

Decaying Photos for Enhanced Privacy: User Perceptions Towards Temporal Redactions and ‘Trusted’ Platforms

SABID BIN HABIB PIAS, Department of Computer Science, Indiana University Bloomington, USA

IMTIAZ AHMAD, Department of Computer Science, Indiana University Bloomington, USA

TASLIMA AKTER, Department of Computer Science, Indiana University Bloomington, USA

APU KAPADIA, Department of Computer Science, Indiana University Bloomington, USA

ADAM J. LEE, Department of Computer Science, University of Pittsburgh, USA

With the rising popularity of photo sharing in online social media, privacy violations have become an increasing concern. While applying image obfuscations has been a useful tool for improving privacy, prior studies found these obfuscation techniques adversely affect viewers’ satisfaction. In the context of ephemeral (or disappearing) photo that has been popularized by Snapchat, people have found workarounds to save these photos before deletion. We conducted an online experiment (N=385) to evaluate people’s sharing preferences with two proposed temporal redactions in different contexts (by varying the photo content and the type of recipient). We also studied people’s sharing behaviors under different levels of assurance provided by the viewer’s platform (i.e., whether the receiver’s platform is secured using trusted hardware). Our findings suggest that although people are comfortable with existing methods, the proposed temporal redaction mechanisms are often preferred. We also found no difference in participants’ sharing behaviors for trusted and non-trusted viewing platforms, suggesting more efforts are needed to convey the benefits of trusted hardware to users.

CCS Concepts: • **Security and privacy** → **Human and societal aspects of security and privacy**.

Additional Key Words and Phrases: Privacy, photo sharing, image obfuscation, trusted hardware

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1 INTRODUCTION

Photo sharing has become one of the dominant methods of sharing digital content in online social media in recent times [1, 69]. Sharing personal photos is a media of sharing ‘small moments’ with close social contacts [9], impression management [70], or increasing social interaction [52, 60]. However online photo sharing also raises several privacy concerns. Embarrassing moments can go viral online through rapid re-sharing of photos in social networks [29], thereby demeaning people’s social impressions through rumours and gossip [22]. Such publicly shared photos can unintentionally include personally identifiable data [51] leading to security and privacy violations. Sometimes, the photos shared online can also raise privacy concerns for bystanders (those people who are incidentally captured in a photo) [57, 64]. Applications such as Snapchat¹ provide a novel layer of protection by allowing people to share ‘ephemeral’ photos, which ‘disappear’ soon after

¹<https://www.snapchat.com/>

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the viewer has opened the photo. The ephemeral version of photo sharing has let the users share ‘personal’ moments with their peers and convey ‘self-expression’ more than the existing persistent versions of photo sharing [4, 16]. However, researchers have found out that it’s possible to save the media file on a viewer’s device [40].

Some studies have indicated that privacy measures can be taken in the form of obscuring a part of the photo before posting the photo on social media [28, 30]. The motivation of image sharing on social media is maintaining social impression [20], gaining respect in social circle [54, 60] besides conveying information and keeping in touch with the peers. Hence, it is important to preserve the satisfaction and experience of the viewers while obscuring a region in the photo [29]. Prior studies have found that strong obfuscation techniques such as ‘masking’ lowers viewers’ satisfaction [29] whereas some ‘beautification’ on the sensitive region may preserve the photo quality to increase viewers’ satisfaction.

Regardless of the privacy preserving techniques used to obscure the sensitive regions of the photos, a privacy threat arises from the lack of control over the viewer’s actions and their control over the viewing platform. Prior studies have showed that the viewer can save the media file when it’s visible on the application [40]. One suggested approach is to enforce restrictions through the use of trusted hardware [24, 62] and Trusted Execution Environments (TEE) [65]. When a viewer’s device is equipped with a TEE, it is possible for the social media application to use the secure enclave of the device to protect sensitive media files [19] and, for example, prevent users from saving the photo on the device.

Although photo sharing in the context of redactions has been explored recently, more work is needed to understand people’s photo sharing experiences and privacy concerns in the context of ‘temporal’ redactions. Beyond the existing ephemeral approach, we explore the delayed and gradual applications of redactions. Prior studies have showed that applying a redaction on a photo while sharing it may decrease the aesthetic appeal of the photo which may hamper the purpose of sharing photo. We intend to explore if temporal redactions are preferred by users as it may help users preserve the aesthetic of the photo while redactions are not being applied initially, but in addition, protect users’ privacy by applying automated redaction after, say, 24 hours of posting the photo. Second, software like Snapchat provide only weak assurances about deleting photos on the viewers’ devices [78]. We study to what extent users find TEE-based solutions more trustworthy and whether such devices increase their likelihood of sharing private photos.

In particular, we explore the following research questions in this study:

RQ1: How do various temporal redaction techniques affect people’s sharing likelihood for different types of sensitive content? How do these preferences change in the context of the target audience?

RQ2: Does the trustworthiness of the viewing platform affect people’s photo sharing likelihood? Is there any affect of trustworthiness of the viewing platform on the choice of temporal redaction or on the content type in the photo?

We conducted an online, survey-based user experiment (N=385) to explore these research questions. In the survey, we studied people’s likelihood of sharing photos that contain sensitive contents with several temporal redaction techniques to obfuscate those particular contents of the corresponding photos. We conducted a between-subjects survey with random assignment based on whether the device of the audience of these photos includes a Trusted Execution Environment (TEE) or not. Each of these two surveys had three within-subject temporal redactions (instant, delayed, and gradual) applied on the same photo along with two base conditions (sharing the original photo and sharing with ephemerality as in Snapchat, i.e., the photo will be deleted after a period of time). We asked the participants about their likelihood of sharing photos with these redaction techniques with four different target audiences — family, friends, colleagues, other followers. Each photo contained

one sensitive type of content from the following: information content, facial expression photo with an entertaining filter, and bystander. All the photos were selected and refined based on feedback from pilot studies.

Our findings indicated that participants prefer the existing methods such as sharing without redaction, or sharing with the instant application of redactions. However, several participants showed a preference towards the delayed and gradual temporal application of redactions in certain circumstances. It will be interesting to evaluate the sharing behavior in participants when they are provided with more control in temporal application of redactions. We did not find a significant difference in participant behavior in terms of sharing photos in trusted and non-trusted viewing platforms. Trusted Execution Environment (TEE) can be a powerful tool to address some security vulnerabilities. Future studies may focus on conveying the utility of TEEs among non-technical users and raise awareness about potential susceptibility in social media photo sharing.

2 RELATED WORK

Various approaches have been explored to find an optimal mechanism to protect privacy while sharing photos on social media. Researchers have looked into several privacy-preserving techniques while sharing information such as controlling the content or the recipient [15]. We will discuss privacy-preserving mechanisms in terms of content and recipient control.

2.1 Content control

Studies have shown that users’ privacy perception in photo sharing behavior is affected by whether the photo contains location information, private information, or impression violating content [33, 34, 48]. One way to protect these contents from being revealed is to obscure sensitive regions of a photo [28, 49]. Prior studies have found that differing customized filter for obscuring the sensitive region based on the content type can be useful in terms of privacy protection and photo utility preservation [28]. Using cartoon stickers to hide unintended faces may also be another medium of obfuscation [47]. Yuan et al. built an iOS application ProShare which applied JPEG scramble on some parts of the photo in a client device [80].

Various approaches have been developed to address the privacy of the people depicted in the photo. Facial recognition can be used to detect people in the photo and ask for their permission before posting the photo online [76]. Some applications such as Face/Off² blur out faces in an image in an automated fashion when the viewer of the photo does not have permission to see those faces [35]. A privacy protection mechanism named “Cardea” can detect users’ privacy preferences based on location, scene, other’s presence, and hand gestures, and eventually blurs out parts of the photo based on user preferences [67]. The popular online platform Youtube also protects publicly identifiable information by blurring out faces and license plates [17]. Some researchers have explored replacing the full body of a bystander in a photo with neighboring views or body of another person [25, 59]. Using other person’s face has a severe ethical implication which required to be reassessed. Dimiccoli et al. showed that bystander privacy concerns can be mitigated through image degradation [23]. Swapping faces of a person in a photo realistically has been an area of interest for researchers [13, 42].

