RECALL: LEARNING CONTENT-ANCHORED SPECTRAL REPRESENTATION VIA RESTORATION-AS-ALLOCATION FOR HIDDEN SCREEN RECONSTRUCTION

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ABSTRACT

Can an ordinary camera positioned behind a wall-facing display recover its content from diffuse wall light alone? Propagation, scattering, occlusion, blur, and sensor integration disperse weak content cues, disrupting local screen-to-wall correspondence and making appearance-based capability allocation ambiguous. We present REpresentation-enabled Content-Anchored aLLocation Learning (RECALL), a wall-image-only framework built around Content-Anchored Spectral Representation (CASR) and Restoration-as-Allocation Learning (RAL). CASR organizes patchwise spectral evidence around a sample-dependent content anchor derived from the wall image with a frozen visual encoder, combining smooth-layout and residual-detail cues. RAL learns soft spatial allocation by comparing the pooled errors of complete reconstructions produced under local and context-augmented capability choices on the same wall observation during training. Across seven screen-content categories, RECALL achieves the strongest overall screen-reconstruction performance among the compared image-restoration methods, with the highest PSNR and SSIM in every category and the lowest LPIPS in five. Across varied capture conditions and screen-content scenes, it coarsely recovers hidden-screen color and brightness distributions, regional layouts, and principal contours from blurred wall-light patches. These experiments demonstrate the feasibility of observing hidden screen content with an ordinary camera capturing only wall light patches.

1 INTRODUCTION

Can the light patch on a wall reveal the content of a display hidden from the camera? We study this question with the display facing a blank wall and an ordinary camera positioned behind it. Propagation, diffuse reflection, chassis occlusion, lens blur, and sensor integration mix contributions from multiple screen regions into a low-contrast RGB wall image observed beyond the display chassis. Indirect imaging has recovered hidden-scene information under active, acoustic, transient, and steady-state sensing assumptions Velten et al. (2012); O'Toole et al. (2018); Lindell et al. (2019a,b); Metzler et al. (2020); Chen et al. (2019); passive optical studies have also shown that ordinary-camera observations can carry hidden-scene and screen cues, including recovery from diffuse reflections Katz et al. (2014); Bouman et al. (2017); Saunders et al. (2019); Wang et al. (2020). Here, we investigate whether coarse screen color and brightness distributions, regional layouts, and principal contours can be recovered from this wall-only observation. The surviving distributed cues carry content evidence even after optical mixing disperses fine text and one-to-one screen-to-wall correspondence. The camera therefore receives neither the screen image nor a stable screen-to-wall correspondence: it must infer content organization from weak evidence whose provenance has been mixed by the optical path. Different screen configurations can produce similar low-contrast wall measurements, while the camera has no direct access to screen-side features or geometry. Recovering even coarse structure therefore requires coordinating weak, non-local cues rather than merely removing blur or enhancing appearance.

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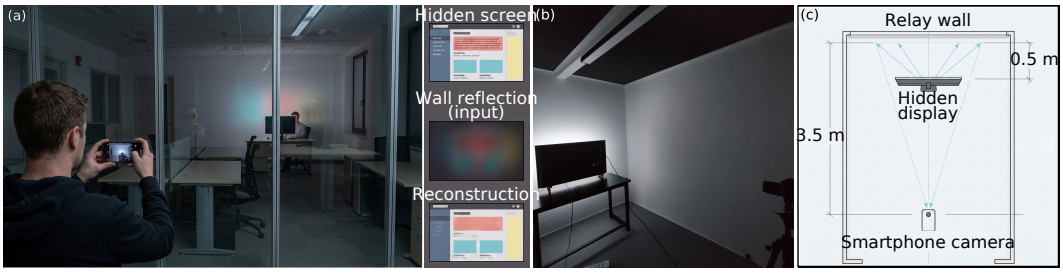


Figure 1: Passive hidden-screen reconstruction setup. (a) Photographic application scene showing wall-only capture. (b) Physical acquisition view of the display, relay wall, and camera. (c) Top-view geometry of the relay wall, hidden display, and ordinary camera, with display–wall and camera–wall distances of 0.5 m and 3.5 m.

This inverse problem couples two challenges. First, diffuse transport mixes screen content many-to-many: each screen location contributes to multiple wall locations, and each wall location combines multiple screen contributions. Neighboring wall pixels therefore contain cues from dispersed screen regions, with weak color, intensity, and spectral variations embedded in wall texture and illumination. Convolutional aggregation and appearance-conditioned attention can therefore emphasize dominant wall texture and illumination as the signal weakens, while downsampling further attenuates weak screen-related strokes and boundary cues Ulyanov et al. (2018); Pan et al. (2021); Wang et al. (2018); Heckel & Hand (2019); Dosovitskiy et al. (2021). A useful representation should relate dispersed responses under a common wall-derived reference while retaining complementary smooth-layout and residual-detail evidence. Second, spatial allocation asks which capability best restores each region, while supervision of the fused reconstruction improves their combined output. Comparing complete reconstructions produced by local and context-augmented capabilities on the same wall evidence provides a direct restoration-utility signal for this allocation.

We address these challenges with REpresentation-enabled Content-Anchored aLLocation Learning (RECALL), a wall-image-only framework that couples content-anchored evidence organization with restoration-utility-guided capability allocation. Content-Anchored Spectral Representation (CASR) uses a frozen visual encoder to derive a sample-dependent global reference from the current wall observation and combines it with trainable multiscale wall features. Patchwise spectral relations and complementary smooth-layout and residual-detail cues organize the dispersed screen evidence. Restoration-as-Allocation Learning (RAL) learns soft spatial preferences between local and context-augmented capabilities from their relative hidden-screen reconstruction errors. Across seven content categories and varied capture conditions, RECALL reconstructs coarse color and brightness distributions, regional layouts, and principal contours, demonstrating that an ordinary camera behind a display can reveal its content through diffuse wall light.

The main contributions are summarized as follows.

(1) We propose RECALL, a unified wall-image-only framework that organizes diffuse reflection evidence and restores hidden screen content in the camera-behind-display setting, learning end-to-end reconstruction from spatially mixed screen evidence.
(2) We introduce CASR to organize mixed evidence around a wall-derived content anchor and RAL to learn capability specialization from soft spatial targets derived from relative reconstruction errors, jointly coupling wall-derived representation and restoration allocation.
(3) We evaluate RECALL across seven screen-content categories through controlled comparisons, module-level ablations, spatial diagnostics, and robustness analyses, demonstrating coarse hidden-screen reconstruction across different capture conditions.

2 Related Work

Indirect Imaging under Active and Passive Observation. Transient imaging recovers hidden geometry through ultrafast measurements, light-cone inversion, and wave-based migration; acoustic imaging uses reflected sound Velten et al. (2012); O'Toole et al. (2018); Lindell et al. (2019a,b). Speckle correlations and steady-state intensity provide further reconstruction cues Katz et al. (2014); Metzler et al. (2020); Chen et al. (2019). Passive methods exploit edge-induced radiance variations and

occlusion-encoded reflections Bouman et al. (2017); Saunders et al. (2019). Wang et al. reconstruct screen images from a laptop's diffuse reflection on a door Wang et al. (2020); Aittala et al. fit hidden-video content and light transport jointly Aittala et al. (2019). RECALL learns a wall-to-screen mapping from paired observations, coupling content-anchored organization with restoration-based allocation to recover screen organization in the camera-behind-display geometry.

Restoration Representation and Conditional Allocation. Restormer, Uformer, and NAFNet provide attention-based and nonlinear-activation-free restoration backbones Zamir et al. (2022); Wang et al. (2022); Chen et al. (2022); FFTformer uses spectral interactions and frequency-selective gating Kong et al. (2023). Retinexformer, HVI-CIDNet, and PromptIR organize illumination, color–intensity, and degradation cues, while CLIP supplies transferable global features Cai et al. (2023); Yan et al. (2025); Potlapalli et al. (2023); Radford et al. (2021). CASR conditions multiscale spectral and layout–detail evidence on the current wall observation. Switch Transformers and V-MoE route tokens among experts, Path-Restore learns regional paths with restoration-and-computation rewards, and MoCE-IR allocates complexity-varying experts Fedus et al. (2022); Riquelme et al. (2021); Yu et al. (2022); Zamfir et al. (2025). RAL compares complete reconstructions under local and context-augmented capabilities, converting their relative errors on the same wall evidence into soft spatial allocation targets.

3 METHOD

3.1 OVERALL ARCHITECTURE

Hidden-screen reconstruction requires relating screen cues dispersed across the wall by optical mixing. RECALL first organizes this evidence with CASR and then assigns it through RAL. The observation model makes this mixing explicit: screen radiance is integrated over the screen, relay wall, and wavelength before the camera receives the sampled wall tensor. Appendix Equation A1 gives the transport interpretation and its compactness analysis.

$$\begin{aligned} w &= \mathsf{SB}\Big(\{\mathcal{O}_{K,\varepsilon}[L](\boldsymbol{z},c)\}_{c,\boldsymbol{z}}\Big) \\ &= \mathsf{SB}\left(\left\{\int_{\Lambda}\int_{A_w}\int_{A_s} K_c(\boldsymbol{z},\boldsymbol{u},\boldsymbol{x},\lambda)L(\boldsymbol{x},\lambda)\,\mathrm{d}\boldsymbol{x}\,\mathrm{d}\boldsymbol{u}\,\mathrm{d}\lambda + \varepsilon_c(\boldsymbol{z})\right\}_{c,\boldsymbol{z}}\right) \in \mathbb{R}^{B\times 3\times H\times W}, \qquad c\in\{1,2,3\}. \end{aligned} \tag{1}$$

Here, A_s, A_w, Λ are the screen, wall, and wavelength domains; $\boldsymbol{x}, \boldsymbol{u}, \boldsymbol{z}$ are screen, wall, and camera coordinates. L is screen radiance, K_c aggregates attenuation, visibility, diffuse reflectance, chassis occlusion, blur, and camera response, and $\varepsilon_c(\boldsymbol{z})$ collects sensor effects. The continuous observation operator $\mathcal{O}_{K,\varepsilon}$ combines integrated transport with the sensor residual; the fixed sampling-and-batching map SB forms w, with batch size B and image dimensions H, W. RECALL takes the sampled wall image w as its inference input.

RECALL applies a deterministic adaptive exposure preconditioner $\widetilde{w} = \mathcal{P}(w)$ and uses a shared encoder–decoder for two restoration passes. Let $q^{(0)} = 0$ and $q^{(1)} = \mathrm{sg}(p)$ denote the zero and detached coarse proposals. At scale i and pass $t \in \{0,1\}$, the complete condition is $c_i^{(t)} = \ell_i(\widetilde{w}, q^{(t)}) + a_i$, where ℓ_i forms local wall/proposal features and a_i is the sample-dependent CASR content anchor shared across passes. Both the backbone and router receive this fused condition. The first pass produces p; the second refines it from the same observation and the detached proposal. RAL converts the relative reconstruction errors of the two capabilities into a soft spatial allocation target:

$$\begin{aligned} \xi_j(\boldsymbol{u}) &= \sigma\left(\frac{(-1)^j[d_1(\boldsymbol{u}) - d_0(\boldsymbol{u})]}{\tau\Delta(\boldsymbol{u})}\right) \\ &= \sigma\left[\frac{(-1)^j\displaystyle\int_{\mathcal{D}} W(\boldsymbol{u},\boldsymbol{v})\,\frac{\|\widetilde{y}_1(\boldsymbol{v}) - s(\boldsymbol{v})\|_1 - \|\widetilde{y}_0(\boldsymbol{v}) - s(\boldsymbol{v})\|_1}{3}\,\mathrm{d}\boldsymbol{v}}{\tau\left(\dfrac{1}{2}\displaystyle\int_{\mathcal{D}} W(\boldsymbol{u},\boldsymbol{v})\sum_{k=0}^{1}\frac{\|\widetilde{y}_k(\boldsymbol{v}) - s(\boldsymbol{v})\|_1}{3}\,\mathrm{d}\boldsymbol{v} + \varepsilon\right)}\right], \qquad j\in\{0,1\}. \end{aligned} \tag{2}$$

Here, $\mathcal{M}_j$ is the complete two-pass model forced to capability j at the supervised module in both passes; $\widetilde{y}_j = \mathrm{clip}_{[0,1]}(\mathcal{M}_j(w;\theta))$ is its RGB output and s the training target. Deterministic kernel W pools channel-mean absolute error from image domain $\mathcal{D}$ to router grid $\mathcal{G}$ as a weighted pixel average,

