

DIFFVAX: OPTIMIZATION-FREE IMAGE IMMUNIZATION AGAINST DIFFUSION-BASED EDITING

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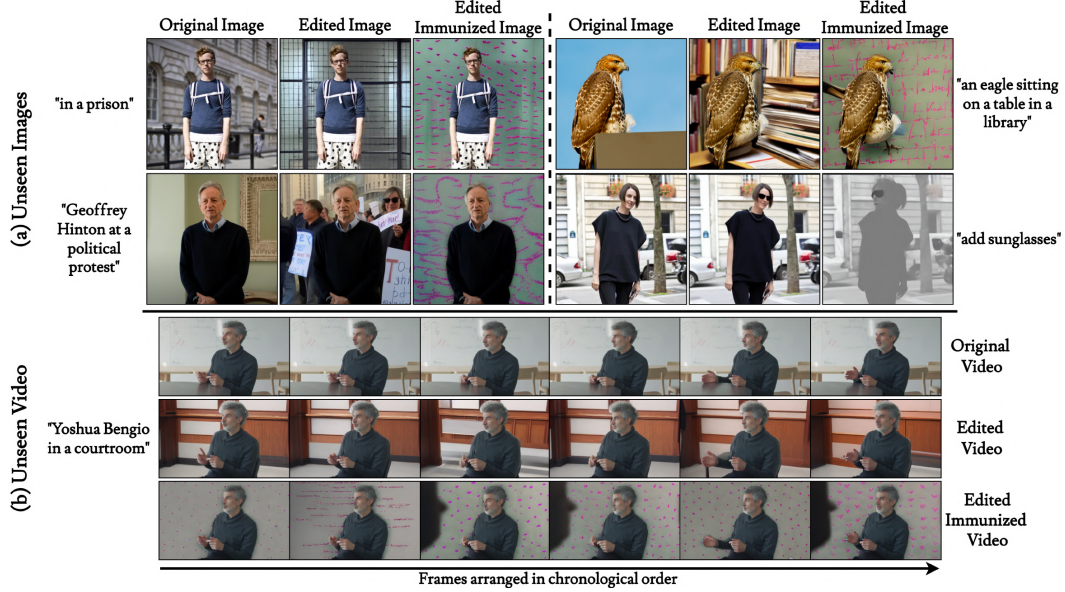


Figure 1: DiffVax is an optimization-free image immunization approach designed to protect images and videos from diffusion-based editing. DiffVax demonstrates robustness across diverse content, providing protection for both in-the-wild (a) *unseen images* and (b) *unseen video* content while effectively preventing edits across various editing methods, including *inpainting* (illustrated with a *human* in the left column and a *non-human foreground object* in the right column) and *instruction-based edits* (right column) with InstructPix2Pix (Brooks et al., 2023).

ABSTRACT

Current image immunization defense techniques against diffusion-based editing embed imperceptible noise into target images to disrupt editing models. However, these methods face scalability challenges, as they require time-consuming optimization for each image separately, taking hours for small batches. To address these challenges, we introduce DiffVax, a scalable, lightweight, and optimization-free framework for image immunization, specifically designed to prevent diffusion-based editing. Our approach enables effective generalization to unseen content, reducing computational costs and cutting immunization time from days to milliseconds, achieving a speedup of 250,000 \times . This is achieved through a loss term that ensures the failure of editing attempts and the imperceptibility of the perturbations. Extensive qualitative and quantitative results demonstrate that our model is scalable, optimization-free, adaptable to various diffusion-based editing tools, robust against counter-attacks, and, for the first time, effectively protects video content from editing. More details are available in our [Project Webpage](#).

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1 INTRODUCTION

Recent advancements in generative models, particularly diffusion models (Sohl-Dickstein et al., 2015; Ho et al., 2020; Rombach et al., 2022), have enabled realistic content synthesis, which can be used for various applications, such as image generation (Saharia et al., 2022; Ruiz et al., 2023; Chefer et al., 2023; Zhang et al., 2023c; Li et al., 2023b; Mou et al., 2024b; Bansal et al., 2023) and editing (Brooks et al., 2023; Couairon et al., 2023a; Hertz et al., 2023b; Meng et al., 2022). However, the widespread availability and accessibility of these models introduce significant risks, as malicious actors exploit them to produce deceptive, realistic content known as deepfakes (Pei et al., 2024). Deepfakes pose severe threats across multiple domains, from political manipulation (Appel & Prietzel, 2022) and blackmail (Blancaflor et al., 2024) to biometric fraud (Wojewidka, 2020) and compromising trust in legal processes (Delfino, 2022). Furthermore, they have become tools for sexual harassment through the creation of non-consensual explicit content (Jean Mackenzie, 2024; Davies & McDermott, 2022; Cole, 2018). Given the widespread accessibility of diffusion models, the scale of these threats continues to grow, underscoring the urgent need for robust defense mechanisms to protect individuals, institutions, and public trust from such misuse.

To address these challenges, one line of research has focused on deepfake detection (Naitali et al., 2023; Passos et al., 2024) and verification methods (Hasan & Salah, 2019), which facilitate post-hoc identification. While effective for detection, these approaches do not proactively prevent malicious editing, as they only identify it after it happens. Another branch modifies the parameters of editing models (Li et al., 2024) to prevent unethical content synthesis (e.g. NSFW material); however, the widespread availability of unrestricted generative models limits its effectiveness. A more robust defense mechanism, known as image immunization (Salman et al., 2023; Lo et al., 2024; Yeh et al., 2021; Ruiz et al., 2020), safeguards images from malicious edits by embedding imperceptible adversarial perturbation. This approach ensures that any editing attempts lead to unintended or distorted results, proactively preventing malicious modifications rather than depending on post-hoc detection. The subtlety of this protection is particularly valuable for large-scale, publicly accessible content, such as social media, where user data is especially vulnerable to malicious attacks. By uploading immunized images instead of the original ones, users can reduce the risk of misuse by malicious actors, highlighting the potential of immunization-based methods for real-world impact.

However, current immunization approaches remain inadequate, as they do not simultaneously satisfy the key requirements of an effective defense: (i) scalability for large-scale content, (ii) memory and runtime efficiency, and (iii) robustness against counter-attacks. PhotoGuard (Salman et al., 2023) (PG) embeds adversarial perturbations into target images to disrupt components of the diffusion model by solving a constrained optimization problem via projected gradient descent (Madry et al., 2018a). Although PhotoGuard was the first immunization model targeting diffusion-based editing, it requires over 10 minutes of runtime per image and at least 15GB of memory, causing both computational and time inefficiency. To alleviate these demands, DAYN (Lo et al., 2024) proposes a semantic-based attack that disrupts the diffusion model’s attention mechanism during editing. While this approach reduces computational load, it remains time-inefficient like PhotoGuard, as it requires a separate optimization process for each image and cannot generalize to unseen content. Furthermore, both approaches are vulnerable to counter-attacks, such as denoising the added perturbation or applying JPEG compression (Sandoval-Segura et al., 2023) to the immunized image. Consequently, neither method is practical for large-scale applications, such as safeguarding the vast volume of image and video data uploaded daily on social media platforms.

To address these challenges, we introduce `DiffVax`, an end-to-end framework for training an “immunizer model” that learns how to generate imperceptible perturbations to immunize target images against diffusion-based editing (see Fig 2). This immunization process ensures that any attempt to edit the immunized image using a diffusion-based model fails. `DiffVax` is more effective than prior works in ensuring editing failure, and it demonstrates the feasibility and generalizability of the image-conditioned feed-forward approach to perturbation generation.

Our training process is guided by two objectives, expressed as separate terms in the loss function: (1) encouraging the model to generate an imperceptible perturbation, and (2) ensuring that any editing attempt on the immunized image fails. Our trained immunizer operates with a single forward pass, completed within milliseconds, eliminating the need for time-intensive per-image optimization. This efficiency enables scalability to high-volume content protection. Additionally, `DiffVax` enhances

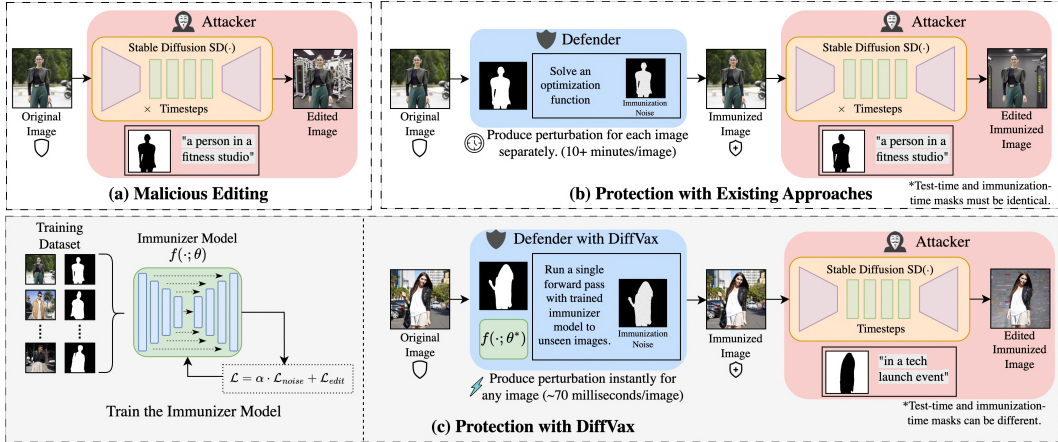


Figure 2: **Comparing DiffVax with existing approaches.** (a) An attacker performs malicious editing on an original image. (b) Existing defenses immunize images by solving a costly optimization problem for each image individually, taking over 10 minutes per image. (c) DiffVax enables scalable protection by first training an immunizer model (green box) on a diverse dataset. Once trained, the model can immunize unseen images with a single forward pass, producing effective perturbations in approximately 70 milliseconds per image.

memory efficiency by avoiding gradient computation during inference, setting it apart from prior methods. It also exhibits robustness against common counter-attacks, such as JPEG compression and image denoising (Sandoval-Segura et al., 2023). In addition, our framework demonstrates superior generalization with other diffusion-based editing methods (see Fig. 1 for examples on inpainting and instruction-based editing). Leveraging these strengths, we extend immunization to video content for the first time, achieving results previously unattainable due to the computational limitations of earlier approaches. As a result, DiffVax satisfies all key requirements for an effective defense.

To summarize, our contributions are as follows:

- We are the first to introduce a training framework in which the model learns to effectively immunize a given image against diffusion-based editing, drastically reducing inference time from days to milliseconds and enabling real-time protection.
- Thanks to its computational efficiency, our model shows promising potential as a foundational step toward immunizing video content.
- Unlike prior methods that require per-image optimization and therefore cannot generalize to unseen data, our approach enables generalization to new content through a learned “image immunizer”.
- DiffVax achieves superior results with substantial degradation of the editing operation, and minimal memory requirement, demonstrating resistance to counter-attacks, making it the fastest, most cost-effective, and robust method available.