But these obfuscation techniques have some limitations in varying circumstances. Prior work has shown that while Blurring and Pixelating a region in the photo does not hamper photo quality significantly, they are vulnerable to the identification of the hidden face or element [49]. Moreover, masking with colored rectangle has been effective against recognition by humans but is found to be less satisfactory to the viewers [28]. In addition to exploring different combinations of pixelating

²<https://apps.apple.com/us/app/face-off/id1317161001>

and masking to preserve the photo quality while protecting private information [29], prior studies have also shown that the latest image recognition algorithms can retrieve information from blurred and pixelated parts of the images [55]. Compared to blurring or pixelating, masking has been proven effective against image recognition techniques to identify faces and body parts in different scenarios in addition to human recognition [28, 49, 61]. Sun et al. [71] proposed a two-stage Head Inpainting mechanism to reduce the risk of identity detection by threat models. We have chosen blurring as an intermediate redaction technique keeping viewer satisfaction in consideration and gray masking as permanent redaction technique to reduce the risk of content retrieval.

2.2 Temporal Content Control

For some time, content sharing in social media has been influenced by the idea of getting rid of the contents after a short period of time. Bernstein et al. studied user behavior in anonymous site 4chan [10] and found that users spend very short time on each content posted by other users. Leavitt et al. showed that Reddit throwaway accounts are getting popular among women because of the concept of temporary identity [46]. Ayalon et al. showed in a study that Facebook³ users lose interest in a posted content over time [6] and suggested an expiry and extensive archival feature for facebook posts by users. But Bauer et al. [8] found a gap between users' privacy preference prediction for their future self and suggested that extensive archival feature would not be suitable for the users. The idea of "Temporary Social Media" [38] has been widely adopted by several SNS platforms such as Snapchat and Instagram, where the photo is automatically removed after some time of sending it to the viewer. The ephemeral story-sharing feature has become widely popular and influential after Facebook integrated the feature into their SNS platform [79]. Younger SNS users are taking advantage of the ephemeral nature of sharing content as they find it easier to control the content flow [2]. Studies have shown that users prefer ephemeral social networking sites more for lightweight entertainment [39, 73] or as a medium of self-expression [74] than for privacy preservation.

Barua et al. [7] discussed elaborate forgetting mechanisms and interfaces where they demonstrated that a decay mechanism of gradually removing obsolete contents would simulate the decay process in human memory. Gulotta et al. designed *BitLogic* and *DataFade* where users can upload Photos and those photos will be decayed over time [27]. They found that some users are protective about their self representation and they are intrigued by the decaying nature of the system. Mohamed et al. studied user behavior on a fictitious system where social media posts were being decayed incrementally each month [56]. In the system, they faded, pixelated or, blurred the whole post including the whole image and image caption. They found that users are interested in the decaying digital artifact given some control over the decay feature.

In this study, we have worked on the degradation of a particular region of the photo which contains a sensitive content. Two kinds of photo decaying techniques have been introduced – gradual redaction where the content of the photo will be blurred within 12 hours of sending the photo to the viewer, and masked with a gray rectangle after 24 hours and delayed redaction where the content will be masked with gray box permanently after 24 hours of sending the photo to the viewers.

2.3 Access control

A common approach to control the access of photos is to allow a specific subset of users to view the photos. However, due to the complex architecture of the privacy settings, users hardly manage the privacy settings frequently and as a result, tend to make unintentional mistakes of sharing photos

³<https://www.facebook.com>

to wrong audiences [50, 53]. Cook et al. categorized different audience groups in online sharing platforms such as Family and Friends, Professional Peers and General Audience in the internet [18]. Knijnenburg et al. explored different categorizations with respect to granularity and found that categories with normal granularities (Family, Friends, Classmates and Colleagues, Acquaintances) are more appropriate for social media users in terms of risk of oversharing and managing privacy settings. Furthermore, a combination of Recipient control and Content control has been adopted as a measure of protecting photo privacy in several studies. For example, PUPPIES [31] is a mechanism where the users can obscure a region of the photo and specify the privacy policy for specific audiences of the photo at the same time.

While social media applications adopt various security mechanisms to protect the user’s data, it’s possible for the viewers to save media files in their device [40]. Third party apps such as SnapKeep was rumored to be used to save snaps without notifying the sender [5, 14]. In addition, there have been incidents of leaked photos from renowned social media and photo sharing sites [26]. P3, a photo encoding algorithm has been proposed where the sensitive region of the photo can be encrypted and extracted in a secure part of a device while preserving the quality of the public part of the photo [63] to ensure that the viewer cannot save the photo in their device. To address unwanted media retrieval, Trusted Execution Environments (TEE) has been adopted among hardware manufacturers. TEE is a mechanism to make sure that the media file cannot be retrieved by the device owner if the device is equipped with a TEE enclave and the media file is encrypted in the enclave [65].

In this study, we have considered family members, friends, colleagues and classmates, and other followers as target audiences with whom the participants may share photos. In addition, we have conducted a between-subject study between two groups of participants where one group was briefed that their photo can only be viewed by those audience whose devices are equipped with a security chip. Another group was briefed that their photos can be viewed in any device.

3 METHOD

We now describe our survey and data analysis procedures.

3.1 Survey study

3.1.1 Selection of Images. Each survey presented the participants with four types of photos, where each photo contained one of three different content types: information content, facial expression, and bystanders. For information content, we have considered common personally identifiable information (PII) such as a vehicle with the license plate number visible or photos of the front of a house, where the house number was visible [68]. Prior studies suggested that these personally identifiable information are considered as sensitive content by users when they share photos online [48]. In some photos with vehicles, a person was posing with the vehicle. For facial expressions, we showed a forward facing photo of a person where they have applied an entertaining filter (distortion or color) on their faces; facial expressions are also considered sensitive content for online photo sharing [48]. The bystander content type contained a bystander (secondary person who is not the subject of the photo) in the photo where the main focus was on another person. All these scenarios were described to the participants with text below the photo. Although the participants did not own or capture the photos, they were instructed to consider the photos as if they owned those photos. The photo descriptions contained the following text.

- **Information:** Assume this is a photo of your car (the front of your house), and you would like to share it
- **Facial Expression:** Assume this is a photo of your face.
- **Bystander:** Assume this is a photo of you with another person behind you.

We selected five images each for facial expression and bystander content types and ten images for information content including five images containing vehicles and five images containing the house number. As personally identifiable objects (PII) can be used to trace a person's identity in online social network [43], we wanted to pick situations that most participants might relate to in their personal lives. We collected the images by conducting searches copyright-free images on Google Images.⁴ Each of the images contain exactly one of the three content types. The images were selected to ensure they were respectful to race, age group, and gender. We excluded images with children. In addition, we tried to keep the quality, illumination, and image dimensions consistent across all images.

3.1.2 Selection of redaction techniques: For each participant, four photos were randomly selected where two photos contained information content (one with car, one with house), one photo contained a facial expression of a person, and one photo had a bystander in background. Each participant was showed each photo five times (for the following five redaction scenarios).

- **Instant Application of Redaction:** The content of the photo will be masked with a gray rectangle before being sent to the audience.
- **Delayed Application of Redaction:** The original photo will be sent without any obfuscation being applied initially. The particular content of the corresponding photo will be masked out automatically on the recipient's device 24 hours after sending the photo(Figure 1b).
- **Gradual Application of Redaction:** The original photo will be sent without any redaction at first. After 12 hours, a particular content of the photo will be blurred where some aspects of that content will be vaguely recognizable. After 24 hours, that content will be masked out (Figure 1a).
- **Original photo:** The original photo will be sent without any redaction applied. There would be no further automated action by the app.
- **Delayed Deletion:** This condition is similar to that of Snapchat stories,⁵ in which no redaction technique is applied, but the entire photo is deleted automatically after 24 hours of posting the photo.