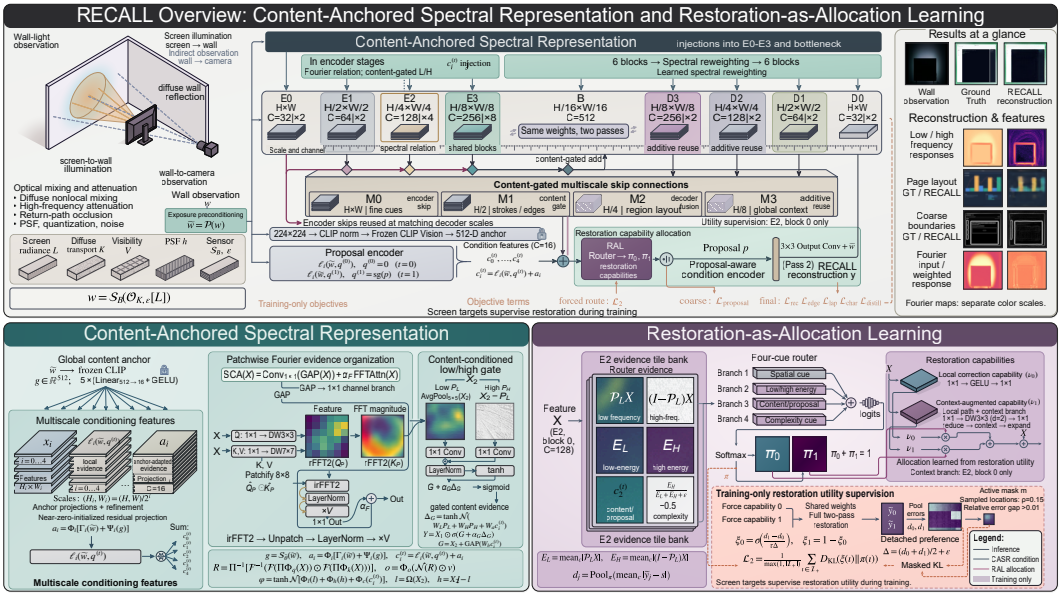


Figure 2: Overall RECALL architecture, showing the deterministic exposure preconditioner, sample-dependent wall content anchor generated by a frozen visual encoder, zero proposal in the first pass, detached coarse proposal in the second pass, and the ordering from CASR to RAL in the shared two-pass reconstruction.

yielding d_j and normalizer $\Delta = (d_0 + d_1)/2 + \varepsilon$. Logistic σ forms detached preferences ξ with softness $\tau > 0$ and stabilizer $\varepsilon > 0$. Suppressed batch indices are restored in $\mathcal{I} = \{1, \ldots, B\} \times \mathcal{G}$; binary active mask m, induced by the sampling ratio and utility-gap threshold described in Appendix Equation A7, selects $\mathcal{I}_+ = \{\iota \in \mathcal{I} : m(\iota) = 1\}$. The preference supervises the normal second-pass allocation π from Equation 4 through $\ell(\iota) = \sum_{j=0}^{1} \xi_j(\iota) \log(\xi_j(\iota)/\pi_j(\iota))$; $\mathcal{L}_2$ averages ℓ over $\mathcal{I}_+$, returning zero when empty.

Figure 2 follows the recovery of a hidden screen from its wall reflection. Exposure preconditioning stabilizes dark observations, CASR organizes dispersed content cues under a shared wall-derived reference, and RAL assigns restoration capabilities to the resulting features. The shared backbone first produces a coarse screen estimate and then uses that estimate to refine the same wall observation.

3.2 Content-Anchored Spectral Representation

Diffuse propagation and wall reflection distribute screen cues across the wall, where local aggregation can mix them with wall texture and illumination. CASR reassociates these responses under a sample-dependent global reference and supplies spectral, smooth-layout, and residual-detail evidence aligned to the receiving feature grids of the shared restoration backbone.

A frozen CLIP visual encoder (Radford et al., 2021) computes a global feature from the complete preconditioned wall image. A trainable wall branch combines spatial features with scale-specific projections of this global feature to produce a_i; near-zero residual projections keep the initial conditioning small. Here, x denotes a wall-conditioned backbone feature and x_2 the second branch of an intermediate learned split at the current scale. The joint computation combines query/key interaction with the value projection in the spectral output and incorporates the fused condition $c_i^{(t)}$ into the gate:

$$
\begin{aligned}
(o, \varphi) &= \Big(\Phi_o(\mathcal{N}(R) \otimes v),\ \tanh\mathcal{N}\Big[\Phi_l(l) + \Phi_h(h) + \Phi_c(c_i^{(t)})\Big]\Big) \\
&= \Bigg(\Phi_o\Big(\mathcal{N}\Big(\Pi^{-1}\Big[\mathcal{F}^{-1}(\mathcal{F}(\Pi\Phi_q(x)) \otimes \mathcal{F}(\Pi\Phi_k(x)))\Big]\Big) \otimes \Phi_v(x)\Big)\,, \\
&\qquad \tanh\mathcal{N}\Big[\Phi_l(\Omega(x_2)) + \Phi_h(x_2 - \Omega(x_2)) + \Phi_c\Big(\ell_i(\widetilde{w}, q^{(t)}) + \Phi_i[\Gamma_i(\widetilde{w}) + \Psi_i(\mathcal{S}_{\tilde{\theta}}(\widetilde{w}))]\Big)\Big]\Bigg).
\end{aligned}
\tag{3}
$$

Here, $g = \mathcal{S}_{\bar{\theta}}(\widetilde{w}) \in \mathbb{R}^{B\times D}$ and $a_i = \Phi_i[\Gamma_i(\widetilde{w}) + \Psi_i(g)]$. The encoder parameters $\bar{\theta}$ are frozen; g and every a_i depend on the current wall observation. At scales $i = 0, \ldots, 4$, a_i, $\ell_i(\widetilde{w}, q^{(t)})$, and $c_i^{(t)}$ lie in $\mathbb{R}^{B\times C_i\times H_i\times W_i}$, with $\Psi_i(g)$ broadcast spatially. Real q, k, v are query/key/value projections, distinct from proposal $q^{(t)}$; R is the inverse-transformed, unpartitioned product of the query/key patch spectra. The maps Γ, Ψ, Φ are learned; Π partitions patches, $\mathcal{F}$ is the discrete Fourier transform, $\mathcal{N}$ normalizes features, Ω is local averaging, and $\otimes$ is elementwise multiplication. Smooth/residual fields l, h from x_2 supply gate correction φ. Condition inputs are aligned to the receiving feature grid. Appendix Equation A2 gives the gating application and deepest spectral modulation.

Equation 3 contains the patch operator and layout–detail gate examined by Table 3; Appendix Table A2 evaluates the complete representation under low light. Its trainable projections, spectral operators, gates, and modulation factors receive reconstruction gradients, while the visual encoder parameters remain frozen. At inference, the sample-dependent anchors and local wall/proposal features jointly supply the condition for evidence organization and allocation.

3.3 Restoration-as-Allocation Learning

The spatially heterogeneous evidence organized by CASR calls for local and context-augmented restoration capabilities. RAL uses capability-specific restoration utility to supervise allocation, comparing complete two-pass reconstructions under forced capability choices. Its router combines the fused condition $c_i^{(t)}$, current spatial features, normalized low/high energy, and local complexity, then applies a soft capability mixture as a residual update:

$$
\begin{aligned}
x' &= x + \sum_{j=0}^{1} \pi_j \otimes \nu_j = x + \sum_{j=0}^{1} [\mathrm{Softmax}(r)]_j \otimes \left(\Phi_j(x) + \mathbf{1}_{\{j=1\}}\delta_{i,b}\Psi(x)\right) \\
&= x + \sum_{j=0}^{1} \Bigg[\mathrm{Softmax}\Bigg(\Phi_r(c_i^{(t)}) + \Phi_s(x) + \Phi_f\Big(\frac{\langle|\Omega(x)|\rangle_c \,\|\, \langle|x-\Omega(x)|\rangle_c}{\mu(\langle|\Omega(x)|\rangle_c \,\|\, \langle|x-\Omega(x)|\rangle_c) + \varepsilon}\Big) \\
&\qquad + \Phi_a(c_i^{(t)}) + \gamma\Big(\frac{\langle|x-\Omega(x)|\rangle_c}{\langle|\Omega(x)|\rangle_c + \langle|x-\Omega(x)|\rangle_c + \varepsilon} - \frac{1}{2}\Big)\chi\Bigg)\Bigg]_j \otimes \left(\Phi_j(x) + \mathbf{1}_{\{j=1\}}\delta_{i,b}\Psi(x)\right).
\end{aligned}
\tag{4}
$$

Here, $x, x', \nu_j \in \mathbb{R}^{B\times C\times H\times W}$ use current feature-grid dimensions, and $c_i^{(t)}$ is the fused wall/content/proposal condition. Smooth/residual fields $l = \Omega(x)$ and $h = x - \Omega(x)$ yield channel-mean absolute energies e_1, e_2; their normalized concatenation is f, and the centered residual-energy fraction is local complexity e_3. The bracket denotes channel mean, $\|$ channel concatenation, and μ the mean over nonbatch axes. Logits r, allocation π, and f have two channels; e_1, e_2, e_3 have one. Softmax acts over capabilities, with fixed ordering code $\chi \in \mathbb{R}^{1\times 2\times 1\times 1}$ and learned γ. Learned $\Phi_r, \Phi_s, \Phi_f, \Phi_a$ form router logits, whereas Φ_j forms capability j's correction from x. Learned Ψ augments the context capability only in the first restoration block at encoder scale E2, with $\delta_{i,b} = \mathbf{1}_{\{i=2,b=0\}}$ and block index b; the branch is reused in both passes. Appendix Equation A5 specifies these branches.

The update $x \mapsto x'$ operates inside both shared-backbone calls: $p = \mathcal{M}(\widetilde{w}, c^{(0)}; \theta)$ and $y = \mathcal{M}(\widetilde{w}, c^{(1)}; \theta)$, where $c^{(t)} = \{c_i^{(t)}\}_{i=0}^{4}$ collects the fused conditions. The shared readout $\mathcal{M}$ produces coarse and final RGB outputs p, y; sg stops gradients through the proposal used to form $c^{(1)}$.

Utility supervision records normal two-pass router logits and runs two gradient-free evaluations, forcing each capability in turn. Equation 2 pools full-image L1 errors into detached preferences: lower error receives greater weight, with preference strength set by the normalized gap. The masked KL term $\mathcal{L}_2$ supervises second-pass allocation; Appendix Equation A7 defines its active set. This separates the source of the training signal from the normal reconstruction path: the forced evaluations construct the detached target but do not receive gradients, while the router learns which capability improves recovery on the same mixed evidence. Regions where context augmentation yields a larger error reduction are therefore encouraged to use the context capability, while locally sufficient regions retain the local correction. At inference, the router uses fused wall-derived conditions and spatial/frequency evidence.

4 EXPERIMENTS AND RESULTS

4.1 EXPERIMENTAL SETUP

The dataset contains approximately 19,700 paired wall observations and ground-truth screen targets across seven screen-content categories, with each pair consisting of a 256-by-256 RGB wall image and simultaneous screen target. Browser, Figure, Game, and Software use disjoint 700/100/200 train/validation/test lists, while OS-Home, OS-Lock, and Photo contribute category-level evaluations. Comparisons, ablations, and one-factor tests follow the same core-category split. We report PSNR, SSIM, and LPIPS for pixel fidelity, structural consistency, and perceptual proximity (Huynh-Thu & Ghanbari, 2008; Wang et al., 2004; Zhang et al., 2018); higher PSNR and SSIM and lower LPIPS are better. We select model checkpoints using mean validation PSNR over Browser, Figure, Game, and Software. The comparison pool spans unified, general, degradation-specific, and enhancement-oriented restoration methods. Appendix Section A.3 describes exposure preconditioning, the shared two-pass implementation, and training-time utility probing.

4.2 COMPARISON WITH STATE-OF-THE-ART

Figure 3 places wall input, ground truth, and RECALL side by side: diffuse light supports recovery of broad colors, interface layout, and principal contours across low-light and dense screen content.