2 RELATED WORK

Adversarial attacks Adversarial attacks exploit model vulnerabilities by introducing perturbations that induce misclassification. Early gradient-based methods efficiently generated such examples via gradient manipulation (Goodfellow et al., 2015; Madry et al., 2018b), later refined to minimize perceptual distortion (Carlini & Wagner, 2017; Moosavi-Dezfooli et al., 2016). Generative approaches advanced these attacks by synthesizing realistic adversarial inputs (Xiao et al., 2018). Subsequent work improved transferability and query efficiency using momentum and random search (Dong et al., 2018; Andriushchenko et al., 2020), while ensemble-based methods strengthened robustness evaluation (Croce & Hein, 2020). Universal perturbations (Moosavi-Dezfooli et al., 2017; Hayes & Danezis, 2018) and generative perturbation networks (Poursaeed et al., 2018) further generalized attacks across data and models. Building on these advances, our work focuses on immunizing against diffusion-based editing, addressing its unique characteristics.

Preventing image editing The proliferation of Latent Diffusion Models (LDMs) has underscored the demand for robust immunization strategies against unauthorized image manipulation. Initial efforts focused on Generative Adversarial Network (GAN)-based models, employing adversarial perturbations to inhibit edits (Yeh et al., 2021; Aneja et al., 2022). PhotoGuard (Salman et al., 2023) extended this line of work to diffusion models via encoder- and model-level perturbations but incurred substantial computational overhead due to backpropagation across multiple timesteps. To alleviate this, Lo et al. (2024)¹ proposed an attention-disruption strategy that bypasses full gradient computation, though its reliance on fixed prompts limits robustness. DiffusionGuard (Choi et al., 2025) enhances PhotoGuard by optimizing over augmented masks, yet remains computationally intensive. Similarly, PCA (Guo et al., 2024) proposes a grey-box attack by inducing posterior collapse in the VAE encoder to disrupt editing. Addressing instruction-guided editing, EditShield (Chen et al., 2023) introduces perturbations to shift latent representations, causing semantic mismatches in the edited output. Meanwhile, Shih et al. (2025) bypass the reliance on VAE encoders by proposing a feature-based attack effective against pixel-domain diffusion models. Other approaches, including Mist (Liang & Wu, 2023), AdvDM (Liang et al., 2023), SDS (Xue et al., 2024), and Glaze (Shan et al., 2023), target text-to-image diffusion or fine-tuned models, but exhibit high computational demands and limited resilience to adaptive attacks. In contrast, `DiffVax` introduces a model-agnostic immunizer that generalizes to unseen data via a single forward pass. Furthermore, we present, for the first time, promising results in the direction of video immunization.

Diffusion-based image editing Diffusion models have emerged as powerful tools for image editing tasks such as inpainting (Wang et al., 2023; Lugmayr et al., 2022; Zhang et al., 2023a), style transfer (Wang et al., 2023; Mou et al., 2024a; Yang et al., 2023; Hertz et al., 2023a), and text-guided transformations (Brooks et al., 2023; Lin et al., 2024; Ravi et al., 2023), by conditioning on prompts or image regions. Edits are guided through attention manipulation (Parmar et al., 2023) and multi-step noise prediction. Approaches include both training-based (Couairon et al., 2023b; Kim et al., 2022) and training-free methods (Mokady et al., 2023; Miyake et al., 2023) requiring minimal fine-tuning. We use stable diffusion inpainting as our primary editing model and include results with InstructPix2Pix (Brooks et al., 2023) to show model-agnostic performance.

3 METHODOLOGY

3.1 PRELIMINARIES

Image immunization Adversarial attacks exploit the vulnerabilities of machine learning models by introducing small, imperceptible perturbations to input data, causing the model to produce incorrect or unintended outputs (Szegedy et al., 2014; Biggio et al., 2013). In the context of diffusion models, such perturbations can be crafted to disrupt the editing process, ensuring that attempts to modify an adversarially perturbed image fail to achieve intended outcomes. Given an image \mathbf{I} , the goal is to transform it into an adversarially immunized version, \mathbf{I}_{im} , by introducing a perturbation ϵ_{im} :

$$\mathbf{I}_{\text{im}} = \mathbf{I} + \epsilon_{\text{im}}, \quad \text{subject to: } \|\epsilon_{\text{im}}\|_p < \kappa, \quad (1)$$

where κ is the perturbation budget that constrains the norm of the perturbation to ensure that it remains imperceptible. The norm p could be chosen as 1, 2, or ∞ , depending on the application.

Latent diffusion models LDMs (Rombach et al., 2022) perform the generative process in a lower-dimensional latent space rather than pixel space, achieving computational efficiency while maintaining high-quality outputs. This design is ideal for large-scale tasks like image editing and inpainting. Training an LDM starts by encoding the input image \mathbf{I}_0 into a latent representation $z_0 = \mathcal{E}(\mathbf{I}_0)$ using encoder $\mathcal{E}(\cdot)$. The diffusion process operates in this latent space, adding noise over T steps to generate a sequence z_1, \dots, z_T , with $z_{t+1} = \sqrt{1 - \beta_t} z_t + \sqrt{\beta_t} \epsilon_t$, $\epsilon_t \sim \mathcal{N}(\mathbf{0}, \mathbf{I})$, where β_t is the noise schedule at step t . The training aims to learn a denoising network ϵ_θ that predicts the added noise ϵ_t by minimizing $\mathcal{L}(\theta) = \mathbb{E}_{t, z_0, \epsilon \sim \mathcal{N}(\mathbf{0}, \mathbf{I})} [\|\epsilon - \epsilon_\theta(z_t, t)\|_2^2]$. In the reverse process, a noisy latent vector $z_T \sim \mathcal{N}(\mathbf{0}, \mathbf{I})$ is iteratively denoised via the trained denoising network to recover z_0 , which is decoded into the final image $\tilde{\mathbf{I}} = \mathcal{D}(z_0)$ with decoder $\mathcal{D}(\cdot)$.

¹Code unavailable despite request.

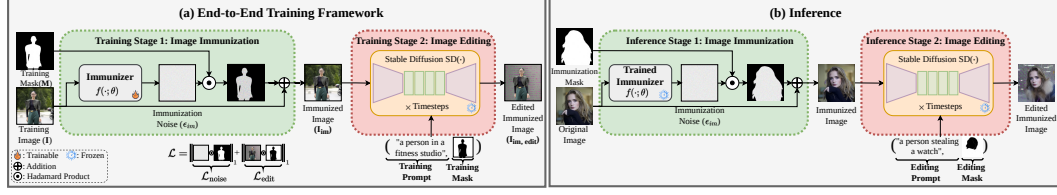


Figure 3: **Overview of DiffVax.** Our end-to-end training framework is illustrated in (a). The training process consists of two stages. In Stage 1, immunization is applied to the training image \mathbf{I} . In Stage 2, the immunized image \mathbf{I}_{im} is edited using a stable diffusion model $\text{SD}(\cdot)$ with the specified text prompt and mask, during which the $\mathcal{L}_{\text{noise}}$ and $\mathcal{L}_{\text{edit}}$ are computed. During inference (b), the trained immunizer model generates immunization noise (see Inference Stage 1 in (b)) applied to the original (target) image using an immunization mask. When a malicious user attempts to attack these immunized images with an editing mask, the editing tool (see Inference Stage 2 in (b)) is unable to produce the intended edited content.

3.2 PROBLEM FORMULATION

Let $\mathbf{I} \in \mathbb{R}^{H \times W \times C}$ represent an image with height H , width W , and C color channels. A malicious user using a diffusion-based editing tool, $\text{SD}(\cdot)$, attempts to maliciously edit the image based on a prompt \mathcal{P} and a binary mask $\mathbf{M} \in \{0, 1\}^{H \times W \times C}$, which defines the target area for editing, with a value of 1 indicating the region of interest and 0 denotes the background or irrelevant areas. Ideally, this target region can represent any meaningful part of the image, such as a human body or a face. Our objective is to immunize the original (target) image \mathbf{I} by carefully producing a noise ϵ_{im} that satisfies two key criteria: (a) ϵ_{im} remains imperceptible to the user, and (b) the edited immunized image $\mathbf{I}_{\text{im,edit}}$ fails to accurately reflect the prompt \mathcal{P} applied by the malicious users. In other words, the immunized image disrupts the editing model $\text{SD}(\cdot)$ such that any attempt to edit the image results in unsuccessful or unintended modifications. While our approach is broadly applicable to any diffusion-based editing tool, such as inpainting models and InstructPix2Pix (Brooks et al., 2023), this study follows previous work (Salman et al., 2023; Lo et al., 2024) by using inpainting as the primary editing tool for problem formulation and quantitative experiments. We focus on scenarios where the sensitive regions such as human body or face remains constant, with other areas considered editable, reflecting real-world malicious editing scenarios. Additional results for other objects and tools (e.g. InstructPix2Pix) are provided in Fig. 1, Fig. 4, and in our Appendix A.2.

3.3 OUR APPROACH

End-to-end training framework To overcome the speed limitations of previous methods, which require solving an optimization problem independently for each image, we propose an end-to-end training framework. This framework enables an immunizer model $f(\cdot; \theta)$ to instantly generate immunization noise for a given input image. Our training algorithm (see Appendix A.1, and Fig. 3 (a)) consists of two stages. In the first stage, we employ a UNet++ (Zhou et al., 2018) architecture for the “immunizer” model $f(\cdot; \theta)$, which takes an input image \mathbf{I} and generates the corresponding immunization noise ϵ_{im} . Subsequently, ϵ_{im} is multiplied by the immunization mask \mathbf{M} , which targets the region of interest (e.g. a person’s face). The resulting masked noise is then added to the training image to produce the immunized image, computed as $\mathbf{I}_{\text{im}} = \mathbf{I} + \epsilon_{\text{im}} \odot \mathbf{M}$. Finally, the image is clamped to the $[0, 1]$ range. To ensure the noise remains imperceptible to the human eye, we introduce the following loss:

$$\mathcal{L}_{\text{noise}} = \frac{1}{\text{sum}(\mathbf{M})} \|(\mathbf{I}_{\text{im}} - \mathbf{I}) \odot \mathbf{M}\|_p \quad (2)$$

where p is empirically chosen to be 1. $\mathcal{L}_{\text{noise}}$ penalizes deviations within the masked region, ensuring that the change between the immunized image and the training image is imperceptible. In the second stage, after generating the immunized image \mathbf{I}_{im} , we apply diffusion-based editing using the editing tool $\text{SD}(\cdot)$. This model takes the immunized image \mathbf{I}_{im} , the training mask \mathbf{M} , and the training prompt \mathcal{P} as input, performing edits in the regions specified by the mask. To ensure that the edited image is effectively distorted, we define the loss function:

$$\mathcal{L}_{\text{edit}} = \frac{1}{\text{sum}(\sim \mathbf{M})} \|\text{SD}(\mathbf{I}_{\text{im}}, \sim \mathbf{M}, \mathcal{P}) \odot (\sim \mathbf{M})\|_1, \quad (3)$$