To make the participants understand the obfuscation techniques better, we included both visual and text explanations of how the obfuscations would work. For the visual explanation, we showed a timeline (Fig 1) of the image conditions, which showed the transformed image at different times for each corresponding obfuscation technique. For the text explanation, the image condition was comprehensively described for each condition as follows:

“Assume this is a photo of you and your car, and you would like to share it with the license plate of the car being obscured by the app gradually over 24 hours in the recipient's device.”

The explanation text varied according to the photo content and the application of redaction of the photo. The visual and text explanations were briefed to the participants both before starting to respond on any image, and while they responded to the images. Overall, each participant was asked questions about a total of twenty scenarios in random order (Appendix A.4.1).

3.1.3 Type of target audiences: For each scenario in the survey, we asked the participants about their likelihood of sharing the photo with four kinds of audiences (family, friends, colleagues, and other followers). These four recipient categories were chosen based on prior literature [48]. The fourth category ‘acquaintances’ was rephrased as ‘other followers’.

⁴<http://images.google.com>

⁵<https://www.snapchat.com/>

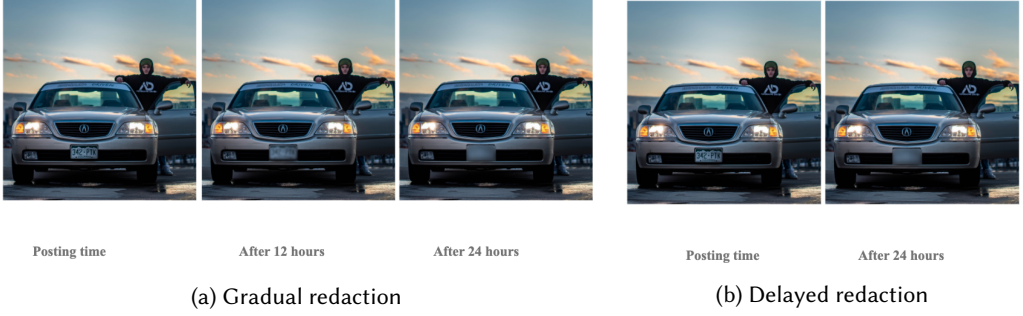


Fig. 1. A timeline based visual depiction of gradual and delayed obfuscation techniques

3.1.4 Device type of the image viewers: The participant pool was divided into two groups randomly to conduct a between-subject study based on the device condition of the image viewer. They were briefed that their images contain sensitive content. To make sure that the original images with sensitive content cannot be saved or captured as a screenshot in the viewers’ devices, we described two different approaches to these two groups. The instructions contained the following texts for the two conditions

- **Trusted device:** “Assume the recipient’s phone is equipped with a special security chip that will make it impossible for the viewer to save or take a screenshot of the photo.”
- **Non-trusted device:** “Assume the recipient’s social media app does not allow the viewer to save the photo and (like Snapchat) notifies the sender of the photo if the viewer takes a screenshot.”

The full instruction is portrayed in Appendix A.3.1.

3.1.5 Measuring sharing likelihood. We asked the following question (paraphrased) for each scenario (see Appendix ?? for our survey instrument):

Q. Assume this is a photo of you and your car, and you would like to share it with the license plate of the car being masked by the security chip in the recipient’s phone after 24 hours in the recipient’s device. This question varied based on the redaction condition, device TEE condition and the content type in the photo. Participants were asked to select from a seven-point Likert scale: (1) extremely unlikely (2) moderately unlikely (3) slightly unlikely (4) neither likely nor unlikely (5) slightly likely (6) moderately likely, and (7) extremely likely. The likert scale is adapted from [75].

3.1.6 Organization of the survey. The survey consisted of 52 questions in mostly close-ended form. The survey instrument was organized as follows (see Appendix A for the survey instrument):

- CAPTCHA to prevent automated responses
- Pledge to provide authentic and high quality responses
- Consent form
- Questions about which (if any) social media platforms they use, and how often they visit these sites
- Questions about which (if any) social media platforms they use to share photos online, and how often they share their photos.
- Twenty scenarios with four unique photos along with descriptive text, presented in random order (within-subjects), each with four questions about sharing likelihood with family, friends, colleagues, and other followers. Note that each participant was assigned to a single device

condition (whether the target audience's device contains a TEE or not), and these questions were asked in the context of one kind of device.

- Questions about whether they had ever shared a photo containing sensitive information and their most recent experience sharing an image (Appendix A.6)
- Question about their privacy preference (Appendix A.7)
- Questions about their interpersonal trust level (Appendix A.8)
- Five demographic questions (age, gender, race or nationality, education, and how long they have lived in the USA).

3.1.7 Recruitment. The survey was conducted on Qualtrics over a period of two months between May and July 2021. The survey was rolled out to small batches of participants on different days of the week and different times of the day to lower any kind of temporal bias. We recruited over 500 participants from Prolific.⁶

3.1.8 Compensation and ethical considerations . Our protocol was approved by our institution's ethics review board. We performed several online pilot studies to determine the approximate time range required to participate in the study. The median time taken for the study was a little above 16 minutes and the mean time was almost 18 minutes. Regardless of whether or not we used their responses, each participant was paid \$3.00 to complete the 15–20 min survey. The payment amount is in line with – and surpasses – the recommendation in Silberman et al [68] to pay workers at least minimum wage in the study's location.

3.1.9 Pilot study. We conducted online pilot studies with small batches of participants (20–30) to determine whether the participants were understanding the scenarios properly and whether the survey structure needed to be modified. We also requested them to suggest improvements to our survey (if any). The pilot studies occurred in five phases, each phase improved from the previous phase with the recommendation of the pilot participants such as improving instruction text or image selection. In the fifth phase, each participant provided satisfactory feedback and thus we finalized our survey.

3.2 Data analysis procedure

We now describe our quantitative analysis procedures.

3.2.1 Quantitative analysis. We collected our data in likert-scale form. Our data do not meet the assumptions of parametric tests, such as normality and equal variance of errors. Hence, We used non-parametric versions for all the statistical tests. We have one dependent variable (sharing likelihood) and several independent variables (content type, redaction techniques, device condition, target audience). We used linear mixed-effects models with fixed slopes and random intercepts for each participant. We also added interaction terms involving redaction techniques, target audience, and content types. The linear mixed-effect model was chosen because it considers the effects of having participants contribute multiple data points. We used estimated marginal means to compute all the pairwise comparisons, which helped determine the significant effects across the interaction effects. The p-values were adjusted with the Tukey method as it considers multiple comparisons and adjusts p-value to minimize the risk of Type I error.

⁶<https://prolific.co/>

4 FINDINGS

The omnibus test involving the mixed effect model is showed in Table 1. Content, redaction, target and some interaction terms showed significant effects on photo sharing likelihood. In the following sections, we present our key findings.

	Sum Sq	Mean Sq	DoF	Den DoF	F statistic	η_p^2
Content	108.3	54.1	2	10.1	19.45***	<0.01
Trust Condition	5.2	5.2	1	377.6	1.86	<0.01
Redaction	193.7	48.4	4	29692.3	17.3988***	<0.01
Target	19599	6533	3	29692	2347.25***	0.8
Content: Trust Condition	60.3	30.2	2	29704.7	10.83***	<0.01
Redaction: Target	381.9	31.8	12	29692.3	11.44***	0.016
Content: Redaction	2891.9	361.5	8	29692.3	129.8***	0.12
Trust Condition: Redaction	33.9	8.5	4	29692.3	3.04*	<0.01
Trust Condition: Target	38.7	12.9	3	29692.3	4.63**	<0.01

Table 1. Type III ANOVA Table (with Satterthwaite’s method). (* = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$). The effect size η_p^2 (partial η^2) can be interpreted as small if $\eta_p^2 = 0.01$, medium if $\eta_p^2 = 0.06$, and large if $\eta_p^2 = 0.14$ [45]

. Viewing platform condition is rephrased as ‘Trust condition’.