RECALL achieves the highest PSNR and SSIM in all seven categories and the lowest LPIPS in five (Table 1). On Software, its 21.63 dB exceeds Retinexformer at 14.66 dB by 6.97 dB; on Browser, its 19.52 dB exceeds Ada-Deblur at 14.12 dB by 5.40 dB. These margins accompany recovered page regions, software panels, and broad game canvases: the numerical gains and reconstructed regions jointly show RECALL recovering screen organization carried by diffuse wall light.

Method	Source	Software			Figure			Browser			Game			OS-Lock			OS-Home			Photo		
		PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines																						
PromptIR [30]	NeurIPS'23	14.22	0.5905	0.5418	17.73	0.6283	0.6240	12.50	0.4888	**0.5896**	15.41	0.5154	**0.6437**	15.06	0.5617	0.6486	**13.14**	**0.4694**	0.7381	12.04	0.3515	0.7665
UniProcessor [13]	ECCV'24	11.56	0.4844	0.6733	16.81	0.6132	0.6346	11.82	0.4138	0.6728	12.81	0.4618	0.6858	14.05	0.5116	0.6582	12.01	0.4578	0.7686	11.93	0.3515	0.8269
AST [49]	CVPR'24	9.78	0.4814	0.6589	17.70	0.5853	0.6322	11.15	0.4825	0.6694	12.43	0.4588	0.7035	13.01	0.4555	0.6868	10.85	0.4028	0.7536	9.27	0.2733	0.7858
OneRestore [16]	ECCV'24	9.99	0.4455	0.6990	12.54	0.5326	0.7013	9.31	0.3962	0.7107	10.36	0.4484	0.7441	12.38	0.4949	0.7261	11.33	0.4243	0.7828	11.24	0.3413	0.8355
General restoration backbones																						
Restormer [46]	CVPR'22	12.84	0.5815	0.5977	17.43	0.6231	**0.6017**	14.03	0.5036	0.6326	14.83	0.5211	0.6612	**16.24**	**0.5706**	**0.6447**	12.90	0.4678	0.7263	11.87	0.3484	0.7915
X-Restormer [6]	ECCV'24	13.29	0.5888	0.5804	18.14	0.6291	0.6094	13.27	0.5317	0.6367	14.90	0.5165	0.6663	14.58	0.5238	0.6754	12.23	0.4579	0.7421	12.03	**0.3537**	0.8008
NAFNet [4]	ECCV'22	12.54	0.5210	0.5995	17.02	0.6411	0.6096	12.79	0.4633	0.6049	14.08	0.4612	0.6546	14.72	0.5313	0.6602	11.24	0.3552	0.7323	10.10	0.2010	0.7841
Pixel2Pixel [26]	TPAMI'25	11.04	0.4764	0.6129	15.36	0.5657	0.6285	11.03	0.3889	0.6369	11.27	0.3896	0.6647	12.59	0.4878	0.7124	10.81	0.3332	0.7179	11.21	0.2759	**0.7453**
ConvIR [9]	TPAMI'24	11.08	0.4670	0.6366	16.55	0.6196	0.6576	12.25	0.4247	0.6763	14.09	0.4903	0.6912	8.88	0.1029	0.7746	12.17	0.4425	0.7670	11.73	0.3511	0.8107
Uformer [40]	CVPR'22	8.68	0.4448	0.6929	17.15	0.5529	0.6311	11.19	0.5022	0.6519	10.29	0.4424	0.7201	11.18	0.4476	0.7049	9.84	0.3868	0.7882	10.55	0.3136	0.7915
U-Net [33]	MICCAI'15	8.50	0.3402	0.7317	9.85	0.4507	0.7231	7.86	0.3052	0.7665	8.86	0.3644	0.7901	12.38	0.4611	0.7367	8.88	0.3254	0.7788	11.08	0.2947	0.7890
Degradation-specific restoration																						
Ada-Deblur [42]	TIP'23	13.19	0.5704	0.5906	18.33	0.6368	0.6236	**14.12**	**0.5347**	0.6263	**15.56**	**0.5403**	0.6603	15.00	0.5438	0.6616	13.05	0.4661	0.7349	12.04	0.3531	0.7802
DehazeFormer [35]	TIP'23	12.26	0.5361	0.6508	18.08	**0.6497**	0.6710	13.29	0.5217	0.6660	14.07	0.4567	0.6912	14.55	0.4946	0.6731	12.24	0.4152	0.7448	11.44	0.3097	0.7942
OKNet [10]	AAAI'24	12.27	0.5255	0.6667	16.94	0.6124	0.6475	12.96	0.4735	0.6531	14.05	0.4766	0.6881	14.48	0.5118	0.6761	12.75	0.4638	0.7864	12.28	0.3495	0.7898
DnCNN [47]	TIP'17	9.22	0.4231	0.6419	11.89	0.5067	0.6792	8.87	0.3863	0.6762	8.21	0.3348	0.7323	11.79	0.4415	0.7076	9.16	0.3612	0.7508	10.42	0.2833	0.7753
Enhancement-oriented restoration																						
Retinexformer [3]	ICCV'23	**14.66**	**0.5960**	**0.5155**	17.35	0.6354	0.6221	11.35	0.4349	0.6502	14.72	0.5053	0.6629	14.62	0.5338	0.6448	12.39	0.4576	**0.7137**	**12.32**	0.3376	0.7620
HVI-CIDNet [43]	CVPR'25	12.50	0.5186	0.6299	**18.46**	0.6231	0.6335	13.10	0.5112	0.6363	14.97	0.5108	0.6800	15.40	0.5339	0.6848	12.54	0.4639	0.7259	11.30	0.3305	0.8178
IRNeXt [8]	ICML'23	12.87	0.5318	0.6110	16.95	0.6094	0.6253	13.29	0.4654	0.6602	13.81	0.4832	0.6881	15.30	0.5362	0.6799	12.51	0.4522	0.7409	12.07	0.3402	0.8021
DEA-Net [7]	TIP'24	10.46	0.3925	0.7186	17.18	0.6250	0.6758	10.80	0.4334	0.7082	10.80	0.4455	0.7328	15.05	0.5526	0.6993	12.02	0.4414	0.7707	11.88	0.3454	0.8248
SFHformer [21]	ECCV'24	8.86	0.3885	0.7543	12.91	0.5368	0.6986	8.43	0.3013	0.8460	8.73	0.3484	0.7850	12.31	0.4558	0.7338	9.98	0.3902	0.8276	11.48	0.3267	0.8348
DeepSN-Net [11]	TPAMI'25	8.97	0.3653	0.7307	13.44	0.4436	0.6961	7.71	0.2676	0.7453	9.27	0.3370	0.7437	12.20	0.3919	0.7498	8.75	0.2970	0.8076	11.25	0.2789	0.8463
DarkIR [15]	CVPR'25	4.84	0.0489	0.8540	4.34	0.0394	0.8928	5.73	0.0505	0.8620	4.71	0.0396	0.8908	8.89	0.0922	0.7928	6.67	0.0642	0.8541	6.46	0.0497	0.8657
Proposed method																						
Recall(Ours)	-	**21.63**	**0.7395**	**0.4073**	**19.94**	**0.6615**	**0.6005**	**19.52**	**0.6798**	**0.4616**	**19.18**	**0.6029**	**0.5895**	**17.45**	**0.5768**	**0.5909**	**14.56**	**0.4727**	0.7318	**13.71**	**0.3708**	0.7848

Table 1: Hidden-screen reconstruction across seven screen-content categories, grouped by restoration family. Higher PSNR (dB) and SSIM and lower LPIPS are better. PSNR uses two decimals; SSIM/LPIPS use four. Blue marks the best external value, including ties at displayed precision; external rows with at least three blue entries have a pale-blue background. Recall(Ours) has a pale-red row: its name and best values are red, while its two non-leading LPIPS values remain black.



Figure 3: Six-category comparison. Each category shows Input, GT, Ours, A–E (first row), then F–M (second row). A–M denote NAFNet, PromptIR, ConvIR, Ada-Deblur, Uformer, HVI-CIDNet, Retinexformer, DehazeFormer, Restormer, AST, UniProcessor, IRNeXt, and Pixel2Pixel, respectively.

4.3 Ablation Study

Variant	Reference Model	Source	Browser			Figure			Game			Software		
			PSNR↑	SSIM↑	LPIPS↓	PSNR↑	SSIM↑	LPIPS↓	PSNR↑	SSIM↑	LPIPS↓	PSNR↑	SSIM↑	LPIPS↓
Content-Anchored Spectral Representation (CASR)														
w/o CASR	-	-	**19.22**	**0.6579**	**0.4951**	**19.51**	0.6562	**0.6263**	**18.57**	**0.5817**	**0.5952**	**20.45**	**0.7354**	0.4114
Fourier → CNN	ResNet	CVPR'16	18.76	0.6413	0.5272	19.30	0.6434	0.6346	18.49	0.5651	0.6202	19.75	0.7025	0.4457
Fourier → Attention	Uformer	CVPR'22	18.76	0.6413	0.5272	19.30	0.6434	0.6346	18.49	0.5651	0.6202	19.75	0.7025	0.4457
Restoration-as-Allocation Learning (RAL)														
w/o RAL	-	-	19.21	0.6578	0.4952	19.50	**0.6563**	**0.6263**	**18.57**	**0.5817**	**0.5952**	20.44	**0.7354**	0.4115
Context → CNN	ResNet	CVPR'16	18.76	0.6413	0.5272	19.30	0.6434	0.6346	18.49	0.5651	0.6202	19.75	0.7025	0.4457
Context → Attention	Uformer	CVPR'22	18.76	0.6413	0.5272	19.30	0.6434	0.6346	18.49	0.5651	0.6202	19.75	0.7025	0.4457
Joint comparison														
w/o CASR+RAL	-	-	**19.22**	**0.6579**	**0.4951**	**19.51**	0.6562	0.6264	**18.57**	0.5816	**0.5952**	**20.45**	0.7353	**0.4113**
Added Capacity	-	-	18.76	0.6413	0.5272	19.30	0.6434	0.6345	18.49	0.5650	0.6202	19.75	0.7025	0.4457
Reference														
Recall(Ours)	-	-	**19.52**	**0.6798**	**0.4616**	**19.94**	**0.6615**	**0.6005**	**19.18**	**0.6029**	**0.5895**	**21.63**	**0.7395**	**0.4073**

Table 2: CASR/RAL removals, replacements, and capacity controls; CNN: ResNet [17]; attention: Uformer [40]. Tables 2–3: blue marks best variant values and displayed ties; rows with three or more blue entries are shaded.

Variant	Reference Model	Source	Browser			Figure			Game			Software		
			PSNR↑	SSIM↑	LPIPS↓	PSNR↑	SSIM↑	LPIPS↓	PSNR↑	SSIM↑	LPIPS↓	PSNR↑	SSIM↑	LPIPS↓
Joint-deletion reference														
w/o CASR+RAL	-	-	**19.22**	**0.6579**	**0.4951**	**19.51**	**0.6562**	**0.6264**	**18.57**	**0.5816**	**0.5952**	**20.45**	**0.7353**	**0.4113**
Content anchor														
w/o anchor	-	-	18.76	0.6413	0.5272	19.30	0.6434	0.6346	18.49	0.5651	0.6202	19.75	0.7025	0.4457
Shuffled anchor	CLIP	ICML'21	18.76	0.6413	0.5272	19.30	0.6434	0.6346	18.49	0.5651	0.6202	19.75	0.7025	0.4457
Global average	SENet	CVPR'18	18.76	0.6413	0.5272	19.30	0.6434	0.6346	18.49	0.5651	0.6202	19.75	0.7025	0.4457
Spectral														
w/o spectral	-	-	18.76	0.6413	0.5272	19.30	0.6434	0.6346	18.49	0.5651	0.6202	19.75	0.7025	0.4457
Fourier														
w/o Fourier	-	-	18.76	0.6413	0.5272	19.30	0.6434	0.6346	18.49	0.5651	0.6202	19.75	0.7025	0.4457
Fourier → CNN	ResNet	CVPR'16	18.76	0.6413	0.5272	19.30	0.6434	0.6346	18.49	0.5651	0.6202	19.75	0.7025	0.4457
Fourier → Attention	Uformer	CVPR'22	18.76	0.6413	0.5272	19.30	0.6434	0.6346	18.49	0.5651	0.6202	19.75	0.7025	0.4457
Detail gate														
w/o gate	-	-	18.76	0.6413	0.5272	19.30	0.6434	0.6346	18.49	0.5651	0.6202	19.75	0.7025	0.4457
Gate → Raw	-	-	18.76	0.6413	0.5272	19.30	0.6434	0.6346	18.49	0.5651	0.6202	19.75	0.7025	0.4457
Reference														
Recall(Ours)	-	-	**19.52**	**0.6798**	**0.4616**	**19.94**	**0.6615**	**0.6005**	**19.18**	**0.6029**	**0.5895**	**21.63**	**0.7395**	**0.4073**

Table 3: CASR ablations of content anchoring, spectral interaction, and layout–detail gating. Anchor controls use CLIP [31] and SENet [19]; highlighting follows Table 2.