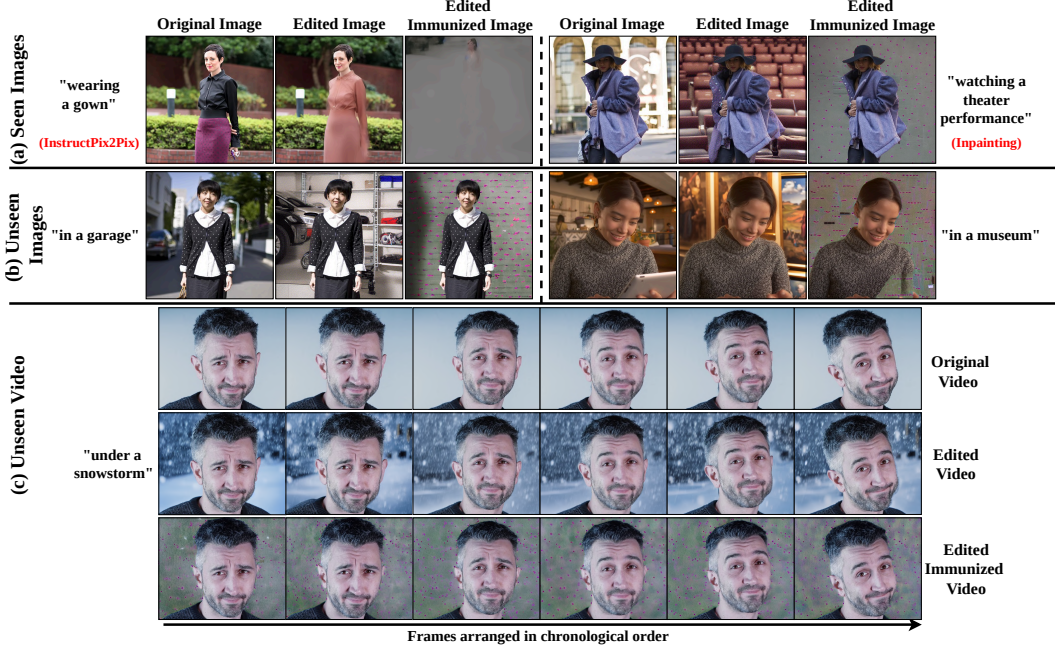


Figure 4: **Qualitative results with DiffVax.** Our method effectively immunizes (a) seen images and generalizes to (b) unseen images with diverse text prompts. Additionally, it extends to (c) unseen human videos, demonstrating its adaptability to new content. Furthermore, it supports various poses and perspectives, from full-body shots (a) to close-up face shots (c).

where $\sim \mathbf{M}$ represents the complement of the masked area and $\text{SD}(\cdot)$ is the stable diffusion inpainting model that modifies the region $\sim \mathbf{M}$ in \mathbf{I}_{im} according to the prompt \mathcal{P} . This loss function is the key to our method, as it ensures that the immunization noise disrupts the editing process by forcing the unmasked regions to be filled with 0s. Note that for editing models that do not rely on masks, we exclude masks from the loss calculations.

To enable training, we curate a dataset of image, mask, and prompt tuples, represented as $\mathcal{D} = \{(\mathbf{I}^k, \mathbf{M}^k, \mathcal{P}^k)\}_{k=1}^N$. Specifically, we collect 1000 images of individuals from the CCP (Yang et al., 2014) dataset and use the Segment Anything Model (SAM) (Kirillov et al., 2023) to generate masks corresponding to the foreground objects in these images. To ensure diverse text descriptions for the editing tasks, we utilize ChatGPT OpenAI (2024) (see Appendix A.1). At each training step, a sample is selected from the dataset and initially processed by the immunizer model $f(\cdot; \theta)$ to generate immunization noise ϵ_{im}^n , which is added to the masked region of the training image and then clamped. The resulting immunized image \mathbf{I}_{im}^n is then passed through the editing model $\text{SD}(\cdot)$ to produce the edited immunized image $\mathbf{I}_{\text{im,edit}}^n$. The final loss function, $\mathcal{L} = \alpha \cdot \mathcal{L}_{\text{noise}} + \mathcal{L}_{\text{edit}}$, is used for backpropagation with respect to the immunizer model’s parameters. Backpropagating through the stable diffusion stages allows the immunizer to learn the interaction between the perturbation and the generated pixels. Through this iterative process, the immunizer model learns to generate perturbations that disrupt the editing model. Following the insights from PhotoGuard’s encoder attack, we do not condition the immunizer model on text prompts, as the noise is empirically shown to be prompt-agnostic (see Appendix A.6).

Inference During inference, the trained immunizer model generates immunization noise for any original (target) image using the mask of the region intended for protection. This noise is then applied to create the immunized image, with the noise restricted to the masked region. The resulting immunized image can be safely shared publicly. When a malicious user inputs this immunized image along with an editing mask into a diffusion-based editing tool (the same tool used during training), the immunization noise disrupts the edited output (see Fig. 3 (b)). Unlike previous approaches that require the same mask to be used during both training and inference, our method decouples these phases. This separation allows the immunizer model to generalize to unseen content, addressing the limitation of previous methods where malicious users could exploit different masks during editing (e.g. using an immunization mask of full-body but applying an editing mask of face).

4 EXPERIMENTATION

Baselines We compare DiffVax with several existing image immunization methods. As a naive baseline, we include **Random Noise**, which applies arbitrary noise to images. We also evaluate two variants of PhotoGuard (Salman et al., 2023): **PhotoGuard-E**, which embeds adversarial perturbations in the latent encoder, and **PhotoGuard-D**, which disrupts the entire generative process. Additionally, we compare against **DiffusionGuard** (Choi et al., 2025), an extension of PhotoGuard that augments masks during optimization. To evaluate robustness against counter-attacks, we develop three additional baselines where editing is applied after immunization: (i) passing the image through a convolutional neural network (CNN)-based denoiser (Li et al., 2023a), denoted as DiffVax w/ D.; (ii) compressing the image as JPEG (Sandoval-Segura et al., 2023) with a 0.75 compression ratio, denoted as DiffVax w/ JPEG; and (iii) applying the IMPRESS defense (Cao et al., 2023), denoted as DiffVax w/ IMPRESS.

Evaluation metrics and dataset We focus on four key aspects in evaluation: (a) *the amount of editing failure*, where we follow previous approaches (Salman et al., 2023) and utilize SSIM (Wang et al., 2004), PSNR and FSIM (Zhang et al., 2011) metrics to measure the visual differences between the edited immunized image and the edited original image; (b) *imperceptibility*, where the amount of the immunization noise quantified by measuring the SSIM between the original image and the immunized image, denoted as SSIM (Noise); (c) *the degree of textual misalignment* evaluated using CLIP (Radford et al., 2021) by measuring the average similarity between the edited immunized image and the text prompt, denoted as CLIP-T; and (d) *scalability* by reporting the average runtime and GPU memory required to immunize a single image on average from the dataset. We curate a dataset of 875 human images from the CCP (Yang et al., 2014) dataset. Of these, 800 images are used for training (including the 75 seen images in our experiments), and 75 unseen images are reserved for testing.

Qualitative results Figures 1 and 4 illustrate the qualitative success of our method. DiffVax effectively immunizes images against various editing techniques, including standard inpainting and instruction-based models like InstructPix2Pix (Brooks et al., 2023) (Figure 1). As further detailed in Appendix A.2, the model demonstrates a strong ability to generalize to unseen images and a wide range of prompts, accommodating various human perspectives from full-body to close-up shots (Figure 4). Although trained primarily on human subjects, our model also extends its robustness to non-human objects. When compared to baseline methods (Figure 5), our approach is qualitatively superior on both seen and unseen images, generating backgrounds that deviate more significantly from the intended edits. Notably, in many cases with our approach, it is impossible to infer the original prompt from the immunized image’s background, a stark contrast to PhotoGuard, which often retains discernible hints of the prompt. More examples, including comparisons and results with other editing models, are provided in Appendix A.2.

DiffVax is more effective in corrupting edits As shown in Table 1, DiffVax achieves the lowest SSIM, PSNR, and FSIM values overall, securing second place in the SSIM metric for unseen data, with a small margin behind PG-D, indicating that malicious edits on immunized images are significantly distorted, even on previously unseen data, whereas baseline methods, which require optimization to be re-run for each image, do not differentiate between seen and unseen data. Additionally, CLIP-T results, which measure textual misalignment, further verify these findings by measuring the misalignment semantically in the edited immunized images. DiffVax outperforms the baselines by maintaining the highest SSIM (Noise) values for both seen and unseen data, highlighting its effectiveness in corrupting malicious edits while keeping the immunized image imperceptible. This superior imperceptibility is achieved because our model learns to generate visually subtle, low-frequency perturbations, in contrast to the scattered, high-frequency noise produced by prior methods (see Appendix A.5 for a detailed discussion). Thus, *training an immunizer model enables it to learn how to strategically place immunization noise to effectively disrupt diffusion-based editing, by aggregating over the training set*. In contrast, prior optimization-based works only see a single target image at a time.

DiffVax is more scalable In addition to its strong qualitative performance, DiffVax offers significant advantages in speed and memory efficiency. It completes the immunization process in just 0.07 seconds per image on average, compared to 207.0 seconds for PhotoGuard-E, 911.6 seconds for PhotoGuard-D, and 131.1 seconds for DiffusionGuard. In terms of GPU memory usage, DiffVax requires only 5,648 MiB, much lower than PhotoGuard-E (9,548 MiB), PhotoGuard-D (15,114



Figure 5: *Qualitative comparison of edited images across immunization methods.* This figure shows the results of different immunization methods: Random Noise, PhotoGuard-E, PhotoGuard-D, DiffusionGuard, and our proposed method, *DiffVax*. Results for (a) seen and (b) unseen images are shown, with different prompts applied to each (right side). The first column contains the original images, while subsequent columns show the edited outputs under different settings, as depicted on the top. Note that *DiffVax* is *substantially more effective* than PhotoGuard-E, -D and DiffusionGuard in degrading the edit.

Table 1: *Performance comparisons on images.* The SSIM, PSNR, FSIM, SSIM (Noise), and CLIP-T metrics are reported separately for the *seen* and *unseen* splits of the test dataset. Runtime and GPU requirements are measured as the average time (in seconds) and memory usage (in MiB) needed to immunize a single image. “N/A” indicates that the corresponding value is unavailable. The symbols \uparrow and \downarrow indicate the direction toward better performance for each metric, respectively. **Bold** values indicate the best scores, while underlined values denote the second-best scores.

Immunization Method	Amount of Editing Failure						Imperceptibility		Text Misalignment		Scalability	
	SSIM ↓		PSNR ↓		FSIM ↓		SSIM (Noise) ↑		CLIP-T ↓		Runtime (s) ↓ (Immunization)	GPU Req. (MiB) ↓ (Immunization)
	seen	unseen	seen	unseen	seen	unseen	seen	unseen	seen	unseen		
Random Noise	0.586	0.585	16.09	16.40	0.460	0.458	0.902	0.903	31.68	31.62	N/A	N/A
PhotoGuard-E	0.558	0.565	15.29	15.63	0.413	0.408	0.956	0.956	31.69	30.88	207.00	9,548
PhotoGuard-D	<u>0.531</u>	0.523	14.70	14.92	<u>0.386</u>	<u>0.379</u>	<u>0.978</u>	<u>0.979</u>	29.61	29.27	911.60	15,114
DiffusionGuard	0.551	0.556	<u>14.37</u>	<u>14.71</u>	0.389	0.386	0.965	0.966	<u>26.98</u>	<u>27.10</u>	<u>131.10</u>	<u>6,750</u>
DiffVax (Ours)	0.510	<u>0.526</u>	13.96	14.32	0.353	0.362	0.989	0.989	23.13	24.17	0.07	5,648

MiB), and DiffusionGuard (6,750 MiB). This makes *DiffVax* a *practical and scalable solution* for large-scale applications.