4.1 Effects of Redaction Applications, Sensitive Content Types, Target Audiences, and Viewing Platform Conditions on Photo Sharing Likelihood

To investigate the main effects of redaction techniques, sensitive content types, target audiences, and viewing platform conditions, we conducted posthoc pairwise tests (Table 2). We observed slight differences in applications of redactions. For sensitive content types, we found that participants are more likely to share photos containing bystanders than facial expression photos. Regarding target audience, participants were much more likely to share photos with family members and friends compared to other followers. We did not find any significant difference in sharing photos between trusted and non-trusted viewing platforms (Figure 2).

4.2 Interaction effect of Redaction Applications and Sensitive Content Types on Photo Sharing Likelihood

Table 3 shows the estimated mean values of the redaction applications grouped by sensitive content types. To further investigate this interaction effect, we conducted Tukey posthoc pairwise tests. In particular, we tested the following hypothesis.

H1 : Sharing likelihood is affected when a particular temporal redaction technique is applied based on the type of sensitive content.

Instant redaction is preferred for photos containing critical information or bystander. On the other hand, sharing original photo or sharing photo with ephemerality was deemed to be popular when facial expression is involved in a photo. We observed statistically significant differences for some of the pairwise comparisons of images with different redaction techniques for each sensitive content type (Table 4).

Information content: We observed that the participants somewhat preferred the instant application of redaction over all other redaction applications. On the other hand, participants were slightly reluctant to share the original version of the photo compared to ephemeral photo sharing or

Pairwise Comparisons	Estimate	SE	t ratio	Effect Size (Cohen's <i>d</i>)	P-value
Redaction Techniques					
Delayed < Instant	0.14		4.36	0.08 (negligible)	0.0001*
Gradual < Instant	0.13		4.21	0.08 (negligible)	0.0002*
Original < Instant	0.1		3.24	0.06 (negligible)	0.01*
Gradual < Deleted	0.13		4.14	0.07 (negligible)	0.0003*
Delayed < Deleted	0.13		4.29	0.08 (negligible)	0.0002*
Deleted < Original	0.1		3.17	0.06 (negligible)	0.013*
Content Types					
Facial expression < Bystander	1.18	0.19	6.28	0.7 (medium)	0.0002*
Information < Bystander	0.5		2.88	0.28 (small)	0.04*
Information < Facial expression	0.7	0.17	4.14	0.41 (small)	0.005*
Target Audiences					
Friends < Family	0.11		4.25	0.07 (negligible)	0.0001*
Other followers < Family	1.93		69.5	1.13 (large)	<0.0001*
CnC < Family	1.3		45.8	0.75 (medium)	<0.0001*
CnC < Friends	1.15	0.03	41.54	0.68 (medium)	<0.0001*
Other followers < Friends	1.81		65.3	1.06 (large)	<0.0001*
Other followers < CnC	0.66		23.76	0.39 (small)	<0.0001*

Table 2. Pairwise comparison of sharing likelihood in photos for redaction techniques, content types, and target audiences. CnC= 'Colleagues and classmates'. Significance after Tukey adjustment are indicated with p-values. The direction of the difference is indicated by '<' and '>'. Pairs without any significant difference are skipped.

the delayed or gradual application of redaction when the photo contained personally identifying information such as car registration number or house number in their photos.

Facial expression: Sharing the original photo without any obfuscation applied was slightly preferred when the photo involved facial expression with an entertaining filter. Overall, the participants slightly preferred delayed or gradual application of redaction compared to instant application of redaction in this case.

Bystander: When there was a bystander present in the photo, participants were slightly more willing to mask out the face of the bystander right away (instant redaction) while posting the photo in social media compared to applying the obfuscation at a later time.

Overall, these findings indicate that sharing preference differed in terms of the presence of any sensitive content in the photo. Participants were somewhat more comfortable with applying redactions instantly when there is a critical information or a bystander in the photo (Figure 3) compared to the other applications of redactions or the base conditions. For photos containing facial expression, participants were much more likely to share photos without any application of redaction or ephemeral photos compared to application of instant redaction on the face.

4.3 Interaction Effect of Redaction Applications and Target Audience on Photo Sharing Likelihood

The estimated mean of photo sharing likelihood for each redaction application grouped by target audiences can be found in Table 5. We conducted another set of Tukey posthoc pairwise tests to compare redaction applications and target audiences (Table 6). We tested the following hypothesis:

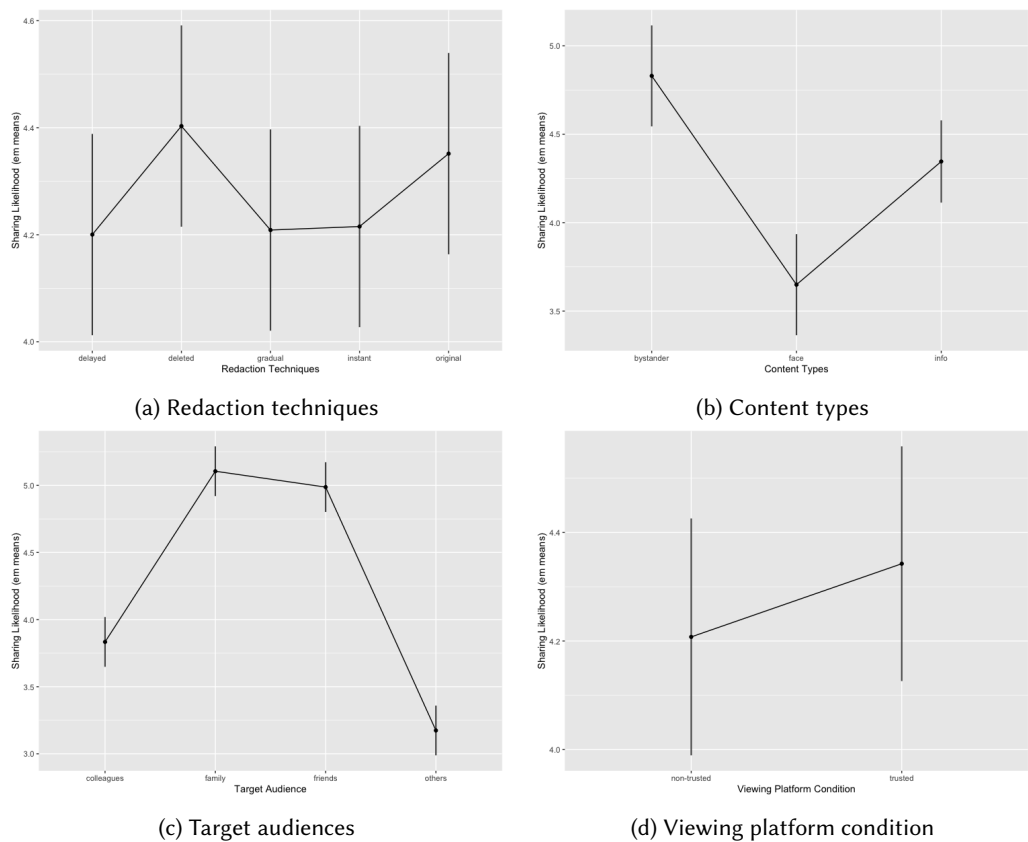


Fig. 2. Differences in sharing likelihood (emmeans) for different variables

H2: Sharing likelihood varies when different temporal redaction techniques are applied on the photo for the same recipient group. Our observations are as follows for different target audiences.

Family Members: Participants were somewhat more prone to share original photos compared to applying any redaction techniques (instant, gradual or delayed) when it came to sharing photos with a family member. Also, deleting photos after 24 hours of sending was slightly preferred over instant, gradual and delayed application of redactions.

Friends: Participants’ sharing preference with their friends was similar to their sharing pattern with family. For instance, sharing original photos was slightly preferred over delayed, instant or gradual application of redaction, and sharing ephemeral photo was slightly preferred over all other techniques.