Joint CASR/RAL removal reduces PSNR by 0.30, 0.43, 0.61, and 1.18 dB across Browser, Figure, Game, and Software (Table 2). The largest gain is on Software, where layout and boundaries separate dense panels. Tables 3 and A4 examine CASR and RAL components; paired refinement improves all twelve category–metric combinations (Table A6).

4.4 Spatial Region Diagnostics

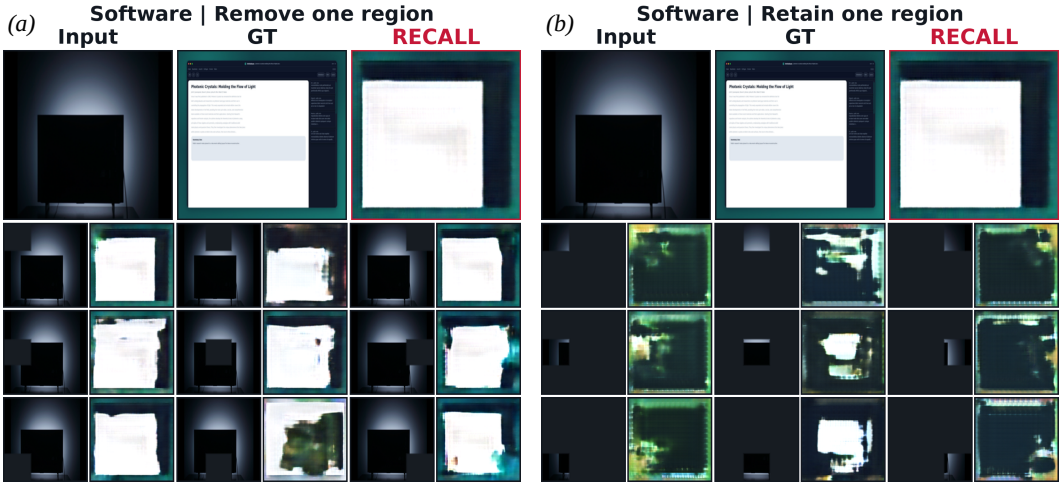


Figure 4: Nine-region intervention: (a) remove one region; (b) retain one region. Pairs follow R1–R9 in row-major order, showing modified input (left) and reconstruction (right).

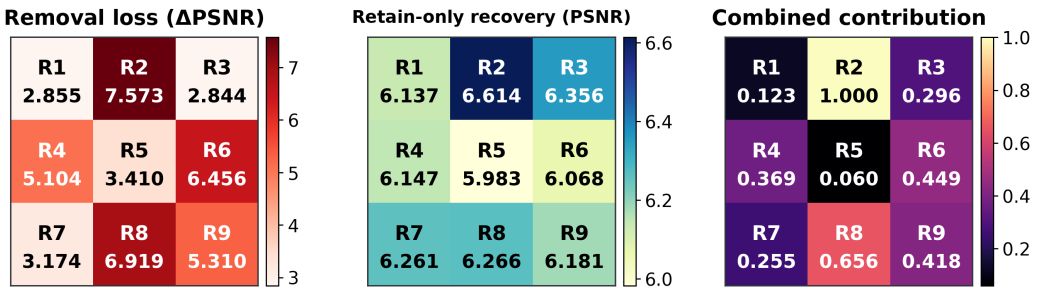


Figure 4(c) (continued): Removal loss, retain-only PSNR, and their separately min–max-normalized average (combined contribution), macro-averaged over categories. Values: Appendix Table A3.

Removing R8 (11% of the wall input) concentrates 90% of the induced change within 24% of the reconstruction (Spread90 = 2.15). This broad influence links compact wall regions to dispersed screen content. R2 and R8 yield the largest removal losses; R2 gives the highest retain-only PSNR. These contributions motivate content-anchored organization of wall evidence.

4.5 One-Factor Robustness Overview

Do the gains persist as wall observations change? RECALL leads PSNR in all six tests (Figure 5). Browser PSNR stays within 19.45–19.57 dB under shot noise; the other sweeps extend recovery across signal strength, observation scale, blur, ambient light, and wall texture.

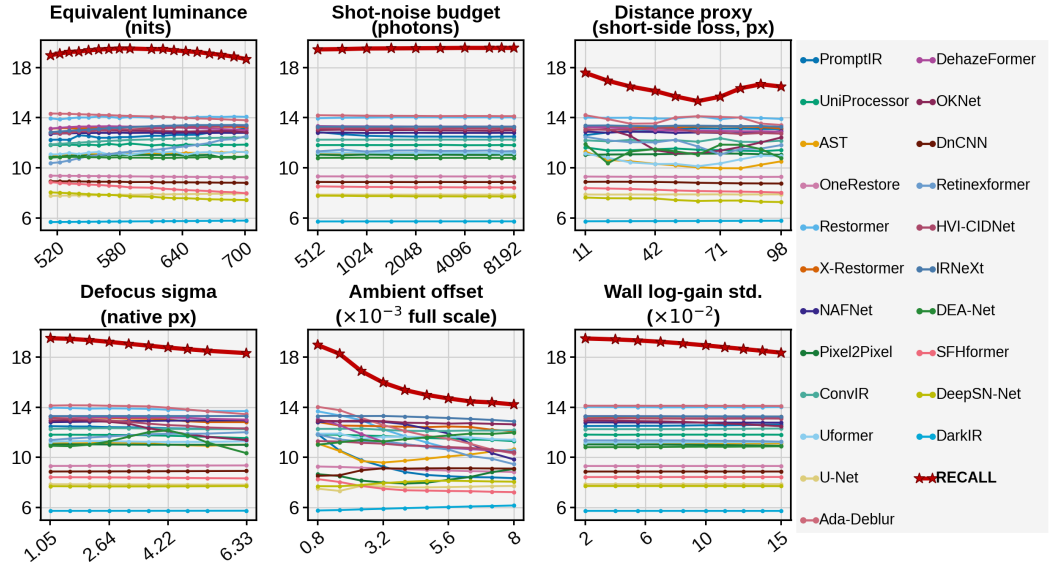


Figure 5: Hidden-screen reconstruction under one-factor variations (Browser): PSNR (dB). Luminance uses nits (600-nit reference); shot noise uses expected photon count (log axis). Short-side loss and defocus sigma use native pixels (1080-px short side). Ambient offset and wall log-gain standard deviation are dimensionless, scaled by 10^{-3} and 10^{-2}.

Full sweeps: Appendix Tables A30, A37, A28, A41, A44, and A13.

5 Conclusion

RECALL demonstrates that an ordinary camera behind a wall-facing display can recover coarse hidden-screen content from diffuse wall light alone. CASR organizes spatially mixed spectral, smooth-layout, and residual-detail responses around a wall-derived content anchor; RAL learns soft spatial allocation from the capabilities' relative reconstruction errors. Across seven content categories, RECALL achieves the highest PSNR and SSIM in every category and the lowest LPIPS in five. Its recovery of color and brightness distributions, regional layouts, and principal contours across varied capture conditions establishes that wall reflections make hidden screen organization observable from behind the display.

REFERENCES

[1] Miika Aittala, Prafull Sharma, Lukas Murmann, Adam Yedidia, Gregory Wornell, Bill Freeman, and Fredo Durand. Computational mirrors: Blind inverse light transport by deep matrix factorization. In *Advances in Neural Information Processing Systems*, volume 32, 2019. URL https://proceedings.neurips.cc/paper_files/paper/2019/hash/5a2afca61e35f45a7dd44ca46e0225f4-Abstract.html.

[2] Katherine L. Bouman, Vickie Ye, Adam B. Yedidia, Frédo Durand, Gregory W. Wornell, Antonio Torralba, and William T. Freeman. Turning corners into cameras: Principles and methods. In *Proceedings of the IEEE International Conference on Computer Vision*, pp. 2289–2297, 2017. doi: 10.1109/ICCV.2017.249.

[3] Yuanhao Cai, Hao Bian, Jing Lin, Haoqian Wang, Radu Timofte, and Yulun Zhang. Retinexformer: One-stage retinex-based transformer for low-light image enhancement. In *Proceedings of the IEEE/CVF International Conference on Computer Vision*, pp. 12470–12479, 2023. doi: 10.1109/ICCV51070.2023.01149.

[4] Liangyu Chen, Xiaojie Chu, Xiangyu Zhang, and Jian Sun. Simple baselines for image restoration. In *European Conference on Computer Vision*, Lecture Notes in Computer Science, pp. 17–33. Springer, 2022. doi: 10.1007/978-3-031-20071-7_2.

[5] Wenzheng Chen, Simon Daneau, Fahim Mannan, and Felix Heide. Steady-state non-line-of-sight imaging. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 6790–6799, 2019. URL https://openaccess.thecvf.com/content_CVPR_2019/html/Chen_Steady-State_Non-Line-Of-Sight_Imaging_CVPR_2019_paper.html.

[6] Xiangyu Chen, Zheyuan Li, Yuandong Pu, Yihao Liu, Jiantao Zhou, Yu Qiao, and Chao Dong. A comparative study of image restoration networks for general backbone network design. In *Computer Vision – ECCV 2024*, volume 15129 of *Lecture Notes in Computer Science*, pp. 74–91. Springer Nature Switzerland, 2024a. doi: 10.1007/978-3-031-73209-6_5.

[7] Zixuan Chen, Zewei He, and Zhe-Ming Lu. DEA-Net: Single image dehazing based on detail-enhanced convolution and content-guided attention. *IEEE Transactions on Image Processing*, 33:1002–1015, 2024b. doi: 10.1109/TIP.2024.3354108.

[8] Yuning Cui, Wenqi Ren, Sining Yang, Xiaochun Cao, and Alois Knoll. IRNeXt: Rethinking convolutional network design for image restoration. In *Proceedings of the 40th International Conference on Machine Learning*, volume 202 of *Proceedings of Machine Learning Research*, pp. 6545–6564. PMLR, 2023. URL https://proceedings.mlr.press/v202/cui23d.html.

[9] Yuning Cui, Wenqi Ren, Xiaochun Cao, and Alois Knoll. Revitalizing convolutional network for image restoration. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 46(12):9423–9438, 2024a. doi: 10.1109/TPAMI.2024.3419007.

[10] Yuning Cui, Wenqi Ren, and Alois Knoll. Omni-kernel network for image restoration. In *Proceedings of the AAAI Conference on Artificial Intelligence*, volume 38, pp. 1426–1434, 2024b. doi: 10.1609/aaai.v38i2.27907.

[11] Xin Deng, Chenxiao Zhang, Lai Jiang, Jingyuan Xia, and Mai Xu. DeepSN-Net: Deep semi-smooth newton driven network for blind image restoration. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 47(4):2632–2646, 2025. doi: 10.1109/TPAMI.2024.3525089.

[12] Alexey Dosovitskiy, Lucas Beyer, Alexander Kolesnikov, Dirk Weissenborn, Xiaohua Zhai, Thomas Unterthiner, Mostafa Dehghani, Matthias Minderer, Georg Heigold, Sylvain Gelly, Jakob Uszkoreit, and Neil Houlsby. An image is worth 16x16 words: Transformers for image recognition at scale. In *International Conference on Learning Representations*, 2021. URL https://dblp.org/rec/conf/iclr/DosovitskiyB0WZ21.

[13] Huiyu Duan, Xiongkuo Min, Sijing Wu, Wei Shen, and Guangtao Zhai. UniProcessor: A text-induced unified low-level image processor. In *Computer Vision – ECCV 2024*, volume 15125 of *Lecture Notes in Computer Science*, pp. 180–199. Springer Nature Switzerland, 2024. doi: 10.1007/978-3-031-72855-6_11.

[14] William Fedus, Barret Zoph, and Noam Shazeer. Switch transformers: Scaling to trillion parameter models with simple and efficient sparsity. *Journal of Machine Learning Research*, 23(120):1–39, 2022. URL https://jmlr.org/papers/v23/21-0998.html.