DiffVax is more robust to counter-attacks Table 2 shows that *DiffVax* is robust to common counter-attacks, including CNN-based denoising, JPEG compression, and IMPRESS (Cao et al., 2023). *DiffVax* consistently outperforms PhotoGuard-D across all scenarios, as further evidenced by the detailed results in Appendix A.3.3. This robustness arises from *DiffVax*’s ability to learn spatially targeted, low-frequency perturbations. Unlike existing approaches that produce more uniform, high-frequency noise, our method’s perturbations are less susceptible to removal by techniques like JPEG compression, which discards high-frequency content, or by denoisers trained to suppress uniform noise. Crucially, as shown in Appendix A.3.2, *DiffVax* achieves superior edit disruption with a much smaller mean magnitude of noise than baselines with larger fixed budgets. This highlights that its strength lies in the strategic placement of noise, not simply its magnitude, supporting our claim that *DiffVax* learns a more efficient and targeted noise distribution. Furthermore, our extensive robustness evaluations in Appendix A.3 show that *DiffVax* also maintains its effectiveness against attackers who vary their inference-time settings, consistently outperforming baselines across different sampling steps and diffusion samplers.

User study results We also conduct a user study with 67 participants on Prolific (2024), in which participants compare the “unrealisticness” level of baselines, and the edited image across 20 randomly selected image pairs, including both seen and unseen samples. For each model, we report the average rank, with our model achieving the top position with an average rank of 1.64, demonstrating clear superiority (see Appendix A.3.5), followed by PhotoGuard-D with a rank of 2.63.

Table 2: **Performance comparisons on edits with counter-attacks.** We report the SSIM, SSIM (Noise) and CLIP-T metrics for the denoiser (D.), JPEG (compression ratio of 0.75) counter-attacks separately for the *seen* and *unseen* splits of the test dataset.

Method	SSIM ↓		PSNR ↓		FSIM ↓		SSIM (Noise) ↑		CLIP-T ↓	
	<i>seen</i>	<i>unseen</i>	<i>seen</i>	<i>unseen</i>	<i>seen</i>	<i>unseen</i>	<i>seen</i>	<i>unseen</i>	<i>seen</i>	<i>unseen</i>
PG-D w/ D.	0.702	0.709	18.27	18.43	0.528	0.528	0.966	0.965	31.48	31.20
DiffusionGuard w/ D.	0.708	0.719	18.26	18.69	0.530	0.531	0.964	0.964	31.08	30.99
DiffVax w/ D.	0.552	0.565	14.48	14.91	0.388	0.392	0.960	0.960	27.32	27.74
PG-D w/ JPEG	0.664	0.674	17.32	17.68	0.495	0.501	0.956	0.956	32.15	32.48
DiffusionGuard w/ JPEG	0.680	0.684	17.45	17.83	0.505	0.503	0.951	0.951	31.52	31.53
DiffVax w/ JPEG	0.522	0.538	14.17	14.61	0.374	0.382	0.959	0.959	26.04	26.05
PG-D w/ IMPRESS	0.578	0.563	15.89	16.07	0.436	0.426	0.640	0.634	31.35	31.26
DiffusionGuard w/ IMPRESS	0.604	0.595	15.89	16.09	0.453	0.442	0.636	0.630	30.88	30.50
DiffVax w/ IMPRESS	0.488	0.500	14.04	14.38	0.355	0.359	0.644	0.637	24.88	25.27

Table 3: **Ablation study.** We report the SSIM and SSIM (Noise) metrics for each loss term ablation, with results presented individually for the *seen* and *unseen* splits of the dataset.

Method	SSIM ↓		PSNR ↓		FSIM ↓		SSIM (Noise) ↑		CLIP-T ↓	
	<i>s</i>	<i>u</i>	<i>s</i>	<i>u</i>	<i>s</i>	<i>u</i>	<i>s</i>	<i>u</i>	<i>s</i>	<i>u</i>
DiffVax w/o $\mathcal{L}_{\text{noise}}$	0.508	0.520	13.57	13.82	0.335	0.344	0.785	0.786	24.34	25.78
DiffVax w/o $\mathcal{L}_{\text{edit}}$	0.944	0.932	31.36	31.05	0.821	0.806	0.999	0.999	32.01	32.27
DiffVax	0.510	0.526	13.96	14.32	0.353	0.362	0.989	0.989	23.13	24.17

Ablation study To assess the contribution of each component in our framework, we conduct an ablation study by individually removing $\mathcal{L}_{\text{edit}}$ and $\mathcal{L}_{\text{noise}}$. As shown in Table 3, when $\mathcal{L}_{\text{noise}}$ is removed, the model achieves slightly better performance on unseen data in terms of failed immunized editing (measured by SSIM, PSNR, FSIM and CLIP-T). However, the immunization noise is no longer imperceptible, as indicated by the change in the SSIM (Noise) metric. Conversely, when $\mathcal{L}_{\text{edit}}$ is removed, the SSIM (Noise) metric reaches its highest value, indicating minimal noise, but the model fails to prevent malicious editing, as reflected in the SSIM, PSNR, FSIM and CLIP-T metrics. Thus, *combining both terms in the final loss function is crucial for balancing imperceptibility and robustness in the training process* (see Appendix A.7).

5 CONCLUSION AND DISCUSSION

Discussion on generalization While a universal immunizer remains an open challenge, DiffVax demonstrates superior generalization over prior optimization-based work across three key dimensions. First, it addresses **generalization to unseen models**. Universal cross-model transferability is a difficult open problem, and like prior work, DiffVax is primarily model-specific and does not perfectly generalize to all unseen models. However, as detailed in Appendix A.4.1, it demonstrates significantly better performance in the challenging black-box transfer task from a model trained on Stable Diffusion (SD) v1.5 to an unseen SD v2 model. In this scenario, our learned immunization successfully transfers its protective effect, whereas optimization-based methods like PhotoGuard and DiffusionGuard fail completely, showing a clear improvement in cross-model robustness. Second, its feed-forward nature enables **generalization to unseen content**, a significant advantage over methods requiring costly per-image optimization. As discussed in Appendix A.4.2, the success of DiffVax proves that the set of effective perturbations has a learnable structure, allowing it to immunize new images, prompts, and even videos with a single pass. Finally, DiffVax is uniquely robust in its **generalization to unseen masks**. Unlike prior work, it does not overfit to the training mask’s shape or scale, maintaining its edit-disrupting effectiveness even when test-time editing masks differ significantly from the immunization mask, as shown in Appendix A.4.3.

Discussion on applications To further validate the versatility of DiffVax, we evaluate its effectiveness across a broad spectrum of real-world editing scenarios, as illustrated in Figure 6. Our experiments demonstrate robust protection against diverse manipulation types, ranging from **global transformations** such as artistic style transfer (e.g., converting an image to Cubism) to **localized edits** like facial expression changes and object attribute modification. Furthermore, the framework proves effective in complex settings involving multiple object editing, object replacement, and tex-

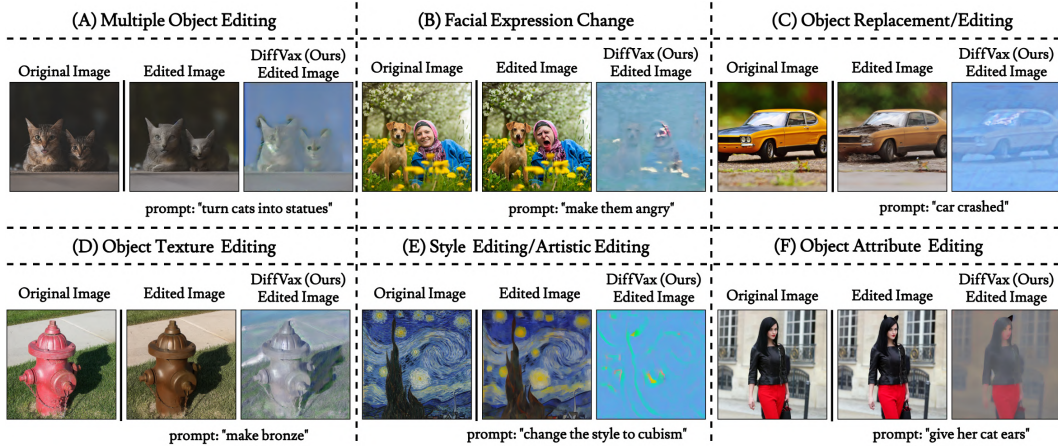


Figure 6: **DiffVax performance across diverse editing applications.** Our method effectively immunizes images against various manipulation types, including (A) multiple object editing, (B) facial expression changes, (C) object replacement, (D) texture editing, (E) artistic style transfer, and (F) attribute editing.

ture alteration. This wide applicability confirms that `DiffVax` does not merely memorize specific noise patterns for simple inpainting but learns to disrupt the underlying semantic guidance required for various high-level editing tasks.

Discussion on editing models Following prior work, our main evaluations are conducted using inpainting-based editing methods. However, we emphasize that our framework is model-agnostic and can be applied to various editing tools. To demonstrate this, we include additional results using the instruction-based model `InstructPix2Pix` (IP2P) (Brooks et al., 2023) (see Figure 10 in the Appendix) and the training-free model `MagicBrush` (Zhang et al., 2023b) (see Table 4 in the Appendix). We find that IP2P is particularly well-suited for complex or localized editing tasks, such as background modifications, stylistic changes, or edits outside sensitive regions, whereas inpainting-based approaches are more specialized for background editing tasks. Specifically, inpainting methods can introduce unintended alterations in sensitive areas like faces when the provided mask only partially covers the target region. This can conflict with the intent of a malicious user, whose goal is often to preserve identity while making selective edits.

Conclusion In this work, we present `DiffVax`, an optimization-free image immunization framework that protects against diffusion-based editing. Central to our approach is a trained “image immunizer” model that generates imperceptible perturbations to disrupt the editing process. At inference, `DiffVax` requires only a single forward pass, enabling scalability to large-scale deployments. Leveraging this efficiency, we extend our framework to video, demonstrating promising results for the first time (see Appendix A.3.6). Moreover, `DiffVax` is compatible with any diffusion-based editing tool and demonstrates strong robustness against counter-attacks. Overall, it establishes a new benchmark for scalable, real-time, and effective content protection.

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A APPENDIX

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A.1 MODEL ALGORITHM AND IMPLEMENTATION DETAILS

Implementation Details We employ a UNet++ architecture (Zhou et al., 2018) for the immunizer model. We selected this over a standard U-Net because its nested skip pathways facilitate denser feature aggregation at different semantic levels. Empirically, we found that this dense connectivity provides significantly better training stability for the unstable optimization task of predicting adversarial noise, allowing the model to generate more precise, imperceptible high-frequency perturbations. We train our immunizer model for 350 epochs using a batch size of 5 on an NVIDIA A100 GPU. We use the Adam optimizer (Kingma & Ba, 2015) with an initial learning rate of 0.00001 and set the loss weight parameter $\alpha = 4$. Training takes approximately 22 hours and leverages 16-bit precision to reduce memory consumption and speed up computation. As illustrated in Figure 7, the training process exhibits high stability; the noise loss converges rapidly to ensure imperceptibility, while the edit loss decreases steadily as the model progressively learns to disrupt the editing process. For the editing tools, we use a pre-trained Stable Diffusion v1.5 inpainting model (Rombach et al., 2022) for inpainting-based editing, and InstructPix2Pix (Brooks et al., 2023) for instruction-based editing tasks.