Other Followers: Participants slightly preferred instant redaction over sharing the original photo or applying gradual or delayed redaction for the general audience.

Colleagues and Classmates: We did not find any significant effects among redaction applications when photos were being shared with Colleagues and Classmates.

In short, our findings suggest that participants slightly preferred not to apply any kind of temporal redaction on their photos when they share a photo with their friends or family members. In contrast, they slightly preferred instant application of redaction while sharing photos to the general audience (Figure 4).

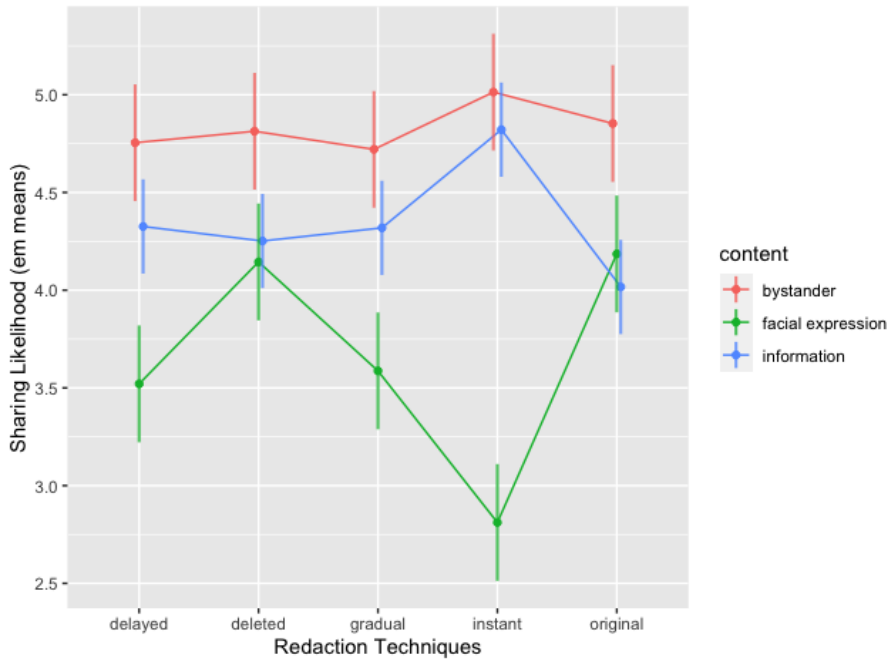


Fig. 3. Differences in sharing likelihood (emmeans) for different content types

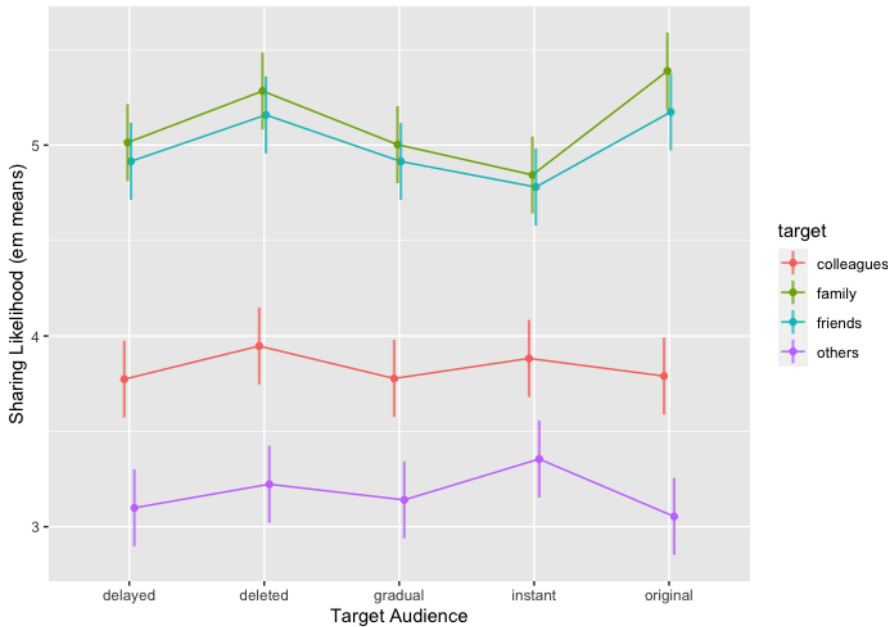


Fig. 4. Differences in sharing likelihood (emmeans) for different target audiences

Content Type	Redaction technique	Estimated mean	SE	DF	CI
Information	Instant	4.82	0.116	20.1	0.48
	Delayed	4.32			0.49
	Gradual	4.32			0.48
	Deleted	4.25			0.48
	Original	4.01			0.49
Facial Expression	Original	4.18	0.144	17.1	0.6
	Deleted	4.14			0.6
	Gradual	3.58			0.6
	Delayed	3.51			0.61
	Instant	2.81			0.61
Bystander	Instant	5.01	0.143	17.1	0.61
	Original	4.85			0.61
	Deleted	4.81			0.61
	Delayed	4.75			0.6
	Gradual	4.71			0.61

Table 3. Sharing Likelihood grouped by content type across redaction techniques, in terms of estimated mean values, standard error, degree of freedom, and confidence intervals. Results are averaged over the levels of: target audience, condition. Degrees-of-freedom method: Satterthwaite. Confidence level used: 0.95

4.4 Effect of Trusted Device Condition

We analyzed the interaction effect of the trusted device condition with redaction, content type, and target audience separately. In addition, we analyzed the main effect of trusted device condition. We did not find any significant effect of trusted device condition in the sharing likelihood of photos except in two cases.

4.5 Preference for Temporal Redaction

For each participant, we took the sharing likelihood involving the 16 combinations of content types (four) and target audiences (four) for each redaction application. We counted how many participants had highest sharing likelihood for delayed or gradual redaction involving each content type–target combination. We considered delayed or gradual redaction having highest sharing likelihood if they had a tie with other redaction or the base conditions. Table 8 shows that a part of the participants preferred delayed or gradual redactions in particular situations.

4.6 Effect of Social Media Platform

Out of 385 participants, 291 participants (75.6%) reported sharing photos online with frequency ranging from multiple times a day to a few times a month, and only one (0.26%) participant reported never posting photos online. A majority (233, 60.5%) of participants indicated that they share most of their photos in Instagram,⁷ while 193 (50.1%) use Facebook,⁸ 96 (24.9%) participants use Twitter,⁹ and 68 (17.6%) use Snapchat¹⁰ as their medium to share photos frequently. Some participants marked multiple platforms as photo sharing social media.

⁷<https://www.instagram.com/>

⁸<https://www.facebook.com/>

⁹<https://www.twitter.com/>

¹⁰<https://www.snapchat.com/>

Redaction technique	Estimate	SE	t ratio	Effect Size (Cohen's <i>d</i>)	P-value
Information					
Original < Deleted	0.234		5.48	0.14 (negligible)	<0.0001*
Original < Instant	0.81		18.77	0.48 (small)	<0.0001*
Original < Gradual	0.303		7.05	0.18 (negligible)	<0.0001*
Original < Delayed	0.31	0.043	7.22	0.19 (negligible)	<0.0001*
Deleted < Instant	0.57		13.2	0.34 (small)	<0.0001*
Gradual < Instant	0.5		11.72	0.3 (small)	<0.0001*
Delayed < Instant	0.49		11.56	0.3 (small)	<0.0001*
Facial Expression					
Gradual < Original	0.6		9.87	0.36 (small)	<0.0001*
Delayed < Original	0.66		10.96	0.4 (small)	<0.0001*
Instant < Original	1.37		22.67	0.83 (large)	<0.0001*
Instant < Deleted	1.33		21.99	0.8 (large)	<0.0001*
Instant < Delayed	0.707	0.06	11.7	0.43 (small)	<0.0001*
Instant < Gradual	0.77		12.79	0.47 (small)	<0.0001*
Gradual < Deleted	0.56		9.19	0.34 (small)	<0.0001*
Delayed < Deleted	0.62		10.29	0.38 (small)	<0.0001*
Bystander					
Gradual < Instant	0.26		4.83	0.18 (negligible)	0.0014*
Delayed < Instant	0.29	0.06	4.27	0.156 (negligible)	0.0001*

Table 4. Pairwise comparison of sharing likelihood in photos with different redaction techniques for each content type. Significance after Tukey adjustment are indicated with p-values. The direction of the difference is indicated by '<' and '>'. Pairs without any significant difference are skipped.