[15] Daniel Feijoo, Juan C. Benito, Alvaro Garcia, and Marcos V. Conde. DarkIR: Robust low-light image restoration. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 10879–10889, 2025. doi: 10.1109/CVPR52734.2025.01016.

[16] Yu Guo, Yuan Gao, Yuxu Lu, Huilin Zhu, Ryan Wen Liu, and Shengfeng He. OneRestore: A universal restoration framework for composite degradation. In *Computer Vision – ECCV 2024*, volume 15077 of *Lecture Notes in Computer Science*, pp. 255–272. Springer Nature Switzerland, 2024. doi: 10.1007/978-3-031-72655-2_15.

[17] Kaiming He, Xiangyu Zhang, Shaoqing Ren, and Jian Sun. Deep residual learning for image recognition. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 2016.

[18] Reinhard Heckel and Paul Hand. Deep decoder: Concise image representations from untrained non-convolutional networks. In *International Conference on Learning Representations*, 2019. URL https://dblp.org/rec/conf/iclr/HeckelH19.

[19] Jie Hu, Li Shen, and Gang Sun. Squeeze-and-excitation networks. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 2018.

[20] Quan Huynh-Thu and Mohammed Ghanbari. Scope of validity of psnr in image/video quality assessment. *Electronics Letters*, 44(13):800–801, 2008. doi: 10.1049/el:20080522.

[21] Xingyu Jiang, Xiuhui Zhang, Ning Gao, and Yue Deng. When fast fourier transform meets transformer for image restoration. In *Computer Vision – ECCV 2024*, Lecture Notes in Computer Science, pp. 381–402. Springer Nature Switzerland, 2024. doi: 10.1007/978-3-031-72995-9_22.

[22] Ori Katz, Pierre Heidmann, Mathias Fink, and Sylvain Gigan. Non-invasive single-shot imaging through scattering layers and around corners via speckle correlations. *Nature Photonics*, 8(10):784–790, 2014. doi: 10.1038/nphoton.2014.189.

[23] Lingshun Kong, Jiangxin Dong, Jianjun Ge, Mingqiang Li, and Jinshan Pan. Efficient frequency domain-based transformers for high-quality image deblurring. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, pp. 5886–5895, 2023.

[24] David B. Lindell, Gordon Wetzstein, and Vladlen Koltun. Acoustic non-line-of-sight imaging. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 6773–6782, 2019a. doi: 10.1109/CVPR.2019.00694.

[25] David B. Lindell, Gordon Wetzstein, and Matthew O'Toole. Wave-based non-line-of-sight imaging using fast f-k migration. *ACM Transactions on Graphics*, 38(4):1–13, 2019b. doi: 10.1145/3306346.3322937.

[26] Qing Ma, Junjun Jiang, Xiong Zhou, Pengwei Liang, Xianming Liu, and Jiayi Ma. Pixel2Pixel: A pixelwise approach for zero-shot single image denoising. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 47(6):4614–4629, 2025. doi: 10.1109/TPAMI.2025.3546870.

[27] Christopher A. Metzler, Felix Heide, Prasana Rangarajan, Muralidhar Madabhushi Balaji, Aparna Viswanath, Ashok Veeraraghavan, and Richard G. Baraniuk. Deep-inverse correlography: Towards real-time high-resolution non-line-of-sight imaging. *Optica*, 7(1):63–71, 2020. doi: 10.1364/OPTICA.374026.

[28] Matthew O'Toole, David B. Lindell, and Gordon Wetzstein. Confocal non-line-of-sight imaging based on the light-cone transform. *Nature*, 555(7696):338–341, 2018. doi: 10.1038/nature25489.

[29] Jinshan Pan, Jiangxin Dong, Yang Liu, Jiawei Zhang, Jimmy Ren, Jinhui Tang, Yu-Wing Tai, and Ming-Hsuan Yang. Physics-based generative adversarial models for image restoration and beyond. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 43(7):2449–2462, 2021. doi: 10.1109/TPAMI.2020.2969348.

[30] Vaishnav Potlapalli, Syed Waqas Zamir, Salman Khan, and Fahad Shahbaz Khan. Promptir: Prompting for all-in-one image restoration. In *Advances in Neural Information Processing Systems*, volume 36, pp. 71275–71293, 2023. doi: 10.52202/075280-3121.

[31] Alec Radford, Jong Wook Kim, Chris Hallacy, Aditya Ramesh, Gabriel Goh, Sandhini Agarwal, Girish Sastry, Amanda Askell, Pamela Mishkin, Jack Clark, Gretchen Krueger, and Ilya Sutskever. Learning transferable visual models from natural language supervision. In *Proceedings of the 38th International Conference on Machine Learning*, 2021.

[32] Carlos Riquelme, Joan Puigcerver, Basil Mustafa, Maxim Neumann, Rodolphe Jenatton, Andre Susano Pinto, Daniel Keysers, and Neil Houlsby. Scaling vision with sparse mixture of experts. In *Advances in Neural Information Processing Systems*, volume 34, pp. 8583–8595, 2021. URL https://arxiv.org/abs/2106.05974.

[33] Olaf Ronneberger, Philipp Fischer, and Thomas Brox. U-Net: Convolutional networks for biomedical image segmentation. In *Medical Image Computing and Computer-Assisted Intervention – MICCAI 2015*, volume 9351 of *Lecture Notes in Computer Science*, pp. 234–241. Springer, 2015. doi: 10.1007/978-3-319-24574-4_28.

[34] Charles Saunders, John Murray-Bruce, and Vivek K. Goyal. Computational periscopy with an ordinary digital camera. *Nature*, 565(7740):472–475, 2019. doi: 10.1038/s41586-018-0868-6.

[35] Yuda Song, Zhuqing He, Hui Qian, and Xin Du. Vision transformers for single image dehazing. *IEEE Transactions on Image Processing*, 32:1927–1941, 2023. doi: 10.1109/TIP.2023.3256763.

[36] Dmitry Ulyanov, Andrea Vedaldi, and Victor Lempitsky. Deep image prior. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 9446–9454, 2018. doi: 10.1109/CVPR.2018.00984.

[37] Andreas Velten, Thomas Willwacher, Otkrist Gupta, Ashok Veeraraghavan, Moungi G. Bawendi, and Ramesh Raskar. Recovering three-dimensional shape around a corner using ultrafast time-of-flight imaging. *Nature Communications*, 3(1):745, 2012. doi: 10.1038/ncomms1747.

[38] Feng Wang, Alberto Eljarrat, Johannes Müller, Trond R. Henninen, Rolf Erni, and Christoph T. Koch. Multi-resolution convolutional neural networks for inverse problems. *Scientific Reports*, 10:5730, 2020. doi: 10.1038/s41598-020-62484-z.

[39] Xintao Wang, Ke Yu, Chao Dong, and Chen Change Loy. Recovering realistic texture in image super-resolution by deep spatial feature transform. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 606–615, 2018. doi: 10.1109/CVPR.2018.00070.

[40] Zhendong Wang, Xiaodong Cun, Jianmin Bao, Wengang Zhou, Jianzhuang Liu, and Houqiang Li. Uformer: A general u-shaped transformer for image restoration. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 17662–17672, 2022. doi: 10.1109/CVPR52688.2022.01716.

[41] Zhou Wang, Alan C. Bovik, Hamid R. Sheikh, and Eero P. Simoncelli. Image quality assessment: From error visibility to structural similarity. *IEEE Transactions on Image Processing*, 13(4):600–612, 2004. doi: 10.1109/TIP.2003.819861.

[42] Qiucheng Wu, Yifan Jiang, Junru Wu, Victor Kulikov, Vidit Goel, Nikita Orlov, Humphrey Shi, Zhangyang Wang, and Shiyu Chang. Broad spectrum image deblurring via an adaptive super-network. *IEEE Transactions on Image Processing*, 32:5270–5282, 2023. doi: 10.1109/TIP.2023.3312912.

[43] Qingsen Yan, Yixu Feng, Cheng Zhang, Guansong Pang, Kangbiao Shi, Peng Wu, Wei Dong, Jinqiu Sun, and Yanning Zhang. HVI: A new color space for low-light image enhancement. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 5678–5687, 2025. doi: 10.1109/CVPR52734.2025.00533.

[44] Ke Yu, Xintao Wang, Chao Dong, Xiaoou Tang, and Chen Change Loy. Path-restore: Learning network path selection for image restoration. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 44(10):7078–7092, 2022. doi: 10.1109/TPAMI.2021.3096255.

[45] Eduard Zamfir, Zongwei Wu, Nancy Mehta, Yuedong Tan, Danda Pani Paudel, Yulun Zhang, and Radu Timofte. Complexity experts are task-discriminative learners for any image restoration. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, pp. 12753–12763, 2025.

[46] Syed Waqas Zamir, Aditya Arora, Salman Khan, Munawar Hayat, Fahad Shahbaz Khan, and Ming-Hsuan Yang. Restormer: Efficient transformer for high-resolution image restoration. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 5718–5729, 2022. doi: 10.1109/CVPR52688.2022.00564.

[47] Kai Zhang, Wangmeng Zuo, Yunjin Chen, Deyu Meng, and Lei Zhang. Beyond a gaussian denoiser: Residual learning of deep cnn for image denoising. *IEEE Transactions on Image Processing*, 26(7): 3142–3155, 2017. doi: 10.1109/TIP.2017.2662206.

[48] Richard Zhang, Phillip Isola, Alexei A. Efros, Eli Shechtman, and Oliver Wang. The unreasonable effectiveness of deep features as a perceptual metric. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 586–595, 2018. doi: 10.1109/CVPR.2018.00068.

[49] Shihao Zhou, Duosheng Chen, Jinshan Pan, Jinglei Shi, and Jufeng Yang. Adapt or perish: Adaptive sparse transformer with attentive feature refinement for image restoration. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 2952–2963, 2024. doi: 10.1109/CVPR52733.2024.00285.

Supplementary Material

From Wall Light to Hidden Screen Recovery: RECALL Scenarios, Mechanisms, and Supplementary Evidence

This supplement expands the evidence chain of the main paper. It follows the observed wall light through content-anchored spectral representation and restoration-as-allocation learning to the recovered screen. The results show how RECALL recovers coarse color and brightness distributions, regional layouts, and principal contours from wall-light observations across the reported screen-content categories.

Roadmap

Section A describes the task, data, evaluation scope, and implementation. Section B connects diffuse wall-light transport and the single-bounce observation model to CASR and then RAL. Section C presents quantitative comparisons before their corresponding visual evidence, following CASR representation and spatial diagnostics with RAL allocation and the joint ablation. Section D examines how changes in the wall observation affect hidden-screen reconstruction, with Browser, Figure, Game, and Software results together where available. Section E synthesizes the findings across categories and conditions.

A Task, Data, and Evaluation Setting

A.1 Real Capture Scenario

The reference acquisition setup places a computer display facing a diffuse wall, with the camera positioned behind the display. The reference setup uses a 60-inch self-emissive LED screen, an approximately 0.5 m display–wall separation, and a Sony A7S II camera observing the wall. The geometry illustrated in main-text Figure 1(c) uses display–wall and camera–wall distances of 0.5 m and 3.5 m, respectively. Each wall-light capture is paired with the simultaneously displayed screen content. The seven recorded content categories are OS-Home, OS-Lock, Browser, Figure, Game, Software, and Photo.



Figure A1: Photographs from the real computer-screen acquisition scene. From left to right, the first row shows the display and camera arrangement, a frontal wall-light observation with the display back in view, and a colored wall-light capture. The second row provides additional views of the capture setup and people operating the equipment.

Hidden-screen reconstruction asks how much screen structure remains readable when the camera observes the wall light alone. After preprocessing, the RGB wall observation and its paired screen target are each 256×256 pixels, and inference uses the wall observation and trained model parameters. The same input-output setting anchors every appendix experiment. The evaluation spans seven content categories: everyday computer desktops, lock screens and wallpapers, webpages, charts, video games, complex software interfaces, and real photographs. The chassis occludes the central return path, while diffuse reflection, lens blur, and sensor integration leave low-luminance, low-contrast mixtures around it; these mixtures retain recoverable evidence of content-related color and brightness, layout, and principal structure. This setting places one consistent target across all seven categories and every recorded one-factor variation: recover coarse color and brightness distributions, regional layout, and principal contours from the wall observation.