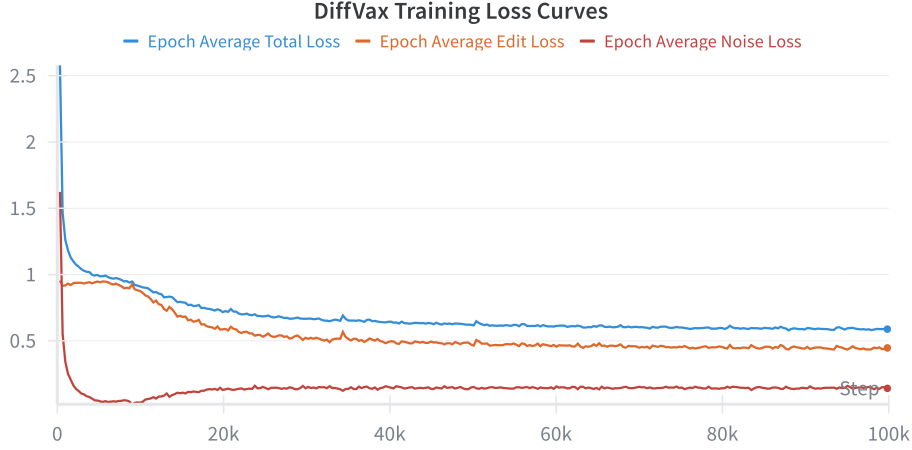


Figure 7: **Training Loss Curves.** We report the epoch-averaged Total Loss (blue), Edit Loss (orange), and Noise Loss (red). The curves demonstrate that the noise loss drops quickly to a low magnitude, ensuring the perturbation remains imperceptible, while the edit loss reduces continuously as the immunizer optimizes for edit disruption.

Training Algorithm Algorithm 1 describes the end-to-end training procedure for our immunizer model. For each data sample, the model generates an immunized image by injecting noise into the masked region. This image is then edited using a black-box editing model. The training objective minimizes both the deviation from the original image in the masked region and the effectiveness of the edit in the unmasked region.

Algorithm 1 End-to-end Training Framework

Input: Immunizer model $f(\cdot; \theta)$, Editing model $\text{SD}(\cdot)$, Dataset \mathcal{D} , Dataset size N , Loss weight α

for $n = 1$ to N **do**

$(\mathbf{I}^n, \mathbf{M}^n, \mathcal{P}^n) \leftarrow \text{sample}(\mathcal{D}, n)$

$\epsilon_{\text{im}}^n \leftarrow f(\mathbf{I}^n; \theta)$

$\mathbf{I}_{\text{im}}^n \leftarrow (\mathbf{I}^n + \epsilon_{\text{im}}^n \odot \mathbf{M}^n). \text{clamp}(0, 1)$

$\mathbf{I}_{\text{im,edit}}^n \leftarrow \text{SD}(\mathbf{I}_{\text{im}}^n, \sim \mathbf{M}^n, \mathcal{P}^n)$

$\mathcal{L}_{\text{noise}} \leftarrow \text{normalize}(\|\mathbf{I}_{\text{im}}^n - \mathbf{I}^n\|_1 \odot \mathbf{M}^n)$

$\mathcal{L}_{\text{edit}} \leftarrow \text{normalize}(\|\mathbf{I}_{\text{im,edit}}^n \odot (\sim \mathbf{M}^n)\|_1)$

$\mathcal{L} \leftarrow \alpha \cdot \mathcal{L}_{\text{noise}} + \mathcal{L}_{\text{edit}}$

$\theta \leftarrow \text{update}(\nabla_{\theta} \mathcal{L})$

end for

Dataset Setup Our dataset consists of 1,000 images, each associated with two prompts, resulting in a total of 2,000 prompts. We split the dataset into 80% for the training set (seen) and 20% for the validation set (unseen). The prompt set was constructed using ChatGPT (OpenAI, 2024), specifically by generating prompts designed for background editing. A total of 1,000 prompts were collected and subsequently split into 80% for the training set (seen) and 20% for the validation set (unseen). Finally, we sampled two random prompts for each image in the dataset, ensuring the prompts corresponded to whether the image was categorized as seen or unseen.

Our dataset is comparable in size to the current datasets used in related works, and is therefore aligned with the current standard of evidence in the field, while more data would always be better. To place our dataset size in the context of prior work, the closest research for training a generative adversarial noise generator is the paper "Generative Adversarial Perturbations" (Poursaeed et al., 2018). For their experiments on semantic segmentation, they used the focused Cityscapes dataset, which contains 2,975 training and 500 validation images. Given that this foundational work was established on a dataset of a few thousand images from a specific domain (urban scenes), we believe our dataset of 875 human images is in a comparable range for a proof-of-concept study. Nevertheless, we believe that extending our method to larger and more diverse datasets is a crucial next step, and we will highlight this as an important avenue for future work.

A.2 ADDITIONAL QUALITATIVE RESULTS AND COMPARISONS

A.2.1 ADDITIONAL RESULTS WITH INPAINTING-BASED EDITING MODELS

Figure 8 presents supplementary qualitative results obtained using inpainting-based editing models. The examples cover a wide range of scenarios and prompts, demonstrating the effectiveness of our immunization method on previously unseen content. Notably, the model performs well even on close-up images, maintaining robustness against malicious edits in both broad and fine-grained contexts.



Figure 8: *Additional qualitative results with DiffVax.* Each row displays a different prompt and input image, illustrating DiffVax’s ability to consistently disrupt harmful edits. Despite varying and challenging prompts, the edited outputs from the protected images show clear signs of disruption, emphasizing the robustness of our method.

A.2.2 ADDITIONAL COMPARISONS WITH INPAINTING-BASED EDITING MODELS

Figure 9 shows extended qualitative comparisons between *DiffVax* and various baseline immunization methods, including Random Noise, PhotoGuard-E, PhotoGuard-D, and DiffusionGuard. These results are produced using inpainting-based editing models. The comparison highlights how *DiffVax* consistently achieves better performance in visually disrupting malicious edits while preserving the semantic integrity of the original image.

We note that other defense methods such as AdvDM (Liang et al., 2023), SDS (Xue et al., 2024), and Mist (Liang & Wu, 2023) have also been proposed in the literature. However, these techniques are tailored for specific editing pipelines like SDEdit (Meng et al., 2022) and are not directly applicable in our inpainting-based setup, thus making direct comparison beyond our experimental scope.

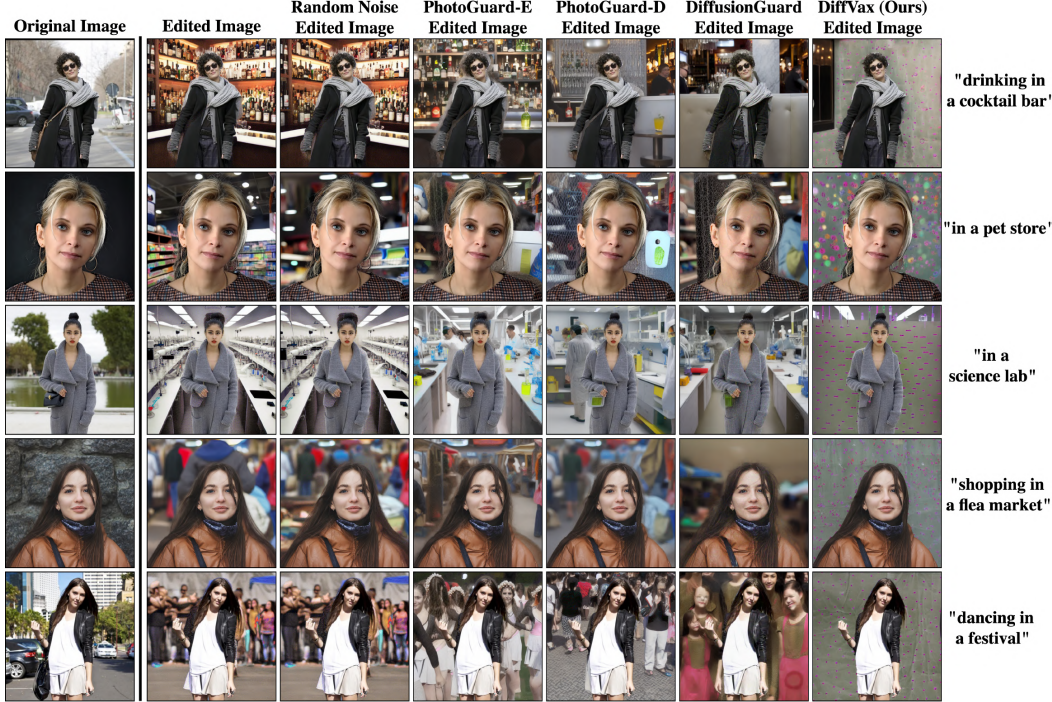


Figure 9: *Additional qualitative comparison between baselines and *DiffVax*.* Each row represents a unique prompt-image pair, while the columns show outputs for different immunization methods. *DiffVax* consistently produces better results, effectively disrupting edits while preserving image quality.

A.2.3 ADDITIONAL RESULTS WITH INSTRUCTION-BASED EDITING MODEL

To further evaluate the generalizability of `DiffVax`, we apply it to edits generated using `Instruct-Pix2Pix` (Brooks et al., 2023), a widely adopted text-guided diffusion-based editing tool. This setting differs significantly from inpainting models, as edits are applied based on high-level natural language instructions. As shown in Figure 10, `DiffVax` consistently disrupts a broad range of editing intents across various image types. The examples illustrate the model’s robustness across:

- **Human attribute edits** (e.g., “add a hat to her head”, “add bowtie to person”, “make him wear a small scarf”): `DiffVax` suppresses the addition of these features, effectively neutralizing changes to facial and clothing attributes.
- **Background edits** (e.g., “make the background a chapel”, “change him to a statue”): Despite significant changes to the scene, the edits fail to render properly on immunized images, showcasing `DiffVax`’s ability to neutralize edits in large non-focal areas.
- **Style transfer edits** (e.g., “change the style to starry nights”, “make the style cubism”, “van gogh style”): `DiffVax` prevents global transformations from taking effect, demonstrating its efficacy in blocking even abstract stylistic alterations.
- **Non-ROI edits** (e.g., “add hot-air balloons to back”, “add necklace to person”, “add headphones”): These involve subtle object insertions in the background or around the subject. Even though the modification targets are not directly in the immunized region, `DiffVax` still effectively disrupts the edit.

These results validate the model-agnostic and instruction-resilient nature of `DiffVax`, confirming its applicability to both local and global edit intents.

