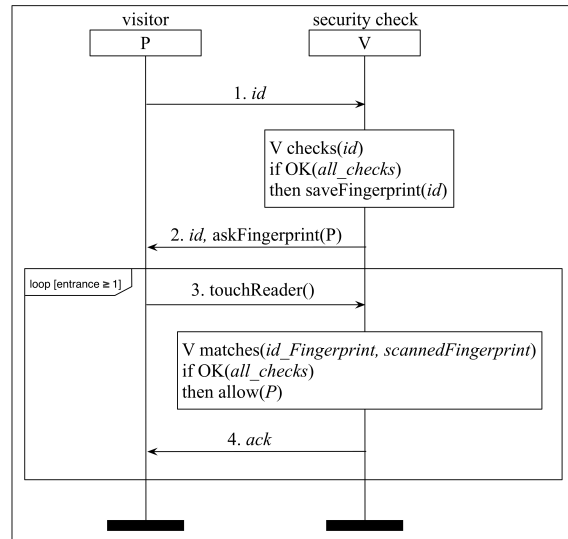


Figure 11: A potentially beautified EU premises access ceremony.

5.4 EU Premises Access Ceremony

Those wishing to gain access to highly-secure buildings, such as some EU premises, have to engage with an authentication ceremony like the one shown in Figure 10, in which the security staff check both a visitor's photo-ID (e.g., a national ID card or a passport) and their fingerprint, which is stored in a database.

This ceremony thus requires a first-time visitor to engage in a time-consuming fingerprint-registration process. This ceremony is repetitive in the case of returning visitors, hence especially frustrating if a person needs to access the premises, for example, multi-

ple times a day.

We can apply G4 to make the ceremony (more) beautiful. Still using biometric technology, it is possible to devise a leaner ceremony that requires the user to engage with fewer interactions. In this beautified ceremony, shown in Figure 11, we have removed the document check for the entrances after the first one, so that the main security checks are only addressed by means of fingerprint control.

6 CROWDSOURCING FOR THE APPLICATION OF BEAUTIFUL SECURITY

Our second questionnaire aimed to determine whether applying our guidelines to ceremonies, or highlighting improvements based on our guidelines in existing ceremonies, had been effective. We wanted to find out whether the beautified alternative we present to the respondents is indeed considered a positive improvement, or not.

6.1 Design of the Second Questionnaire

We designed the questionnaire to present two alternative versions of the same ceremony: an original and a beautified one, the latter arrived at by applying one or more of the beautification guidelines. To that end, we presented respondents with the four different ceremonies we described in Section 5. Respondents were asked to answer by giving a preference on which of the two versions of each ceremony they think is the most beautiful.

The questionnaire consisted of the following four closed-ended questions, allowing people to respond with a single preference:

Q1: You have to choose a new system to be authenticated to vote in an election. Which of the following two alternative systems is more beautiful?

1. A system that requires you to bring your “voting eligibility certificate” in addition to your ID Card.
2. A system that requires you to bring only an electronic ID document.

Q2: You have to choose a new system to log in on your laptop. Which of the following two alternative systems is more beautiful?

1. A system that requires you to type in your password.
2. A system that requires you to approach your laptop with your smart watch.

Q3: You have to choose a new authentication system. Which of the following two alternative systems is more beautiful?

1. A system that requires you to insert a complex password (including requirements such as minimum number of characters, or the use of capital letters, numbers and special characters).
2. A system that requires you to insert whatever password you want but it limits the number of times you may type the password incorrectly before getting locked out.

Q4: The security officers at the entrance of a secure building have registered your ID and fingerprint on the system once you have completed the registration. Which of the following two alternatives to access the building from now on is more beautiful?

1. ID + fingerprint every time.
2. Fingerprint every time.

Q1 thus refers to the two versions of the Italian voting ceremony; Q2 to the two versions of the Laptop login ceremony; Q3 to the two versions of the Password setup ceremony; Q4 to the two versions of the EU Premises access ceremony.

6.2 Findings

We administered the questionnaire to one hundred respondents using the CrowdFlower platform, not constraining respondents in terms of language or geography. As we remarked above, CrowdFlower workers span the globe, so we were assured of a heterogeneous sample. In order to obtain more focused answers from semi-expert respondents, we also administered the questionnaire to 24 students of the “Cryptography and Information Security” course that one of the authors is teaching. The students attending this module are computer science or mathematics students in the final year of their undergraduate studies or in the first year of their master’s studies. We can thus call these respondents “security-savvy”, in contrast to the “generic” respondents on CrowdFlower. Security-savvy respondents were asked the same questions Q1–Q4 but were also shown the MSCs of the ceremonies.

The combined results of the second questionnaire are shown in Figure 12 and we now wish to take stock and reflect on the responses that we received. The respondents provided us with extremely useful, and to some extent slightly surprising, feedback.