A.2 Data and Evaluation Scope

The dataset contains approximately 19,700 paired wall observations and ground-truth screen targets across seven recorded categories. Browser, Figure, Game, and Software use disjoint 700/100/200 train/validation/test lists, while OS-Home, OS-Lock, and Photo contribute category-level evaluations. Comparisons, ablations, and one-factor sweeps follow the same core-category split. We report PSNR, SSIM, and LPIPS for pixel fidelity, structural consistency, and perceptual proximity; higher PSNR and SSIM and lower LPIPS are better. We select model checkpoints using mean validation PSNR over Browser, Figure, Game, and Software. The comparison pool spans unified, general, degradation-specific, and enhancement-oriented restoration methods.

A.3 Implementation and Evaluation Details

We apply deterministic exposure preconditioning before restoration. RGB inputs are clipped to the unit interval and converted from standard RGB to linear light. Luminance is computed with channel weights 0.2126, 0.7152, and 0.0722 and is adaptively pooled to 64 by 64 when either input dimension exceeds 64. A 99th-percentile luminance statistic controls exposure compensation: the raw gain is 0.012 divided by that statistic and clipped from 1 to 4, then blended toward unity by the clipped ratio of 0.003 minus the statistic to 0.002. Compensation is converted back to standard RGB and applied only when the resulting gain exceeds 1.0001.

The same four-level encoder-decoder is reused for two restoration passes. The first pass reads the preconditioned wall image and produces a coarse reconstruction; the second reads that same observation again and uses the detached coarse image as an auxiliary cue. A frozen visual encoder supplies a global wall-derived reference to five scales. Encoder features use 8 by 8 patches for spectral relations and separate the local mean and residual over a 5 by 5 neighborhood. In the first restoration block at encoder scale E2, the context capability additionally uses a broader context branch. During training, utility supervision samples positions with ratio $\rho = 0.15$ at this scale and compares full RGB reconstructions produced by forcing the two capabilities independently. These gradient-free probes supply detached preferences for the masked KL loss $\mathcal{L}_2$, which supervises the normal second-pass allocation alongside image-reconstruction supervision. RECALL takes the sampled wall image as its inference input; screen targets supervise restoration utility during training.

The production utility-guided refinement jointly updates the restoration model and allocator from the pre-refinement model, using

$$\begin{aligned}\mathcal{L}_{\text{train}} = \mathcal{L}_{\text{L1}} + 0.05\mathcal{L}_{\text{edge}} + 0.02\mathcal{L}_{\text{lap}} + 0.25\mathcal{L}_{\text{distill,ns}} + 0.03\mathcal{L}_{\text{distill,global}} \\ + 0.04\mathcal{L}_{\text{char}} + 0.10\mathcal{L}_{\text{proposal}} + 0.10\mathcal{L}_{2}.\end{aligned}$$

The reconstruction, edge, Laplacian, and character terms supervise the final RGB output against the screen target; proposal L1 supervises the first-pass reconstruction. A fixed frequency-modulated NAFNet teacher supplies detached RGB predictions for non-structure and global distillation of the final output. Character consistency weights orientation, magnitude, and contrast by 0.35, 0.35, and 0.30. Utility supervision uses $\rho = 0.15$, $\tau = 1.0$, and $\kappa = 0.01$ in Equation A7; load-balance and router-auxiliary terms have zero weight. This separate refinement experiment uses 300 training pairs per category; its validation results are reported on 400 pairs, whereas the learning-variant comparison in Figure A12 uses 700 training pairs per category.

B From Wall-Light Transport to RECALL

B.1 Light Propagation and Content Mixing

Diffuse propagation turns screen content into a distributed wall evidence field, creating the two restoration responsibilities addressed by CASR and RAL.

One screen location can affect multiple wall locations, and one wall location can superpose contributions from multiple screen regions under the single-bounce diffuse-wall approximation used for interpretation.

Rapid variations such as characters, axes, window boundaries, and natural textures attenuate more strongly than broad luminance and color regions under the stated observation model.

Local wall neighborhoods consequently carry dispersed correspondences with the original screen. CASR reorganizes those responses around a wall-derived content anchor, and RAL specializes local and contextual restoration capabilities according to training-time restoration utility. The single-bounce approximation captures the dominant mixing mechanism that connects this method design to the measured wall evidence.

B.2 Single-Bounce Diffuse-Wall Observation Model

The task-level observation operator makes the central reconstruction tension explicit: useful screen evidence survives, while its spatial provenance is mixed and attenuated. The relation integrates screen radiance over screen position, wall position, and wavelength under a single-bounce approximation, then adds sensor noise.

$$
\begin{aligned}
w_c(\boldsymbol{z}) &= \iiint_{\Lambda\times\mathcal{A}_w\times\mathcal{A}_s} \underbrace{\eta_c(\lambda)\mathcal{V}_c(\boldsymbol{u})\frac{\rho_w(\boldsymbol{u},\lambda)}{\pi}G(\boldsymbol{x},\boldsymbol{u})\mathsf{V}(\boldsymbol{x},\boldsymbol{u})h(\boldsymbol{z}-\Pi_{\mathrm{cam}}(\boldsymbol{u}))}_{\mathcal{K}_c(\boldsymbol{z},\boldsymbol{u},\boldsymbol{x},\lambda)} L(\boldsymbol{x},\lambda)\,\mathrm{d}\boldsymbol{x}\,\mathrm{d}\boldsymbol{u}\,\mathrm{d}\lambda + \varepsilon_c(\boldsymbol{z}) \\
&=: [\mathfrak{T}L]_c(\boldsymbol{z}) + \varepsilon_c(\boldsymbol{z}), \\
\frac{\delta w_c(\boldsymbol{z})}{\delta L(\boldsymbol{x},\lambda)} &= \int_{\mathcal{A}_w} \mathcal{K}_c(\boldsymbol{z},\boldsymbol{u},\boldsymbol{x},\lambda)\,\mathrm{d}\boldsymbol{u} \neq 0 \quad \text{on non-singleton support,} \\
\mathfrak{T} &\in \mathfrak{S}_\infty, \qquad s_n(\mathfrak{T}) \downarrow 0, \qquad \|\mathfrak{T}^\dagger\| = \infty.
\end{aligned}
\tag{A1}
$$

$\boldsymbol{x} \in \mathcal{A}_s$ is a screen location, $\boldsymbol{u} \in \mathcal{A}_w$ is a wall location, $\boldsymbol{z}$ is a camera pixel, $\lambda \in \Lambda$ is wavelength, and $c \in \{1,2,3\}$ indexes RGB channels. The screen radiance is $L : \mathcal{A}_s \times \Lambda \to \mathbb{R}$; η_c is spectral response, $\mathcal{V}_c$ camera visibility, ρ_w wall reflectance, G geometric attenuation, V occlusion, and h, Π_{cam} blur and projection. The residual ε_c collects sensor effects. After sampling and batching, $\boldsymbol{w}$ and $\boldsymbol{s}$ are the observed wall and hidden-screen tensors in $\mathbb{R}^{B\times 3\times H\times W}$. On bounded domains with a square-integrable, non-finite-rank kernel, $\mathfrak{T}$ is compact with decaying singular values and an unbounded generalized inverse, formalizing inversion instability under diffuse transport. Inference takes the sampled wall tensor $\boldsymbol{w}$ as its observation.

The two spatial integrals express many-to-many transport: adjacent wall samples combine signals originating from dispersed screen locations. The sampled RGB wall tensor supplies the restoration network, L defines the hidden source, and the single-bounce relay abstraction connects the measured wall evidence to the reconstruction operators.

The 41 one-factor sweeps turn this transport analysis into controlled evidence by changing one recorded component of strength, position, or frequency composition while holding the other conditions fixed. Their tables and trajectories test the complete reconstruction under these changes, while the representation and allocation ablations examine the contributions of CASR and RAL.

B.3 Content-Anchored Spectral Representation

CASR converts the mixed wall field into content-anchored spectral evidence by supplying a shared reference to five observation scales. A deterministic exposure transform first preconditions the

complete wall observation. The result is normalized and resized inside a frozen visual encoder, projected into a global reference, and injected through learned scale-specific projections.

$$
\begin{aligned}
&\widetilde{\boldsymbol{w}} = \mathcal{P}(\boldsymbol{w}), \quad \boldsymbol{g} = \mathcal{S}_{\bar{\theta}}(\widetilde{\boldsymbol{w}}), \quad \bar{\theta} \text{ fixed during training}, \quad \boldsymbol{x}_i = \Gamma_i(\widetilde{\boldsymbol{w}}), \quad \boldsymbol{a}_i = \Phi_i(\boldsymbol{x}_i + \Psi_i(\boldsymbol{g}))\,, \\
&q^{(0)} = 0, \quad q^{(1)} = \mathrm{sg}(p), \quad c_i^{(t)} = \ell_i(\widetilde{\boldsymbol{w}}, q^{(t)}) + \boldsymbol{a}_i, \quad t \in \{0,1\}, \\
&q = \Phi_q(x), \quad k = \Phi_k(x), \quad v = \Phi_v(x), \quad Q = \mathcal{F}(\Pi q), \quad K = \mathcal{F}(\Pi k), \\
&R = \Pi^{-1}\left[\mathcal{F}^{-1}(Q \otimes K)\right], \quad o = \Phi_o(\mathcal{N}(R) \otimes v), \\
&l = \Omega(x_2), \quad h = x_2 - l, \quad \varphi = \tanh\mathcal{N}\Big(\Phi_l(l) + \Phi_h(h) + \Phi_c(c_i^{(t)})\Big)\,, \\
&\widehat{x} = x_1 \otimes \sigma(x_2 + b_i + \alpha\varphi), \quad X = \mathcal{F}(\widehat{x}), \quad z = \mathcal{F}^{-1}\big(|X| \otimes \omega \otimes e^{\mathrm{i}\angle X}\big)\,.
\end{aligned}
\tag{A2}
$$

The observed and preconditioned wall tensors satisfy $\boldsymbol{w}, \widetilde{\boldsymbol{w}} \in \mathbb{R}^{B\times 3\times H\times W}$, and the global anchor satisfies $\boldsymbol{g} \in \mathbb{R}^{B\times D}$ with fixed encoder parameters $\bar{\theta}$. At scale i, $\boldsymbol{x}_i, \boldsymbol{a}_i, c_i^{(t)} \in \mathbb{R}^{B\times C_i\times H_i\times W_i}$. The fused condition $c_i^{(t)}$ combines local wall/proposal features from ℓ_i with the shared content anchor; p is the first-pass reconstruction and sg stops its proposal gradient. The exposure operator $\mathcal{P}$ is fixed, while $\mathcal{S}_{\bar{\theta}}$ is frozen; Γ_i, Ψ_i, Φ_i and the spectral/gating maps are learned. The feature operators use $x \in \mathbb{R}^{B\times C\times H\times W}$, Π partitions nonoverlapping patches, Q, K are complex spectra, and $\mathcal{N}$ is feature normalization. The smooth field l and residual h provide complementary layout and detail evidence; the learned feature split produces x_1, x_2, with x_2 supplying this evidence and the resulting gate modulating x_1. RAL applies its capability mixture as a residual feature update. The bias b_i is the wall-derived bias from the corresponding learned content projection, α scales the anchored correction, and ω denotes the learned spectral weighting term. All quantities are wall-derived at inference.

The operator creates a single evidence chain across scale and frequency. The shared preconditioner stabilizes the observation for both restoration passes; the frozen encoder forms the global reference; learned projections inject that reference at five scales; and patchwise Fourier relationships connect responses within the anchored feature field. The smooth-layout and residual-detail paths then preserve complementary evidence for regional organization and principal contours.

At inference, CASR produces all five content-anchored feature maps directly from the wall observation and supplies them to restoration capability allocation. The main CASR ablation isolates each part of this representation, the low-light comparison tests its behavior as evidence attenuates, and Appendix Tables A7–A47 with their paired curves evaluate the complete system as evidence strength, frequency composition, and position change.

B.4 Restoration-as-Allocation Learning

RAL turns the organized evidence into a restoration decision by learning which capability produces the stronger reconstruction at each position. Both capabilities process the same evidence during utility probing, while the allocator predicts their mixture from wall-derived features and receives ground-truth-supervised utility during training.