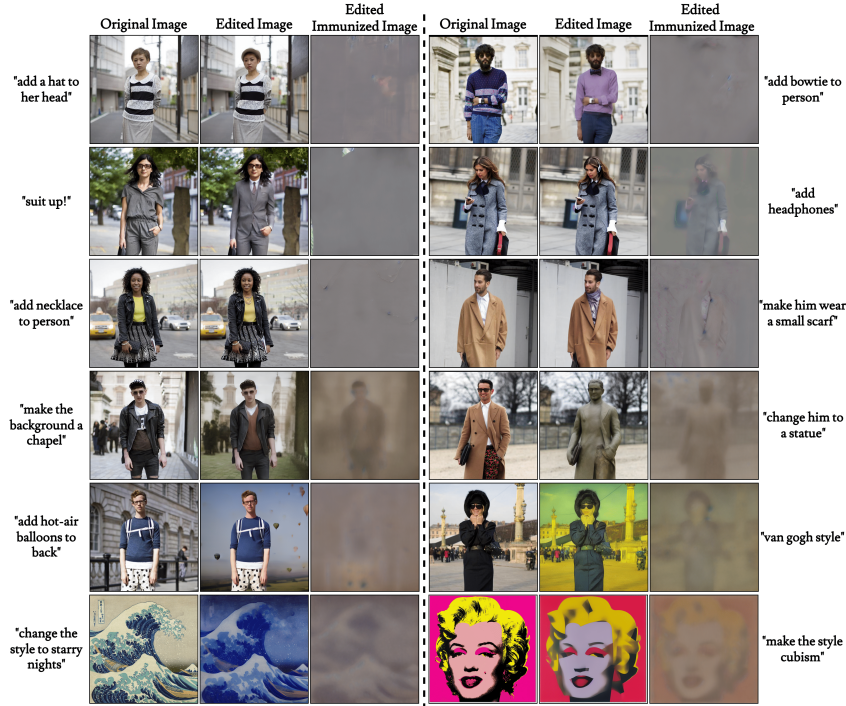


Figure 10: *Qualitative results using the InstructPix2Pix (Brooks et al., 2023) editing model with `DiffVax`.* Each triplet shows an original image, its edited counterpart, and the result after immunization. `DiffVax` successfully prevents a diverse set of edits, including background replacement, style transfer, object insertion, and attribute modification, further demonstrating its generalizability across editing types.

A.2.4 ADDITIONAL EVALUATION WITH MAGICBRUSH AND OTHER EDITING MODELS

The landscape of generative editing models is vast and rapidly evolving. Our choice of evaluation models was guided by established benchmarks in the image immunization literature to ensure a fair and direct comparison with prior state-of-the-art methods. To further strengthen our claims of generalizability, we conducted an additional experiment comparing our approach against PhotoGuard on the modern, training-free editing model MagicBrush. As shown in Table 4, our learned perturbations remain effective at disrupting edits, demonstrating that the protection generalizes beyond the standard inpainting and instruction-based models used in prior benchmarks. Our preliminary results show that DiffVax achieves superior edit disruption (lower SSIM, PSNR, FSIM, and CLIP-T) with comparable imperceptibility (SSIM Noise).

Table 4: *MagicBrush Comparison*

MagicBrush	SSIM ↓	PSNR ↓	FSIM ↓	CLIP-T ↓	SSIM (Noise) ↑
PhotoGuard	0.682	18.81	0.546	25.64	0.967
DiffVax	0.635	18.41	0.529	22.18	0.965

Table 5 contextualizes our evaluation scope by comparing the editing tools used across recent immunization works. The scope of our evaluation is aligned with current best practices. We acknowledge that methods like Prompt-to-Prompt Hertz et al. (2023b) and Null-text inversion Mokady et al. (2023) represent a different editing paradigm not directly compatible with the current experimental setup, and adapting our framework to protect against them is a promising direction for future work.

Table 5: *Editing Models Used*

Method	Editing Models Used
DiffVax (Ours)	SD Inpainting, IP2P, MagicBrush
DiffusionGuard Choi et al. (2025) (ICLR 2025)	SD Inpainting, IP2P
PhotoGuard Salman et al. (2023) (ICML 2023)	SD Inpainting, SDEdit
SDS Xue et al. (2024) (ICLR 2024)	SDEdit, SD Inpainting, Textual inversion
Mist Liang & Wu (2023) (ICML 2023)	Textual inversion, Dreambooth
AdvDM Liang et al. (2023) (ICML 2023)	Textual inversion, SDEdit

A.3 ADDITIONAL ROBUSTNESS EVALUATIONS AND STUDIES

A.3.1 ROBUSTNESS TO DIFFERENT SAMPLING STEPS AND SAMPLER SETTINGS

To evaluate the robustness of DiffVax against attackers who may vary their inference-time settings, we conduct experiments with different sampling steps and diffusion samplers. The results, presented in Table 6 and Table 7, demonstrate that DiffVax consistently and effectively disrupts malicious edits across a range of configurations.

Table 6 shows that DiffVax maintains superior performance across various sampling step counts (10, 20, 30, and 40). In nearly all scenarios, it achieves the best (lowest) scores for PSNR, FSIM, and CLIP-T, indicating its protection is not compromised when an attacker uses fewer or more steps for generation. Similarly, Table 7 illustrates that DiffVax outperforms baselines when different samplers (PNDMScheduler Liu et al., EulerDiscreteScheduler, LMSDiscreteScheduler Karras et al. (2022)) are used. This confirms that our learned immunization is not overfitted to a specific generation algorithm and remains effective in diverse, real-world attack scenarios.

Table 6: *Sampling Step Comparison*

Sampling Step	Model	SSIM ↓	PSNR ↓	FSIM ↓	CLIP-T ↓
10	PG-D	0.637	16.79	0.391	26.54
	DiffusionGuard	0.651	16.65	0.409	23.84
	DiffVax	0.627	16.37	0.366	22.96
20	PG-D	0.564	15.56	0.379	28.89
	DiffusionGuard	0.591	15.28	0.393	26.04
	DiffVax	0.564	14.96	0.360	24.42
30	PG-D	0.523	14.92	0.379	29.27
	DiffusionGuard	0.556	14.71	0.386	27.10
	DiffVax	0.526	14.32	0.362	24.17
40	PG-D	0.507	14.42	0.377	29.68
	DiffusionGuard	0.539	14.16	0.386	27.84
	DiffVax	0.506	13.78	0.356	24.06

Table 7: *Sampler Comparison*

Sampler	Model	SSIM ↓	PSNR ↓	FSIM ↓	CLIP-T ↓
PNDMScheduler	PG-D	0.480	14.31	0.404	26.88
	DiffusionGuard	0.501	14.52	0.404	26.97
	DiffVax	0.440	13.41	0.372	21.67
EulerDiscreteScheduler	PG-D	0.504	14.93	0.399	28.08
	DiffusionGuard	0.530	14.93	0.406	27.28
	DiffVax	0.466	13.91	0.361	22.00
LMSDiscreteScheduler	PG-D	0.487	14.36	0.403	27.82
	DiffusionGuard	0.509	14.47	0.405	27.23
	DiffVax	0.449	13.43	0.367	21.70

A.3.2 IMMUNIZATION NOISE COMPARISON UNDER PERTURBATION BUDGET

We have run experiments comparing DiffVax’s average learned perturbation against baselines with fixed 16/255, 32/255, 64/255 budgets, and we performed evaluation based on the mean magnitude (L_1) of the immunization noise (perturbation).

The results clearly show that DiffVax achieves superior edit disruption with a much smaller mean magnitude (L_1) perturbation than baselines given a larger budget, highlighting that its strength lies in the strategic placement of noise, not simply its magnitude. This supports our claim that DiffVax learns a more efficient and targeted noise distribution rather than applying uniform, high-energy noise.

Unlike methods that enforce a rigid and uniform L_p budget, DiffVax implicitly learns the perturbation’s properties via the trade-off in our loss function, $\mathcal{L} = \alpha \cdot \mathcal{L}_{\text{noise}} + \mathcal{L}_{\text{edit}}$. This allows the model to strategically allocate its “budget,” applying stronger noise only where most effective and least visible.

Table 8: *Comparison Across Immunization Strengths (ϵ)*

ϵ	Method	SSIM ↓	PSNR ↓	FSIM ↓	CLIP-T ↓	SSIM (Noise) ↑	Mean Magnitude (L_1) of Immunization Noise ↓
64/255	PG-D	0.492	14.13	0.355	27.85	0.947	0.007
	DiffusionGuard	0.507	13.98	0.360	24.83	0.900	0.012
32/255	PG-D	0.502	14.23	0.360	29.18	0.950	0.006
	DiffusionGuard	0.526	14.30	0.373	26.13	0.927	0.009
16/255	PG-D	0.528	14.60	0.387	30.27	0.978	0.003
	DiffusionGuard	0.546	14.46	0.388	26.36	0.965	0.005
–	DiffVax	0.496	13.85	0.352	22.96	0.989	0.001

A.3.3 ROBUSTNESS TO COUNTERATTACKS

JPEG compression and denoising techniques are typically designed to remove high-frequency components from images. Since our immunizer model introduces primarily low-frequency perturbations—due to the design of our noise loss—it becomes inherently more robust against such counterattacks.

Table 9 reports results under various JPEG compression ratios and when using IMPRESS (Cao et al., 2023), a model specifically developed for adversarial purification and denoising. Across all configurations, `DiffVax` consistently outperforms `PhotoGuard-D` and `DiffusionGuard` in terms of SSIM, SSIM (Noise), and CLIP-T metrics. These results suggest that `DiffVax` maintains its protective efficacy even when subjected to aggressive counterattack scenarios.

Figure 11 presents qualitative results of two counterattack strategies: (a) applying a denoiser and (b) applying JPEG compression. The edited image, along with its attacked counterpart, is shown for both `PhotoGuard-D` and `DiffVax`. While the visual changes for `PhotoGuard-D` are significant—indicating its vulnerability to counterattacks—`DiffVax` retains its robustness, preventing successful malicious edits.

To further explore robustness, Figure 19 presents additional qualitative comparisons under varying JPEG compression ratios (from 0.85 to 0.55) and under the IMPRESS purification attack. Even at high compression levels, `DiffVax` continues to disrupt the edits, showcasing its superior generalization and resistance to counter-editing.

Table 9: *Additional counterattack experiments.* The SSIM, SSIM (Noise), and CLIP-T metrics are reported for JPEG compression with ratios of 0.85, 0.65, and 0.55, as well as for the adversarial purification model IMPRESS. The metrics demonstrate that `DiffVax` consistently outperforms `PhotoGuard-D` (PG) and `DiffusionGuard` (DG), even when counterattacks are applied to all methods.

Metric	<code>DiffVax</code> (JPEG .85)	DG (JPEG .85)	PG (JPEG .85)	<code>DiffVax</code> (JPEG .65)	DG (JPEG .65)	PG (JPEG .65)	<code>DiffVax</code> (JPEG .55)	DG (JPEG .55)	PG (JPEG .55)	<code>DiffVax</code> (IMPRESS)	DG (IMPRESS)	PG (IMPRESS)
SSIM ↓	0.517	0.646	0.640	0.530	0.696	0.692	0.534	0.706	0.693	0.489	0.605	0.578
SSIM (Noise) ↑	0.968	0.955	0.961	0.951	0.946	0.950	0.944	0.940	0.944	0.644	0.636	0.640
CLIP-T ↓	25.76	30.83	32.00	26.83	31.80	32.15	27.67	31.93	32.20	24.67	30.71	31.35



Figure 11: *Qualitative results of counter-attacks on immunization methods.* The first row shows results when an off-the-shelf denoiser is applied to the immunized image, while the second row displays results under JPEG compression. Columns 2–3 correspond to PhotoGuard-D, while columns 4–5 show results for DiffVax. PhotoGuard-D is visibly more susceptible to counterattacks, whereas DiffVax maintains strong protection.