Frequent Instagram users showed significant difference in photo sharing likelihood in terms of applications of redactions. They showed slight preference for ephemeral photo sharing over delayed or gradual application of redactions. On the other hand, Twitter users had slightly more sharing likelihood for instant redaction over gradual application of redaction (Table 7).

4.7 Demographics

We received 506 responses from Prolific participants. After filtering for attention check question, we included 385 participants in the final sample. In our final sample, 215 (55.8%) participants identified themselves as male, 163 (42.3%) as female, and 6 (1.56%) as non-binary. Most of the participants were under 49 years of age, with 149 (38.7%) between 18 and 29 years, 194 (50.4%) between 30 and 49 years, 35 (9.09%) between 50 and 64 years, and six (1.56%) participants 65 years or older. For the highest level of education, 138 (35.8%) participants mentioned having an undergraduate degree, 41 (10.6%) a high school diploma, 87 (22.6%) a Master's degree, and six (1.56%) a professional degree. Most (243, 63.1%) participants were White, 49 (12.7%) were Black or African American, 50 (13.0%) were Asian, and 18 (4.68%) were Hispanic or Latino.

5 DISCUSSION

In this section, we discuss a) effect of sensitive content types on redaction preferences, b) relation between target audience and redaction preference, c) potential of temporal redaction as a privacy tool, d) intelligibility of trusted hardware among users, e) limitation of our study.

Target Audience	Redaction technique	Estimated mean	SE	DF	CI
Family	Original	5.38	0.098	43.9	0.39
	Deleted	5.28			0.4
	Delayed	5.01			0.4
	Gradual	5.00			0.4
	Instant	4.84			0.4
Friends	Original	5.17	0.098	43.9	0.4
	Deleted	5.15			0.39
	Delayed	4.91			0.4
	Gradual	4.91			0.4
	Instant	4.78			0.39
Colleagues and Classmates	Deleted	3.94	0.098	43.9	0.4
	Instant	3.88			0.39
	Original	3.79			0.39
	Gradual	3.77			0.4
	Delayed	3.77			0.4
Other Followers	Instant	3.35	0.098	43.9	0.4
	Deleted	3.22			0.4
	Gradual	3.14			0.39
	Delayed	3.09			0.39
	Original	3.05			0.4

Table 5. Sharing Likelihood grouped by Target Audiences across Redaction Techniques, in terms of estimated mean values, standard error, degree of freedom, and confidence intervals. Results are averaged over the levels of: content, condition. Degrees-of-freedom method: Satterthwaite. Confidence level used: 0.95

5.1 Redaction decision depends on what type of content the photo contains

Our findings show that participants tend to choose similar redaction techniques to obscure bystanders and sensitive information content types. Participants preferred applying instant, gradual, or delayed application of redactions when there was critical information present in the photo (such as vehicle license plate or house number). This finding is intuitive because of people’s general tendency to preserve their private information. A study on photo privacy detection suggests that people prefer that contents with critical information such as vehicle license plates and driver’s license should not be revealed in social media [72]. Protecting the identity of bystanders with instantly applied redactions supports previous claims that people tend to respect other people’s privacy while sharing photos [3, 11, 34]. Some work also showed that users tend to avoid social tension caused by unauthorized sharing of photos containing other people [12].

In contrast, when participants were asked about photos containing facial expressions with funny filters, most of them chose to share photos without any redactions applied, although several participants showed an inclination towards delayed or gradual applications of redactions along with simply deleting the photo 24 hours after posting. The aversion to using instant redactions on photos with facial expressions with filters can be backed by the previous findings. Choi et al. found that users of ephemeral sites are inclined to share their “true and actual self” [16]. Katz et al. found out that users consider ephemeral sharing as “fun” with their close network [39]. These findings explain the motive behind posting such photos without any obfuscations or as ephemeral photos

Redaction Technique	Estimate	SE	T-ratio	Effect size (Cohen's <i>d</i>)	P-value
Family					
Delayed < Original	0.37	0.06	6.1	0.23 (small)	<0.0001*
Instant < Original	0.54		8.86	0.33 (small)	<0.0001*
Gradual < Original	0.39		6.28	0.23 (small)	<0.0001*
Delayed < Deleted	0.27		4.39	0.16 (negligible)	<0.0001*
Instant < Deleted	0.44		7.16	0.26 (small)	< 0.0001*
Gradual < Deleted	0.28		4.57	0.17 (negligible)	0.0008*
Friends					
Delayed < Original	0.26	0.06	4.2	0.16 (negligible)	0.005*
Gradual < Original	0.26		4.22	0.16 (negligible)	<0.004*
Instant < Original	0.39		6.4	0.24 (small)	<0.004*
Instant < Deleted	0.38		6.15	0.23 (small)	<0.0001*
Gradual < Deleted	0.24		3.97	0.15 (negligible)	0.01*
Delayed < Deleted	0.24		3.95	0.15 (negligible)	0.0115*
Other Followers					
Original < Instant	0.3	0.06	4.9	0.18 (negligible)	0.0001*
Delayed < Instant	0.26		4.17	0.153 (negligible)	0.004*

Table 6. Pairwise comparison of sharing likelihood in photos with different redaction techniques for each target audience type. Significance after Tukey adjustment are indicated with p-values. The direction of the difference is indicated by '<' and '>'. Pairs without any significant difference are skipped.

Redaction technique	Estimate	SE	DF	T-ratio	Effect Size (Cohen's <i>d</i>)	P-value
Instagram						
Delayed < Deleted	0.2	0.04	498.53	4.84	0.11 (negligible)	0.001*
Gradual < Deleted	0.22			5.16	0.11 (negligible)	0.0002*
Twitter						
Gradual < Instant	0.27	0.06	49853	4.09	0.15 (negligible)	0.001*

Table 7. Pairwise comparison of sharing likelihood in photos with different redaction techniques for Frequently used Social Media Platforms. Significance after Tukey adjustment are indicated with p-values. The direction of the difference is indicated by '<' and '>'. Pairs without any significant difference are skipped.

that 'disappear' after a short time period; any instant redactions would hinder expressing one's true self with their close social contacts.

5.2 Social tie affects redaction preference

When sharing photos with family members or friends, participants were reluctant to apply any obfuscations on their photos. This is in line with the findings of prior study where it has been shown that users' sharing likelihood is higher when they share a photo with family members or friends [41]. This sharing behavior can also be attributed to the fact that when it comes to sharing photos, people trust family members and friends more than their other social ties [3, 48]. Another reason could be participants wanted to avoid the negative effect of viewers' satisfaction (when redactions are applied to a region of the photo) when the viewer is a family member or a

	Family	Friends	CnC	Other followers	Redaction
Car	19.9%	18.5%	16.9%	17%	Delayed
	18.7%	17.9%	16.8%	17.1%	Gradual
House	18.9%	19.7%	20.2%	20.8%	Delayed
	18.3%	19%	21.7%	21.8%	Gradual
Bystander	18.4%	19.3%	19.4%	20.2%	Delayed
	19.3%	18%	17.9%	18%	Gradual
Facial expression	17.5%	17.3%	18.8%	18.4%	Delayed
	18.6%	20.3%	19.5%	19.4%	Gradual

Table 8. Percentage of participants having highest sharing likelihood for gradual or delayed redaction involving particular content and target audience. CnC = Colleagues and Classmates.

friend [28, 29, 49]. Besides, Holloway et al. investigated how people have adopted Social Media (Facebook¹¹) for preserving their family photos [32]. They found that some users archive family photos in Facebook to keep them as memories and to share them with family members and close friends for future reference. However, it was interesting to notice that participants were inclined towards the ephemeral mode of photo sharing when sharing photos with family members or friends, where the photo will be deleted after 24 hours. Future studies need to be conducted to find out the motivation behind this sharing behavior.