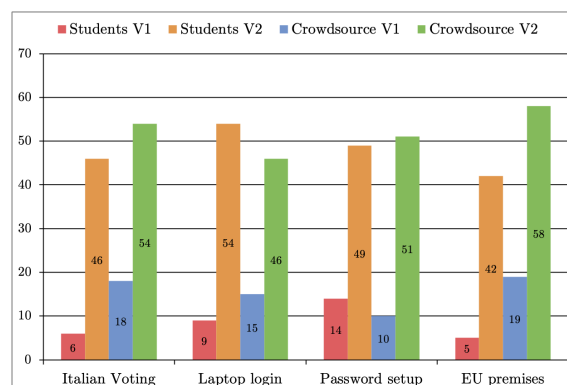


Figure 12: Data obtained from the second crowdsourcing.

The answers to the first question clearly indicate that both generic and security-savvy users find the beautified Italian voting ceremony that we propose to be considerably more beautiful than the ceremony currently in use.

The answers to the fourth question indicate even more strongly that both generic and security-savvy users find the novel EU Premises access ceremony that we propose to be considerably more beautiful than the ceremony currently in use.

Our respondents were almost equally split between the original versions of the second and third ceremonies we considered and their beautified versions. It is, however, instructive to analyse the responses in more detail.

Consider the password setup ceremony. It is interesting to note that the 100 generic respondents have a minimal preference for the proposed beautified ceremony that uses the new NIST rules (51 vs. 49), whereas almost 60% of the semi-expert students would rather engage in the original ceremony based on the 2003 NIST rules. We believe that these results are evidence to the fact that the respondents, especially the security-savvy ones, perceived the original ceremony to be more robust than the newly proposed ceremony, although the latter is potentially more lean and beautiful.

Finally, consider the laptop login ceremony. In this case, 54% of the generic respondents preferred the original ceremony, whereas 62.5% of the security-savvy respondents preferred the novel ceremony using the smart watch. We believe that this indicates that young computer-science/mathematics students are more likely to embrace novel technologies than the cohort of generic respondents, which includes people of different age, education and background, who are thus more likely to meet such technologies with suspicion or even rejection (perhaps also due to the elitist nature of such technologies).

7 CONCLUDING REMARKS AND FUTURE WORK

This paper described how we went about finding a way to beautify security ceremonies, thereby making beautiful security achievable in practice. We first explored the literature to find out what beauty means to users, specifically in the context of interaction with software systems. We then explored general perceptions of security ceremonies by posing questions to crowdsourcing respondents. Having gained insights from this process, we proceeded to “beautify” four security ceremonies. We then posed another round of

questions to crowdsourced participants to judge the success of our beautification of ceremonies. Overall, the outcome of the final stage confirmed that two of the four beautified ceremonies were indeed perceived to be more beautiful than they had previously been. The other two beautified ceremonies were not perceived to be more beautiful by our respondents.

The use of crowdsourcing enabled us to explore and implement the “beautiful” security paradigm, and gain feedback from a diverse and global audience. Our experiments confirmed that security ceremony design has plenty of scope to consider instilling beauty — with the general aim of achieving more beautiful security ceremonies. The assumption that people are normally attracted to beauty, as vastly substantiated by the relevant literature, will then strengthen such a design because it will be secure not just in isolation but *when used* by its users. Beauty may reinforce the designers’ assumptions that the users will conform to the ceremony as intended.

A variety of real-world ceremonies would benefit from being subjected to a beautification process based on guidelines such as those proposed here. The process itself could be developed further, for example by combining and leveraging several guidelines at the same time. This will be particularly important in the case of ceremonies such as Password setup, on which our experiments showed that beauty will also need to convey robustness. The Laptop login ceremony, where newer technologies such as the Apple Watch are used, might not yet be considered to be beautiful by the wider population today.

The methodology discussed here has reached the development stage of a proof of concept but we are aware that it must be developed further. For instance, we plan to repeat the crowdsourcing experiments over a larger sample population to reinforce the actual beautification guidelines as well as the confirmation that the beautification has succeeded.

Moreover, although beautifying existing ceremonies may sometimes lead to simplifying them, simplicity did not turn up in the categories that emerged from the analysis of answers to open question Q4. Arguably, simplifying a security ceremony might compromise security; we thus also plan to develop combinations of empirical, analytical and formal approaches (Bella and Coles-Kemp, 2012; Radke et al., 2011; Karlof et al., 2009; Martina et al., 2015) to help ensure that when the new paradigm is applied to a ceremony, possibly simplifying it, it remains secure. This will require defining degrees of ceremony attractiveness for humans in a formal, logico-mathematical way, in order to then be able to reason about the interplay of beautification and security, ultimately ensur-

ing that the beauty of a ceremony does not come at the expense of its security (which might be the case for some of the ceremonies we considered, e.g., if users choose weak passwords), but instead provably reinforces its security. We expect that this will ultimately lead to defining criteria that formalise when beautification preserves or reinforces security.

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