The reconstruction gradient reaches the allocator through the downstream restoration network. At a batch-feature location ι, the following derivative measures how a capability correction changes the final reconstruction loss through the residual feature mixture.

$$
\begin{aligned}
\boldsymbol{\nu}_{\mathrm{mix}}(\iota) = \sum_{j=0}^{1} \pi_j(\iota)\boldsymbol{\nu}_j(\iota), \qquad x'(\iota) = x(\iota) + \boldsymbol{\nu}_{\mathrm{mix}}(\iota), \\
\boldsymbol{y} = \mathcal{D}_{\mathrm{out}}(x'), \qquad \mathcal{L}_{\mathrm{rec}} = \int_{\mathcal{D}} \ell(\boldsymbol{y}(\boldsymbol{u}), \boldsymbol{s}(\boldsymbol{u}))\ \mathrm{d}\boldsymbol{u}, \\
\frac{\partial \mathcal{L}_{\mathrm{rec}}}{\partial r_j(\iota)} = \pi_j(\iota)\left\langle \nabla_{x'(\iota)}\mathcal{L}_{\mathrm{rec}}, \boldsymbol{\nu}_j(\iota) - \boldsymbol{\nu}_{\mathrm{mix}}(\iota)\right\rangle.
\end{aligned}
\tag{A3}
$$

Here, $x, x', \boldsymbol{\nu}_j$ are feature tensors, $\boldsymbol{\nu}_{\mathrm{mix}}$ is their mixed correction, r_j is the router logit, and $\pi_j(\iota) = \pi_\theta(j \mid \iota)$ is its softmax weight. The downstream restoration map $\mathcal{D}_{\mathrm{out}}$ produces the RGB prediction

$\boldsymbol{y}$. This local derivative holds the input and capability corrections fixed; $\nabla_{x'(\iota)}\mathcal{L}_{\mathrm{rec}}$ carries the downstream reconstruction gradient. Gradients to shared upstream parameters also include their effects on x and $\boldsymbol{\nu}_j$. RAL complements this mixture-dependent gradient with a detached utility target comparing the pooled errors of complete two-pass restorations under forced capability choices.

The router evidence is defined from the same feature field that enters the capability branches. For a feature tensor x, the local mean and residual separate smooth layout from finer variation, while their channel-averaged magnitudes provide complementary frequency evidence and a relative complexity signal:

$$\begin{aligned} &l = \Omega(x), && h = x - l, && e_1 = \langle |l| \rangle_c, \quad e_2 = \langle |h| \rangle_c, \\ &f = \frac{e_1 \parallel e_2}{\mu(e_1 \parallel e_2) + \varepsilon}, && e_3 = \frac{e_2}{e_1 + e_2 + \varepsilon} - \frac{1}{2}. \end{aligned} \tag{A4}$$

Here, $x, l, h \in \mathbb{R}^{B\times C\times H\times W}$; $e_1, e_2, e_3 \in \mathbb{R}^{B\times 1\times H\times W}$; and $f \in \mathbb{R}^{B\times 2\times H\times W}$. The operator Ω is the deterministic 5 x 5 local average shared with CASR, $\langle\cdot\rangle_c$ averages over channels, and $\parallel$ concatenates along the capability-evidence channel. The operator μ averages the concatenated energy over its nonbatch axes, and $\varepsilon = 10^{-6}$ is the numerical stabilizer. The evidence e_3 records relative local complexity.

$$\begin{aligned} r_j(\iota) &= \left[\Phi_r(c_i^{(t)}) + \Phi_s(x) + \Phi_f(f) + \Phi_a(c_i^{(t)})\right]_j(\iota) + \gamma e_3(\iota)\chi_j, \\ \pi_\theta(j \mid \iota) &= \frac{\exp r_j(\iota)}{\sum_{k=0}^{1} \exp r_k(\iota)}, \\ \boldsymbol{\nu}_0(\iota) &= \Phi_0(x)(\iota), \quad \boldsymbol{\nu}_1(\iota) = \Phi_1(x)(\iota) + \delta_{i,b}\Psi(x)(\iota), \quad x'(\iota) = x(\iota) + \sum_{j=0}^{1} \pi_\theta(j \mid \iota)\boldsymbol{\nu}_j(\iota). \end{aligned} \tag{A5}$$

The finite feature grid is $\mathcal{G}$, the batch-location set is $\mathcal{I} = \{1, \ldots, B\} \times \mathcal{G}$, and $\iota \in \mathcal{I}$ consists of one batch member and one feature location. The index $j \in \{0, 1\}$ identifies the local and context-augmented correction branches, and b indexes restoration blocks within encoder scale i. The context branch operates in the first restoration block at encoder scale E2, with $\delta_{i,b} = \mathbf{1}_{\{i=2,b=0\}}$, and is reused in both restoration passes. The fields $x, x' : \mathcal{I} \to \mathbb{R}^C$ are the shared input and residual output; f and e_3 are the normalized frequency and local-complexity evidence. The maps $\Phi_r, \Phi_s, \Phi_f, \Phi_a, \Phi_j$, and Ψ are learned transforms. The allocator satisfies $\sum_{j=0}^{1} \pi_\theta(j \mid \iota) = 1$. Every term in the mixture and router is derived from wall-image features at inference.

The first line forms capability logits from content, spatial, frequency, and complexity evidence; the second line normalizes them into a spatial allocation. The next line computes two corrections on the same feature tensor and activates the broader-context branch only in the first restoration block at encoder scale E2. The final relation combines the corrections residually and continues through the restoration network during both training and inference.

The mixture weights express spatial capability preferences learned from the training samples and restoration-utility targets.

$$\begin{aligned} \widetilde{\boldsymbol{y}}_j &= \mathrm{clip}_{[0,1]}(\mathcal{M}_j(\boldsymbol{w}; \theta)), \qquad d_j(\boldsymbol{u}) = \int_{\mathcal{D}} W(\boldsymbol{u}, \boldsymbol{v}) \frac{\|\widetilde{\boldsymbol{y}}_j(\boldsymbol{v}) - \boldsymbol{s}(\boldsymbol{v})\|_1}{3} \, \mathrm{d}\boldsymbol{v}, \\ \Delta(\boldsymbol{u}) &= \frac{d_0(\boldsymbol{u}) + d_1(\boldsymbol{u})}{2} + \varepsilon, \qquad \xi_0(\boldsymbol{u}) = \sigma\left(\frac{d_1(\boldsymbol{u}) - d_0(\boldsymbol{u})}{\tau\Delta(\boldsymbol{u})}\right), \quad \xi_1 = 1 - \xi_0. \end{aligned} \tag{A6}$$

The operator $\mathcal{M}_j$ is the complete exposure-preconditioned, two-pass model with the supervised RAL module in the first restoration block at encoder scale E2 forced to capability $j \in \{0, 1\}$. The forced output and RGB training target satisfy $\widetilde{\boldsymbol{y}}_j, \boldsymbol{s} \in [0, 1]^{B\times 3\times H\times W}$, and $W(\boldsymbol{u}, \boldsymbol{v})$ is the deterministic pooling kernel mapping full-resolution channel-mean error to router coordinate $\boldsymbol{u}$. The quantities d_j, Δ, ξ_j are training-only local errors, stabilized normalizer, and normalized utility target. The fixed $\tau > 0$ controls preference softness; gradient-free forced outputs and the target yield a detached preference that trains the allocator, which routes wall-derived evidence at inference.

During a training utility probe, the first restoration block at the third encoder scale is forced independently to each capability. The first relation evaluates the complete two-pass RGB output, the second integrates its channel-mean error through W, and the final relation converts the stabilized disparity into ξ. Inference applies the learned allocation directly to wall-derived evidence.

The training-time soft target records relative capability error under sampled examples and transfers that supervision into the deployed allocator.

$$
\begin{aligned}
m(\iota) &= \mathbf{1}[\zeta(\iota) < \rho]\, \mathbf{1}\left[\frac{|d_0(\iota) - d_1(\iota)|}{\frac{d_0(\iota)+d_1(\iota)}{2} + 10^{-6}} > \kappa \right], \\
\ell(\iota) &= \sum_{j=0}^{1} \xi_j(\iota) \log \frac{\xi_j(\iota)}{\pi_\theta(j \mid \iota)}, \\
\mathcal{L}_2 &= \begin{cases} \dfrac{\sum_{\iota \in \mathcal{I}} m(\iota)\ell(\iota)}{\sum_{\iota \in \mathcal{I}} m(\iota)}, & \sum_{\iota \in \mathcal{I}} m(\iota) > 0, \\ 0, & \sum_{\iota \in \mathcal{I}} m(\iota) = 0. \end{cases}
\end{aligned}
\tag{A7}
$$

The set $\mathcal{G}$ is the finite router grid, $\mathcal{I} = \{1, \ldots, B\} \times \mathcal{G}$ is the finite set of batch-location pairs, and ι denotes one member of that set. The uniformly sampled training-only random field satisfies $\zeta : \mathcal{I} \to [0, 1)$, and the resulting binary mask satisfies $m : \mathcal{I} \to \{0, 1\}$. The sampling ratio is $\rho = 0.15$, and the normalized error-gap threshold is $\kappa = 0.01$. The detached target and allocator prediction satisfy $\xi_j, \pi_\theta(j \mid \cdot) : \mathcal{I} \to [0, 1]$, with both distributions summing to one over j. The local divergence satisfies $\ell : \mathcal{I} \to \mathbb{R}_{\geq 0}$, and the scalar $\mathcal{L}_2 \in \mathbb{R}_{\geq 0}$ averages it over the active batch-location pairs. The divergence uses numerically stabilized probabilities before taking logarithms. Training uses the random field, mask, target utility, and loss; inference retains the trained allocator.

The first line samples third-scale batch-location pairs and retains those whose normalized capability-error gap exceeds the threshold. The second line constructs the local forward divergence, and the final piecewise relation averages it over the retained mask or returns a scalar zero when the mask is empty. Inference routes evidence directly with π_θ.

The allocation-target ablations compare this soft supervision with uniform, random, hard-winner, and absent utility targets. Appendix Tables A7–A47 and their paired curves evaluate the resulting complete model.

The sampled loss converts relative restoration performance into a capability-specific learning signal on the training examples. The soft target records which capability restores the current evidence more effectively, and the deployed allocator predicts that preference from wall-derived features.

C Mechanism Evidence and Diagnostics

We examine how content-anchored representation organizes screen evidence, how wall regions contribute jointly, and how restoration-based allocation improves reconstruction. The following comparisons, utility ablations, spatial interventions, and visual examples connect these mechanisms to coarse color and brightness distributions, regional layouts, and principal contours.

C.1 CASR Representation Comparison and Low-Light Evidence

Conventional Representation Comparison

Appendix Table A1 compares complete restoration models on Browser, Figure, Game, and Software and identifies their representation mechanisms. Its reference results follow the main comparison in Table 1.

Table A1: Comparison with conventional restoration methods on the core evaluation categories. Method identifies the compared model; Rep. describes its representation, and Source gives its publication venue. NAF denotes the Nonlinear Activation Free design used by NAFNet, MDTA denotes multi-Dconv head transposed attention, used here as the representation descriptor for Restormer, DeepSN denotes the semi-smooth Newton optimization-unfolding network used by DeepSN-Net, and CASR denotes Content-Anchored Spectral Representation. Values are rounded to two decimals for PSNR and four decimals for SSIM/LPIPS. Blue marks the best external value for each metric, including ties at the displayed precision; external rows with at least three blue entries in a panel receive a pale-blue background, while the Recall(Ours) row receives a pale-red background with red text.

Method	Source	Rep.	Browser			Figure		
			PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
NAFNet	ECCV'22	NAF	12.79	0.4633	**0.6049**	17.02	**0.6411**	0.6096
Restormer	CVPR'22	MDTA	**14.03**	**0.5036**	0.6326	**17.43**	0.6231	**0.6017**
DeepSN-Net	TPAMI'25	DeepSN	7.71	0.2676	0.7453	13.44	0.4436	0.6961
Recall(Ours)	-	**CASR**	**19.52**	**0.6798**	**0.4616**	**19.94**	**0.6615**	**0.6005**

Method	Source	Rep.	Game			Software		
			PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
NAFNet	ECCV'22	NAF	14.08	0.4612	**0.6546**	12.54	0.5210	0.5995
Restormer	CVPR'22	MDTA	**14.83**	**0.5211**	0.6612	**12.84**	**0.5815**	**0.5977**
DeepSN-Net	TPAMI'25	DeepSN	9.27	0.3370	0.7437	8.97	0.3653	0.7307
Recall(Ours)	-	**CASR**	**19.18**	**0.6029**	**0.5895**	**21.63**	**0.7395**	**0.4073**

Recall(Ours) leads the three conventional alternatives on every reported metric and category, showing a consistent complete-model advantage. The advantage spans browser layouts, game structure, dense software regions, and charts, which links the gain to the joint use of content-anchored organization and restoration-based allocation of diffuse wall evidence.