For more distant contacts such as colleagues, our participants did not show any significant tendency towards instant, gradual, or delayed redaction techniques although prior study found that some users don’t share photos with colleagues as the photo may contain sensitive content with potential to reveal “white lies” or remove “plausible deniability” at work [48]. There is a possibility that the type of sensitive content they don’t want to reveal were not included in our study or the participants in general didn’t want to take any risks sharing the photo itself with their co-workers. Future studies need to be conducted to find if there is any particular method that increases sharing photos with colleagues and classmates.

Finally, for sharing photos with ‘other followers’, our participants indicated a slight inclination towards applying instant redactions for photos in general which confirms prior finding that users are reserved in terms of privacy concern while sharing with other followers [41].

5.3 Preferences towards temporal redactions

Although we found an overall tendency towards existing redaction techniques (such as instant redaction or ephemeral photos), we found that participants often preferred other temporal redactions. For example, we counted the fraction of participants having the highest sharing likelihood for delayed or gradual redaction in each of 16 content type– target audience combination (Table 8). We found that a part of the participants had the highest sharing likelihood for delayed or gradual application of redactions involving particular target–content type combinations (more detail in Subsection 4.5).

One possible reason for such preference of gradual or delayed application of redaction can be explained by the temporal protection offered by these obfuscation techniques. For instance, one way of sharing an individual’s photo with his/her friends using an existing redaction technique is to apply instant masking. However, prior studies have shown that using instant masking may reduce the overall appeal of that photo [28, 29, 49]. Given that users trust their friends more while sharing photos in social media [3, 48], some users may prefer to share the original photo with their

¹¹<https://www.facebook.com/>

friends for a certain amount of time retaining the aesthetics of the photo while masking it after a short period to reduce the risk of critical information being revealed.

In addition, some studies have suggested that users are interested to opt-in to a ‘content decay’ feature if they are given the power to undo the decay or are given control on what part of the photo is going to be decayed [56]. It would be interesting to observe how the participants react to temporal redactions if they are provided with more control over the redaction policies.

5.4 Perceived trustworthiness of trusted hardware

Despite our sample size that was chosen to detect medium and large sized effects, we did not find any significant main effect or an interaction effect with redaction techniques, content-type, or target audiences in the sharing likelihood between the trusted device and non-trusted device conditions. Although we found a couple of interaction effects in specific cases, more research is needed to understand trustworthiness perceptions in different contexts.

Prior studies have suggested that ‘visibility’ as a form of ‘affective feedback’ raises privacy awareness in the use of technology [37, 66]. Because ‘secure enclaves’ are not directly visible to participants, it is possible that the participants were not aware of the implications of trusted hardware. In addition, Davinson et al. suggested that users tend to be unaware when they are not briefed about the potential risks online and raising awareness of susceptibility increases users’ security behaviors [21]. Future studies are needed to convey the properties of trusted hardware in the context of potential risks without trusted hardware.

Prior studies have identified that users’ trust in a social media application largely depends on factors such as the reputation of that organization regarding privacy preservation [44], privacy policies, and transparency about technology and company policies. Users tend to be unaware of possible breaches in a feature provided by reputed organization [36]. It is possible that our participants trust the companies behind the applications they use. In addition, some studies have found that users with a security background are more aware of the privacy mechanisms compared to non-security background users [58]. It will be interesting to study users’ sharing behaviors focusing on the participant’s trust in social media and their security background in future studies.

5.5 Limitations

There are some limitations to our study. We have studied participants’ behavior on two concepts—a) temporal photo redaction, b) privacy perception on trusted viewing platforms while sharing photos in social media. While the temporal photo redaction idea has been demonstrated to the participants with visual depiction and text instructions, the trusted device conditions have been described briefly to the groups with non-trusted conditions to avoid any bias toward trusted devices. Our descriptions may have been unable to stimulate any privacy benefits in the context of potential risks. In addition, the images were selected by the research group and they were not owned by the participants. Although this approach is in line with previous work, some participants indicated that they could not relate to some of the scenarios (e.g., photos with particular facial expressions they might not make themselves). Also, we conducted the study only with participants from the USA. Future studies should focus more on participants from other regions as well.

6 CONCLUSION

Evaluating the balance between privacy and satisfaction trade-offs can be tricky while sharing photos on social media. Also, existing privacy mechanisms such as delayed deletion of photos can be susceptible to breaches in application security in viewers’ devices. We conducted a user study (N=385) to investigate the sharing behaviors among participants for gradual and delayed applications of redactions on a region of the photos after the photos are shared with viewers and

compared with exiting sharing mechanisms such as the instant application of redactions, sharing without any obfuscation, and sharing with ephemerality (delayed deletion). We also compared sharing preferences when participants share photos with viewers whose devices include (or do not include) secured enclaves (using trusted hardware to provide higher security and privacy assurances).

Regarding the temporal application of redactions such as gradual or delayed redactions, we found that participants were comfortable with the existing sharing mechanisms in varying circumstances. However, many participants showed a preference towards delayed or gradual application of redaction when the content of the photo did not pose a significant privacy threat or the viewer they shared the photo with was a close social contact. Future studies may provide participants with more control over the decay mechanism of the photo and evaluate their sharing behaviors compared to existing sharing mechanisms. The sharing behavior between the participants presented with the trusted viewing platform vs non-trusted viewing platform did not show any significant differences. Future studies are needed to focus on raising the ‘acceptability’ and ‘understandability’ of secured enclaves among non-technical users so that they can better comprehend the implications and necessity of secured enclaves while sharing content in social media.

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APPENDIX

A THE SURVEY

Display the Captcha, pledge, and consent form. Then display screening questions.

A.1 Social Media Usage Questionnaire

- **Q3.1:** Which social media platforms do you have an account for? (Select all that apply.)
1. Facebook 2. Instagram 3. Pinterest 4. Snapchat 5. Twitter 6. Myspace 7. Flickr 8. Reddit 9. Tiktok 10. LinkedIn 11. Imgur 12. Other (Please describe) 13. I do not use social media
- **Q3.2:** How often you visit social media?
1. Never, 2. Less than once in a month, 3. Once in a month, 4. Multiple times in a month, 5. Once in a week, 6. Multiple times in a week, 7. Once in a day, 8. Multiple times in a day
- **Q3.3:** What social media platform do you use to share photos online the most? (Select all that apply.)
1. Facebook 2. Instagram 3. Pinterest 4. Snapchat 5. Twitter 6. Myspace 7. Flickr 8. Reddit 9. Tiktok 10. LinkedIn 11. Imgur 12. Other (Please describe)
- **Q3.4:** When you share photos online, who do you typically share them with? (Select all that apply.)
1. Family members 2. Friends 3. Colleagues and classmates 4. Other followers

A.2 Image Sharing Behavior Questionnaire

- **Q4.1:** How often do you share photos on social media?
- **Q4.2:** How often do you share pictures taken by you, your friends, or your family on the most frequently used social media?
- **Q4.3:** How often do you share pictures on social media that you found on the internet or that other people took (not including your friends, family or other people you personally know.)?

A.3 Scenario Description

A.3.1 *Trusted and Non-Trusted Device.*

Consider a situation where you have taken a photo and would like to share it with others. You are aware that the photo contains some unusual or sensitive content. Some apps like Snapchat allow the viewer to look at a photo posted to one’s “story” (a collection of photos for that day) for 24 hours, after which the viewer’s app deletes the photo. Imagine a similar social media app that, instead of deleting the photo, obfuscates (hides) parts of the photo from viewers after a certain period of time (instead of deleting the photo). However, the viewer of the photo might attempt to save the photo or screenshot the original photo before the obfuscations are applied.