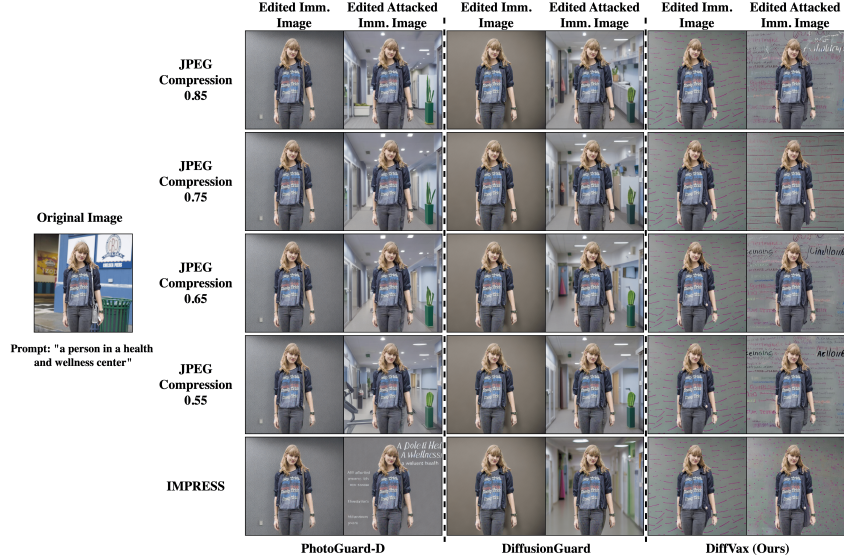


Figure 12: *Additional qualitative results of counter-attacks on immunization methods.* Each row corresponds to a different JPEG compression ratio or the IMPRESS model. DiffVax shows robust behavior across all levels, continuing to suppress harmful edits even under heavy degradation or purification.

A.3.4 ROBUSTNESS TO NON-HUMAN SUBJECTS

To evaluate the generalizability of `DiffVax` beyond human-centric content, we conduct experiments on non-human subjects, such as animals and other inanimate objects. As illustrated in Figure 13, `DiffVax` effectively immunizes these non-person regions, preventing malicious edits while preserving the visual fidelity of the original image. These results further demonstrate the versatility and zero-shot capabilities of `DiffVax` across diverse object domains.



Figure 13: *Qualitative results for non-human objects edited using `DiffVax`.* These examples show that `DiffVax` extends effectively to domains beyond human subjects, maintaining its edit-resistance and imperceptibility.

A.3.5 USER STUDY

To assess the human-perceived quality and effectiveness of each immunization method, we conducted a user study with 67 participants recruited via Prolific. Participants were asked to rank edited images based on how unrealistic or misaligned they appeared.

Each participant was shown a set of five edited images derived from the same input image and text prompt (see Figure 14). These five outputs corresponded to different immunization strategies: Random Noise, PhotoGuard-E, PhotoGuard-D, DiffVax, and an unprotected baseline. For each prompt-image pair, participants were instructed to rank the edits from **least aligned** to **most aligned** with the editing prompt. A lower ranking indicates better disruption of the intended edit (i.e., more effective immunization), as participants found the result less realistic or aligned with the prompt.

We randomly shuffled the order of methods in each trial to avoid position bias. In total, the study included 20 image-prompt pairs covering both seen and unseen examples, ensuring a fair and comprehensive evaluation.

Table 10: *User Study Rankings*. Lower values indicate better perceived editing failure prevention, imperceptibility, and alignment with the original content.

Immunization Method	Average Ranking ↓
Random Noise	3.74
PhotoGuard-E	3.33
PhotoGuard-D	<u>2.63</u>
DiffVax (Ours)	1.64

As shown in Table 10, DiffVax significantly outperforms prior methods, receiving the best average ranking of **1.64**. This demonstrates the effectiveness of our method in fooling editing models in a way that is perceptually convincing to human observers. The next-best method, PhotoGuard-D, trails behind with a score of 2.63, while other methods rank even lower.

Within this User-Study Experiment form, you will encounter **one input image, one text prompt and multiple edited images** for each section. For each question, please rank the edits from **least aligned** to **most aligned** with the **intended background change** described in the prompt.


Note: We randomly shuffle the image editing approaches' order in every section for fairness.

Example: *

Each **edited image** below shows a **change** made to the **background** of the original image based on the **text prompt** written below. Please rank these edits from **least aligned** to **most aligned** with the intended **background change** described in the prompt.

Text Prompt: "A person in a horse racing track"

Input Image



Edited Images




Image 1 Image 2 Image 3 Image 4 Image 5

Least aligned	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Second least aligned	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Middle	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Second most aligned	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Most aligned	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 14: *Instructions provided to user study participants*. Users were asked to rank edited images from least to most aligned with the text prompt. Lower alignment suggests more successful immunization.

A.3.6 VIDEO EVALUATION

To our knowledge, this is the first immunization-based video evaluation using a diffusion model for editing. We construct a video benchmark consisting of 4 human activity videos, each containing 64 frames and paired with 4 unique prompts. Since no prior method directly supports training-free video immunization using inpainting-based diffusion models, we adopt a naive per-frame editing pipeline to extend our approach to video. Despite not incorporating any explicit temporal modeling, our method yields strong results.

As reported in Table 11, `DiffVax` outperforms all baselines across multiple metrics, including PSNR, SSIM (Noise), CLIP-T, and runtime. Notably, it achieves a dramatic reduction in runtime—processing the full dataset in just **0.739 seconds**—compared to PhotoGuard-D’s 64-hour runtime. These results emphasize the efficiency and practicality of our approach in real-time or large-scale settings.

Importantly, we make no architectural or training modifications for video data. The strong results achieved without temporal modeling suggest that our method generalizes well across sequential data, capturing consistent patterns in human identity, pose, and structure across frames. This robustness is further demonstrated in Fig. 1 and Fig. 4 (c), where the model effectively adapts to changes in body motion and facial expressions.

Our work targets general-purpose editing protection and is evaluated on diverse, open-domain video data. The effectiveness of our approach under such settings demonstrates its promise as a scalable and general immunization strategy for future video editing systems.

Table 11: **Results on video editing.** We report the average PSNR, SSIM, FSIM, SSIM (Noise), CLIP-T, and total runtime for Random Noise, PhotoGuard-D, DiffusionGuard, and `DiffVax` on a video dataset consisting of 4 videos, each with 4 prompts and 64 frames. Best results per column are **bolded**.

Method	SSIM ↓	PSNR ↓	FSIM ↓	SSIM (Noise) ↑	CLIP-T ↓	Runtime ↓
Random Noise	0.774	21.09	0.547	0.786	29.62	N/A
PhotoGuard-D	0.738	17.31	0.448	0.965	26.52	64 hours
DiffusionGuard	0.750	17.43	0.478	0.922	25.41	10 hours
<code>DiffVax</code>	0.681	16.78	0.374	0.974	22.51	0.739 seconds

A.4 DISCUSSION ON GENERALIZATION

While a universal immunizer that works zero-shot across all editing model architectures is a challenging open problem, *DiffVax* demonstrates superior generalization compared to existing optimization-based methods across three distinct dimensions: generalization to unseen models, to unseen content, and to unseen masks. This section details these advantages.

A.4.1 GENERALIZATION TO UNSEEN MODELS

Existing immunization methods, including optimization-based approaches like PhotoGuard, are model-specific. While developing a universally transferable immunizer is not the primary focus of this work, *DiffVax* demonstrates significantly better generalization to unseen models than prior methods. We conducted an experiment where immunization noise was generated using a model trained on Stable Diffusion (SD) v1.5 and then tested on an unseen SD v2 model. As shown qualitatively in Figure 15, *DiffVax* successfully transfers its protective effect, whereas PhotoGuard’s perturbations fail completely, leaving the image vulnerable.



Figure 15: *Transferability of perturbations across editing models.* Red labels indicate the immunization training model, and blue labels denote the editing model. The results show how well each immunized image resists edits across different model configurations. When trained on Stable Diffusion (SD) v1.5, *DiffVax* successfully prevents edits even when tested on SD v2. In contrast, PhotoGuard’s perturbations trained on SD v1.5 do not generalize to SD v2. These results illustrate the superior cross-model generalizability of *DiffVax*.

Table 12 provides quantitative results for this black-box transfer task, confirming that *DiffVax* achieves the best performance across all metrics. This provides direct evidence that our learned immunization strategy is more robust and generalizable across model versions than optimization-based approaches.

Table 12: Quantitative results for transferring immunization from SD v1.5 to an unseen SD v2.0 model. Lower values are better for all metrics, indicating more effective edit disruption. *DiffVax* outperforms all baselines.

SD 2.0	SSIM ↓	PSNR ↓	FSIM ↓	CLIP-T ↓
PG-D	0.566	15.17	0.417	32.00
DiffusionGuard	0.609	15.26	0.454	31.73
DiffVax	0.540	14.02	0.384	27.72

A.4.2 GENERALIZATION TO UNSEEN CONTENT

Optimization-based methods inherently handle unseen images by running a costly, per-image optimization process. A key scientific question this paper addresses is whether it is possible to learn a single feed-forward model that can directly generate effective perturbations without optimization. The success of our approach implies that the set of effective perturbations across all possible images possesses sufficient structure and regularity to be learnable. Our experiments demonstrate that *DiffVax* successfully generalizes to **unseen images, unseen prompts, and even unseen videos** with a single forward pass, as demonstrated in Fig. 1 and Fig. 4 (b) and (c) and Table 11. This establishes the learnability of the perturbation set for the first time and enables protection at a scale and speed previously unattainable.

A.4.3 GENERALIZATION TO UNSEEN MASKS DURING TEST TIME

Most existing state-of-the-art (SOTA) methods assume that the same mask is used during both the immunization (training) and editing (testing) phases. While this assumption aligns with standardized deepfake pipelines—where masks are often fixed to cover specific regions such as the head or full body—it limits the robustness of these methods to real-world scenarios involving unpredictable or mismatched editing masks.

To evaluate this limitation, we conduct an experiment where the editing mask during test time differs from the mask used during immunization. As shown in Figure 17, when the test-time mask diverges from the training mask, existing methods such as PhotoGuard (PG) and DiffusionGuard fail to maintain their edit-disrupting behavior. In contrast, *DiffVax* remains effective, successfully disrupting the malicious edits even when significant changes are made to the mask size or region. This robustness can be attributed to our model’s design, which does not overfit to the spatial shape or scale of the mask used during training. Instead, it learns to encode more generalizable perturbations that degrade editing attempts across a range of editing contexts. These findings suggest that *DiffVax* offers better real-world applicability where attackers may alter masks to evade immunization. We further demonstrate this in Figure 16, which illustrates that *DiffVax* maintains its protective capabilities even when the test-time mask only partially covers the subject (e.g., a vertical half-mask), preventing the edit despite the minimal mask overlap.

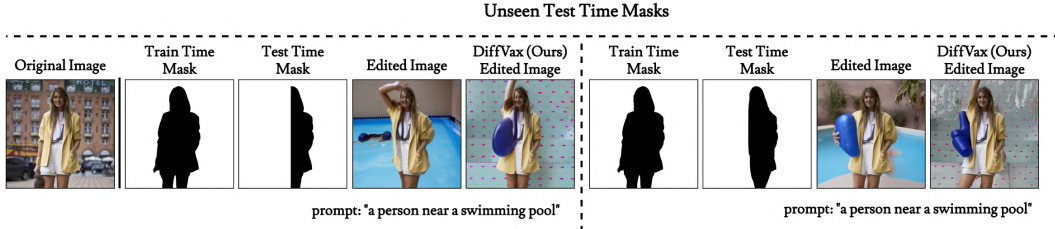


Figure 16: *Additional comparison of partially covering masks.* We evaluate robustness in scenarios where the test-time mask only covers a portion of the subject (e.g., a vertical half-split) compared to the full mask used during immunization. As shown, *DiffVax* successfully maintains protection and disrupts the edit despite the partial mask coverage.



Figure 17: *Comparison of edited immunized images with different immunization and editing masks.* PhotoGuard uses the same mask for both training and testing, making it highly sensitive to changes in the editing mask. *DiffVax*, by contrast, is trained with a fixed immunization mask but remains robust even when the test-time editing mask significantly deviates. The results show consistent disruption of edits by *DiffVax* despite large mask variability.

A.5 IMPERCEPTIBILITY DISCUSSION

To evaluate the imperceptibility of the perturbations introduced by `DiffVax`, we present qualitative comparisons against PhotoGuard in Figure 18. Our method generates noise that is concentrated in the low-frequency components of the image, making it visually more subtle and less disruptive. In contrast, PhotoGuard introduces high-frequency noise that appears scattered across broader regions.

This low-frequency characteristic of `DiffVax` offers two key advantages. First, it enhances the perceptual quality of the immunized images by producing smoother perturbations that minimally interfere with semantic content. Second, it contributes to robustness against counterattacks such as JPEG compression or denoising—these techniques are typically designed to suppress high-frequency information, which is assumed to correspond to noise. Since `DiffVax` avoids relying on high-frequency artifacts, its perturbations are more likely to survive such transformations, preserving the protective effect.

We further examine the role of the loss norm in shaping the visual quality of the immunization. As shown in Figure 19, using L_2 or L_∞ norms leads to less perceptible perturbations than the default L_1 formulation. However, this comes at the expense of reduced edit resistance, underscoring a critical trade-off between imperceptibility and robustness.

Future work will explore more principled approaches to navigating this trade-off, such as incorporating perceptual similarity metrics or frequency-domain regularization directly into the optimization objective.

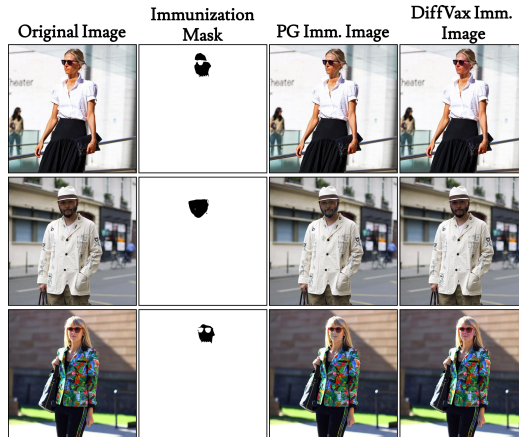


Figure 18: **Comparison of immunization noise.** Visual comparison of immunized images generated by PhotoGuard and `DiffVax` using a face mask. PhotoGuard produces scattered and higher-frequency noise, while `DiffVax` generates smoother, low-frequency perturbations.



Figure 19: **Additional comparison of immunization noise under different norms.** This figure compares immunized images generated using different norm constraints: L_1 , L_2 , and L_∞ , as well as results from PhotoGuard and DiffusionGuard.

A.6 PROMPT-AGNOSTIC IMMUNIZATION EXPERIMENT

We conduct additional experiments to demonstrate that the noise produced by our `DiffVax` (and consequently the immunized images) is prompt-agnostic. To achieve this, we train `DiffVax` three times, using a different image for each training setup. In each experiment, we use a single image with 100 seen prompts for training and evaluate it on 75 seen prompts and 75 unseen prompts (not included in the training set). The results are then averaged across all images for each prompt. As shown in Fig. 20, the quantitative results for seen and unseen metrics are highly similar, and the low variances further confirm that the noise generalizes effectively across diverse prompt conditions.

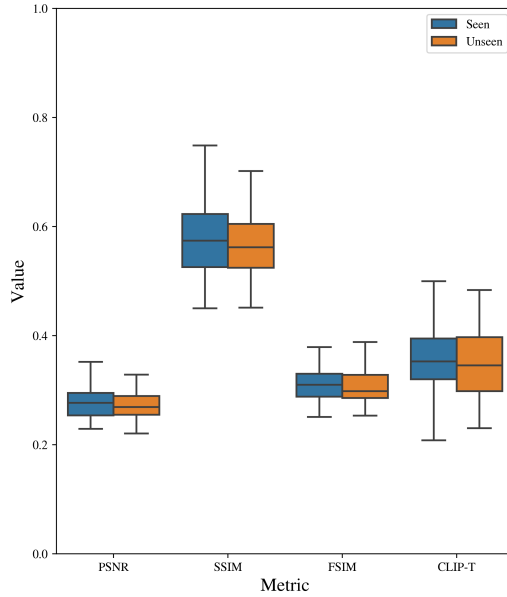


Figure 20: **Experiment results for prompt-agnostic noise.** We present our performance metrics between prompts for 75 prompts seen in training (blue color) and 75 prompts unseen in training (orange color). PSNR and CLIP-T values are divided by 50 for visualization purposes. We can see that the two distributions are almost identical, suggesting that our method performs similarly across all prompts, suggesting the prompt-agnostic nature of our `DiffVax`.

A.7 LOSS WEIGHT SELECTION

The hyperparameter α in `DiffVax`’s loss function controls the balance between imperceptibility and edit disruption. It is defined in the overall loss as $\mathcal{L} = \alpha \cdot \mathcal{L}_{\text{noise}} + \mathcal{L}_{\text{edit}}$, where a larger α emphasizes minimizing visible noise, potentially at the cost of reduced editing resistance, and a smaller α enhances robustness to edits but may introduce more perceptible perturbations.

To determine an optimal value for α , we conduct an ablation study on a subset of 100 images, evaluating three values: $\alpha = 2, 4$, and 6 . The results are summarized in Table 13. We observe that while increasing α improves imperceptibility—as indicated by slightly higher SSIM (Noise) and PSNR scores—the edit disruption becomes weaker, reflected in a deterioration of the SSIM and PSNR metrics.

We select $\alpha = 4$ as the optimal configuration. It provides a strong balance between imperceptibility and disruption: the gain in SSIM (Noise) from $\alpha = 4$ to $\alpha = 6$ is marginal, while the drop in editing robustness is more pronounced. Furthermore, qualitative inspection confirms that the perturbations at $\alpha = 4$ are already imperceptible, making further increase in α unnecessary.

Table 13: *Ablation study on the loss weight α in $\mathcal{L} = \alpha \cdot \mathcal{L}_{\text{noise}} + \mathcal{L}_{\text{edit}}$.* Metrics demonstrate the trade-off between imperceptibility and edit disruption. Best values for SSIM (Noise) are bolded, while lower SSIM and PSNR indicate stronger editing disruption.

Configuration	SSIM ↓	PSNR ↓	SSIM (Noise) ↑
<code>DiffVax</code> w/ $\alpha = 2$	0.536	14.47	0.987
<code>DiffVax</code> w/ $\alpha = 4$	0.588	15.38	0.993
<code>DiffVax</code> w/ $\alpha = 6$	0.625	16.23	0.996

A.8 LIMITATIONS

Despite its strong performance, `DiffVax` exhibits certain limitations, as illustrated in Figure 21. First, the model faces challenges in effectively immunizing scenes with ****multiple small objects**** (Panel A). In such cases, the protective noise may be too dispersed to disrupt the semantic guidance for every individual object, allowing some edits (e.g., turning birds into parrots) to succeed. Second, while generally robust to mask variations, extreme discrepancies between the immunization and editing masks can compromise protection. For instance, if an image is immunized with a full-body mask but the attacker employs a significantly smaller, localized mask (Panel B), the edit may partially bypass the immunization. Finally, although we optimize for imperceptibility, ****occasional perceptible artifacts**** may appear (Panel C), particularly in smooth or uniform regions where the adversarial perturbations are harder to conceal.

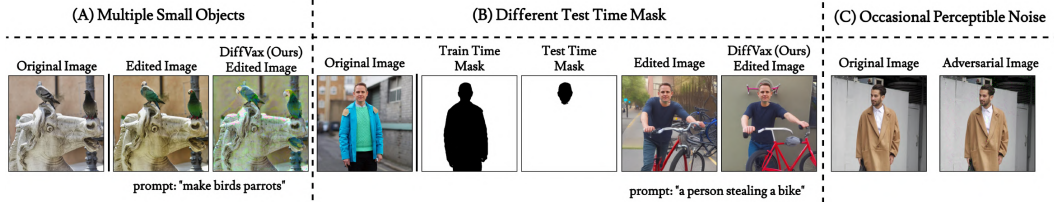


Figure 21: **Limitations.** We highlight three failure cases: (A) `DiffVax` struggles to protect multiple small objects simultaneously; (B) protection may fail when the test-time editing mask (e.g., a small face region) drastically differs from the training-time immunization mask (e.g., full body); and (C) in rare instances, the immunization noise becomes perceptible to the human eye.

A.9 FUTURE DIRECTIONS

While `DiffVax` demonstrates strong generalization within the latent diffusion paradigm, a critical avenue for future research is achieving universal cross-architecture immunization. Current perturbations are optimized for the gradient flow of U-Net-based LDMs, which may not fully transfer to emerging non-LDM architectures, such as flow-matching models or pixel-space diffusion transformers. We envision extending our scalable feed-forward framework to incorporate *Ensemble Adversarial Training*, where the immunizer is trained simultaneously against a diverse set of backbones. This would encourage the model to learn universally disruptive features that transcend specific architectural biases. Additionally, expanding the training distribution to include non-photorealistic domains, such as anime and digital art, will be essential for broader real-world applicability.

Furthermore, while our method effectively immunizes video via per-frame processing, future iterations could explicitly model temporal dynamics. Integrating temporal consistency objectives directly into the training loop would allow the immunizer to exploit motion priors, potentially creating “video-native” perturbations that are even more robust to temporal filtering and video compression. Finally, addressing the physical limitations of extremely small editing masks remains an open challenge; exploring frequency-domain regularization or perceptual loss functions that adaptively balance noise visibility with protective strength in constrained regions could offer a pathway to more granular control.

A.10 REPRODUCIBILITY STATEMENT

The source code of the project is provided in the supplementary. Project can be reproduced by following the provided guidelines and source code. All experiments can be replicated using the instructions and datasets referenced in this paper.

A.11 ETHICS STATEMENT

This work does not raise any foreseeable ethical concerns. The experiments were conducted solely on publicly available datasets.

A.12 LLM USAGE STATEMENT

Large language models (LLMs) were used exclusively for assistance in grammar correction, formatting, and improving the clarity of writing. They were not employed for generating research ideas, designing experiments, or creating results.