Trusted Device scenario: Assume the recipient’s phone is equipped with a special security chip that will make it impossible for the viewer to save or take a screenshot of the photo.

Non-Trusted Device scenario: Assume the recipient’s social media app does not allow the viewer to save the photo and (like Snapchat) notifies the sender of the photo if the viewer takes a screenshot.

A.3.2 *Temporal Redaction Scenario.*

Instantaneous Masking: Parts of your photo will be masked before sharing the photo.

Gradual Redaction: The original photo will be shared, but parts of your photo will be gradually blurred over time by the recipient’s phone. Eventually, the content will be completely masked and be totally obscured.

Delayed Masking: The original photo will be shared and then eventually the content will be completely masked and be totally obscured in the recipient’s phone after 24 hours. Until the content is masked, the entire photo is visible on the recipient’s phone.



Posting time

Fig. 5. Instant redaction sample



Posting time

After 12 hours

After 24 hours

Fig. 6. Gradual redaction sample

A.3.3 General Instruction.

For each photo, please do your best to answer each question as honestly and accurately as possible. Any information you enter is completely anonymous and will not be connected to your identity.

A.4 Experimental Manipulation

How likely are you to share the photo in the following scenario on social media with these groups of people? i) Family members ii) Friends iii) Colleagues and classmates iv) Other followers

1.Extremely unlikely, 2. Moderately unlikely, 3. Slightly unlikely, 4. Neither unlikely nor likely, 5. Slightly likely, 6. Moderately likely, 7. Extremely likely

A.4.1 Temporal Redaction Questions.

These questions were showed in random order. The later part of each question mentioned “by the



Fig. 7. Delayed redaction sample

app” to participants with non-trusted device condition and “by the security chip in the recipient’s phone” to participants with trusted device condition.

- Assume this is a photo of you and your car, and you would like to share it with the license plate of the car being masked by the app/ by the security chip in the recipient’s phone after 24 hours in the recipient’s device.
- Assume this is a photo of the front of your house, and you would like to share it with the house number being obscured by the app/ by the security chip in the recipient’s phone.
- Assume this is a photo of your face, and you would like to share it with the face being obscured by the app/ by the security chip in the recipient’s phone gradually over 24 hours in the recipient’s device.
- Assume this is a photo of you and your car, and you would like to share it with the license plate of the car being obscured by the app/ by the security chip in the recipient’s phone gradually over 24 hours in the recipient’s device.
- Assume this is a photo of your face, and you would like to share it with the face being obscured by the app/ by the security chip in the recipient’s phone.
- Assume this is a photo of you with another person behind you, and you would like to share it with the face of that person being masked by the app/ by the security chip in the recipient’s phone after 24 hours in the recipient’s device.
- Assume this is a photo of you and your car, and you would like to share it with the license plate of the car being obscured by the app/ by the security chip in the recipient’s phone.
- Assume this is a photo of your face, and you would like to share it with the face being masked by the app/ by the security chip in the recipient’s phone after 24 hours in the recipient’s device.
- Assume this is a photo of you with another person behind you, and you would like to share it with the face of that person being obscured by the app/ by the security chip in the recipient’s phone gradually over 24 hours in the recipient’s device.
- Assume this is a photo of the front of your house, and you would like to share it with the house number being masked by the app/ by the security chip in the recipient’s phone after 24 hours in the recipient’s device.

- Assume this is a photo of you with another person behind you, and you would like to share it with the face of that person being obscured by the app/ by the security chip in the recipient's phone.
- Assume this is a photo of the front of your house, and you would like to share it with the house number being obscured by the app/ by the security chip in the recipient's phone gradually over 24 hours in the recipient's device.

A.4.2 Baseline Questions.

These questions were showed in random order. The later part of each question mentioned "by the app" to participants with non-trusted device condition and "by the security chip in the recipient's phone" to participants with trusted device condition.

- Assume this is a photo of you and your car, and the photo will be deleted automatically by the app/ by the security chip in the recipient's phone 24 hours after the recipient views it.
- Assume this is a photo of the front of your house, and you would like to share it without the house number being obscured.
- Assume this is a photo of you with another person behind you, and you would like to share it without the face of that person being obscured.
- Assume this is a photo of the front of your house, and the photo will be deleted automatically by the app/ by the security chip in the recipient's phone 24 hours after the recipient views it.
- Assume this is a photo of you and your car, and you would like to share it without the license plate of the car being obscured.
- Assume this is a photo of your face, and you would like to share it without the face being obscured.
- Assume this is a photo of you with another person behind you, and the photo will be deleted automatically by the app/ by the security chip in the recipient's phone 24 hours after the recipient views it.
- Assume this is a photo of your face, and the photo will be deleted automatically by the app/ by the security chip in the recipient's phone 24 hours after the recipient views it.

A.5 Open Ended Attention Check Question

Q5: Please briefly describe why your sharing preference might have varied for different obfuscations for the last question (minimum 150 characters).

A.6 Privacy Behavior Questionnaire

Answer each of the questions below with options: i) Yes ii) Maybe iii) No

- **Q6.1:** Has anyone ever shared a picture of you online that you did not want them to share?
- **Q6.2:** Has anyone ever shared a picture of you online that you felt violated your privacy?
- **Q6.3:** Have you ever been embarrassed by a picture of yourself that has been posted online?
- **Q6.4:** Have you ever regretted posting a picture of yourself online?
- **Q6.5:** Please select the last option.
- **Q6.6:** Have you ever accidentally posted a picture of yourself online that you did not want to share?
- **Q6.7:** Have you ever shared an embarrassing picture online of someone else you know?
- **Q6.8:** Have you ever regretted posting a picture online of someone else you know?
- **Q6.9:** Have you ever posted a picture online of someone else you know, which may have violated his or her privacy?
- **Q6.10:** Have you ever shared an embarrassing picture online of a stranger (someone that you do not personally know)?

- **Q6.11:** Have you ever regretted posting a picture online of a stranger (i.e., someone you do not personally know)?
- **Q6.12:** Have you ever posted a picture of a stranger (i.e., someone you do not personally know), which may have violated his or her privacy?
- **Q6.13:** Do people you know post pictures that might be embarrassing to other people?
- **Q6.14:** Has anyone you know regretted posting a picture of another person?
- **Q6.15:** Has anyone you know regretted posting a picture of themselves?
- **Q6.16:** Has anyone you know posted a picture that may have violated someone’s privacy?

A.7 Privacy Preference Question

Q7: Are you a private person who keeps to yourself or an open person who enjoys sharing with others? 1) Very Private ... 7) Very Open

A.8 Inter Personal Trust Questionnaire

A 12-item questionnaire by Yamagishi et al. [77].

A.9 Demographic Questions

- **Q9.1:** Please select your gender i) Male ii) Female iii) Would prefer not to answer iv) Other (text input)
- **Q9.2:** How long have you lived in the United States? i) I don’t live in the United States ii) Less than 1 year iii) 1 year and 2 years iv) 2 years- 3 years v) 3 years- 4 years v) 4 years- 5 years vii) 5 years or more.
- **Q9.3:** What’s your age? i) Under 18 years ii) 18-29 iii) 30-49 iv) 50-64 v) 65 or more.
- **Q9.4:** Please select the highest level of education that you have achieved i) None ii) 1st-4th grade iii) 5th-8th grade iv) 9th-12th grade v) High school graduate or GED vi) Some college, no degree vii) Associate’s degree viii) Bachelor’s degree ix) Master’s degree x) Professional (e.g., MD, JD) degree xi) Doctoral degree.
- **Q9.5:** What is your primary racial or ethnic background? Please select all that apply. i) Hispanic or Latino ii) American Indian or Alaskan Native iii) Asian iv) Black or African American v) Native Hawaiian or Other Pacific Islander vi) White vii) Other (text input).