The dedicated comparisons examine the division of labor inside RECALL. CASR supplies a common whole-observation basis for relating dispersed spectral responses and preserving complementary smooth-layout and residual-detail evidence; RAL then assigns that organized evidence by restoration utility. The dedicated ablations isolate these mechanisms, while this table shows that their composition serves multiple forms of screen content through the same evidence principle.

We next compare representation choices within the restoration framework (Figure A2). The CASR examples preserve the separation of dominant screen regions and their principal boundaries, connecting representation choice to the organization of the recovered screen. Figure A3 shows the corresponding feature responses within CASR.

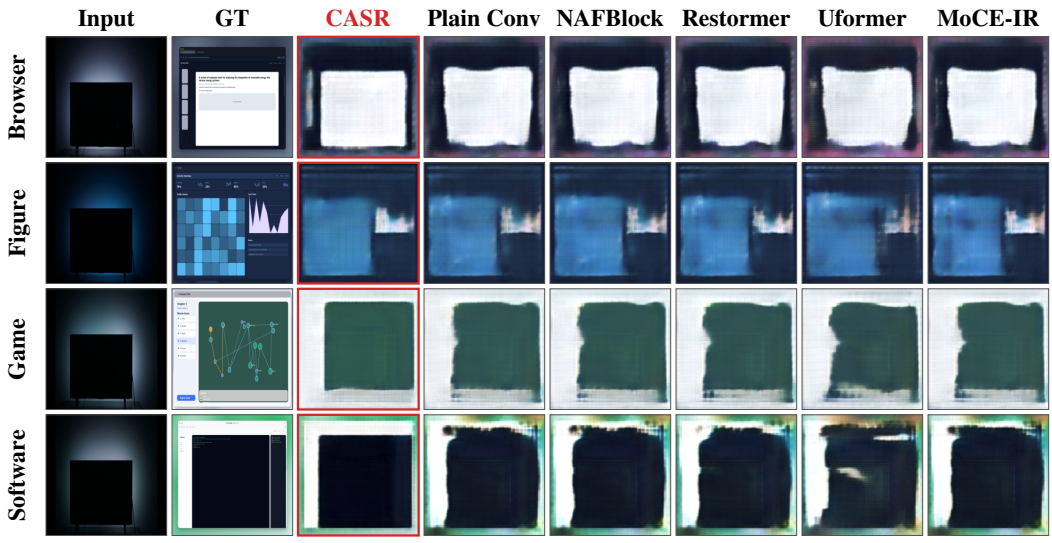


Figure A2: Qualitative comparison of representation choices on four content categories. Rows show Browser, Figure, Game, and Software; columns are Input, GT, CASR, Plain Conv, NAFBlock, Restormer, Uformer, and MoCE-IR. The red frame marks CASR. The model labels Restormer, Uformer, and MoCE-IR identify the comparison entries; their representation descriptors are MDTA, LeWin, and FFTAttention, respectively. The examples show recovery of coarse brightness regions, layout, and principal contours from diffuse wall observations.

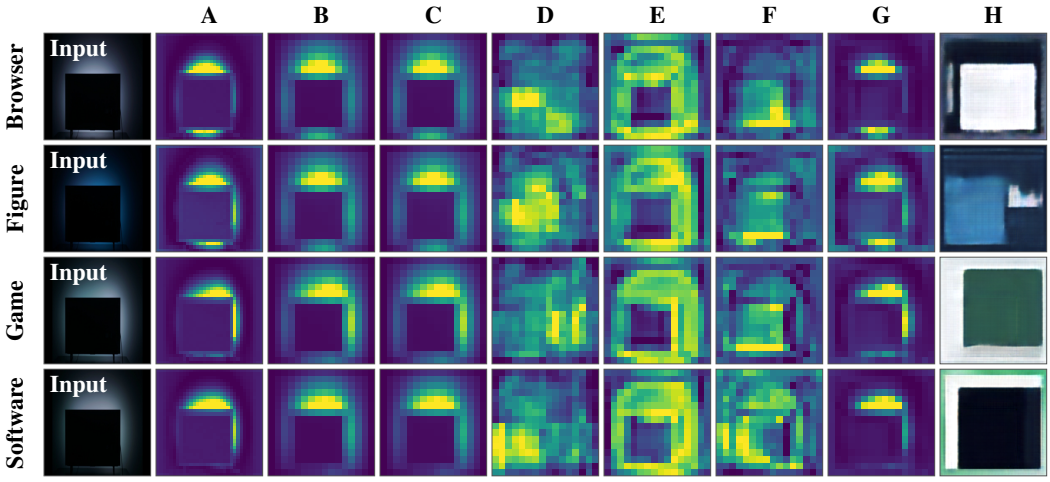


Figure A3: Feature responses within CASR. Input shows the wall reflection; A, encoded feature; B, content-conditioned feature; C, anchor gate; D, spectral response; E, low/high response; F, fused update; G, adapter output; and H, restored screen. Rows show Browser, Figure, Game, and Software. The feature panels provide qualitative views of content conditioning, spectral interaction, and layout–detail processing; H shows the RGB reconstruction.

Low-Light Representation

We compare representation choices within a shared restoration backbone and training budget (Table A2). Results aggregate per-image scores over Browser, Figure, Game, and Software; this study evaluates representation variants, while Table 1 compares complete restoration models. Exposure value (EV) indexes attenuation across eleven conditions. Restormer, Uformer, and MoCE-IR denote the MDTA, LeWin, and FFTAttention representation choices, respectively. The table reports PSNR, 32×32 layout PSNR (Low32 PSNR), and SSIM. For the layout metric, the prediction is clipped to $[0, 1]$; prediction and target are then area-downsampled to 32×32 in RGB; the score is $-10 \log_{10}(\max(\mathrm{MSE}_{32}, 10^{-10}))$ with peak value 1.

Restormer's cross-channel attention and Uformer's locally enhanced window attention Zamir et al. (2022); Wang et al. (2022) yield 11.32 and 11.97 dB, respectively, at 0.75 EV in this shared-backbone comparison. CASR achieves the highest PSNR at all ten nonzero attenuation levels and reaches 13.24 dB at 0.75 EV, exceeding Plain Conv, the strongest alternative at 12.06 dB, by 1.18 dB. The shared content reference conditions dispersed responses across scales, while the layout–detail paths carry broad regional structure and residual boundary evidence into reconstruction. The attenuation results show that this content-anchored representation continues to support screen reconstruction as the wall light weakens.

Figure A4 follows this representation advantage across the full attenuation interval. We next examine where the useful evidence lies on the wall and how contributions from different regions combine to recover the screen.

Table A2: Low-light representation comparison over the exposure-attenuation interval. Each EV condition spans PSNR, Low32 PSNR, and SSIM subcolumns; higher values are better. Values are rounded to two decimals for PSNR/Low32 PSNR and four decimals for SSIM. Blue marks the best alternative representation value, including ties at the displayed precision; rows with at least three blue entries in a panel receive a pale-blue background. Red identifies CASR.

Method	EV = 0.000			EV = 0.125			EV = 0.250			EV = 0.375		
	PSNR	Layout PSNR	SSIM	PSNR	Layout PSNR	SSIM	PSNR	Layout PSNR	SSIM	PSNR	Layout PSNR	SSIM
Plain Conv	15.69	16.91	0.5947	15.71	16.92	0.5902	15.45	16.61	0.5792	14.79	15.76	0.5623
NAFBlock	15.54	16.73	0.5833	15.46	16.62	0.5765	15.02	16.08	0.5634	14.01	14.83	0.5443
Restormer	15.84	17.11	0.5954	15.81	17.09	0.5887	15.41	16.57	0.5739	14.53	15.47	0.5520
Uformer	15.94	17.20	0.5896	15.91	17.17	0.5827	15.53	16.68	0.5676	14.70	15.65	0.5454
MoCE-IR	16.02	17.32	0.5993	15.96	17.24	0.5935	15.65	16.84	0.5823	15.03	16.07	0.5659
CASR	16.00	17.29	0.5975	15.99	17.27	0.5940	15.84	17.09	0.5861	15.50	16.65	0.5730

Method	EV = 0.500			EV = 0.625			EV = 0.750			EV = 0.875		
	PSNR	Layout PSNR	SSIM	PSNR	Layout PSNR	SSIM	PSNR	Layout PSNR	SSIM	PSNR	Layout PSNR	SSIM
Plain Conv	13.95	14.74	0.5452	13.04	13.70	0.5274	12.06	12.62	0.5101	11.21	11.71	0.4965
NAFBlock	12.98	13.64	0.5264	12.21	12.78	0.5119	11.56	12.08	0.5005	10.95	11.42	0.4876
Restormer	13.47	14.21	0.5289	12.40	13.01	0.5052	11.32	11.84	0.4830	10.47	10.94	0.4662
Uformer	13.86	14.65	0.5252	12.97	13.64	0.5075	11.97	12.54	0.4917	11.14	11.64	0.4759
MoCE-IR	14.12	14.97	0.5446	12.97	13.65	0.5194	11.63	12.18	0.4915	10.53	10.99	0.4721
CASR	14.91	15.92	0.5551	14.13	14.99	0.5347	13.24	13.95	0.5128	12.28	12.88	0.4900

Method	EV = 1.000			EV = 1.125			EV = 1.250		
	PSNR	Layout PSNR	SSIM	PSNR	Layout PSNR	SSIM	PSNR	Layout PSNR	SSIM
Plain Conv	10.60	11.05	0.4854	10.12	10.55	0.4741	9.74	10.14	0.4624
NAFBlock	10.36	10.79	0.4723	9.84	10.25	0.4572	9.41	9.79	0.4429
Restormer	9.94	10.37	0.4559	9.60	10.01	0.4500	9.35	9.75	0.4442
Uformer	10.56	11.03	0.4604	10.11	10.55	0.4475	9.73	10.14	0.4368
MoCE-IR	9.93	10.35	0.4667	9.59	9.99	0.4593	9.32	9.70	0.4498
CASR	11.32	11.83	0.4691	10.48	10.93	0.4518	9.83	10.24	0.4365

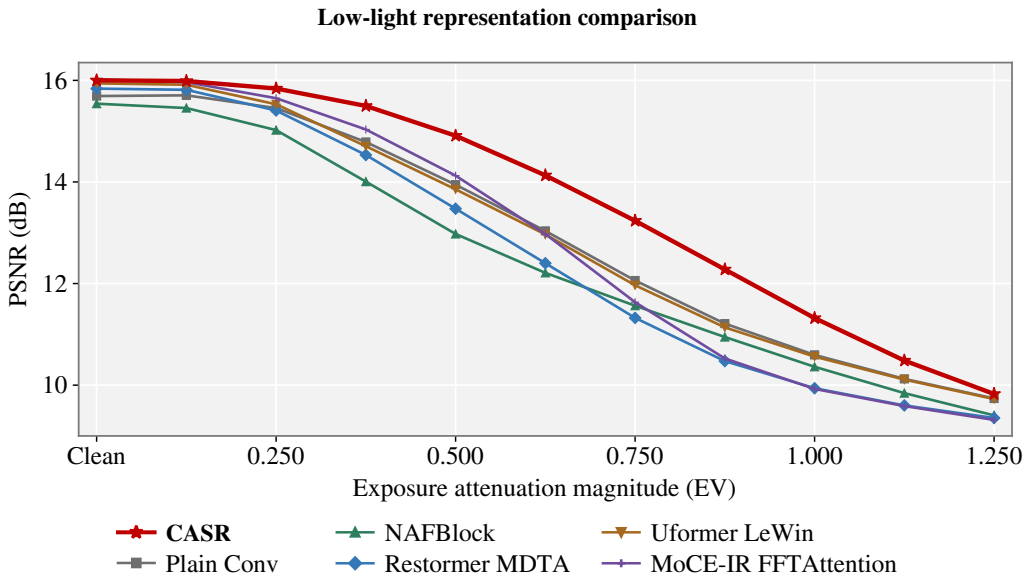


Figure A4: Low-light representation trajectories paired with Appendix Table A2, comparing PSNR among the listed representations as attenuation increases over the interval. All eleven exposure conditions are shown.

C.2 Region Contribution and Continuous Completion

Region Diagnostics

Appendix Table A3 tests the spatial premise behind content-anchored evidence: a compact wall region can participate in a much broader screen reconstruction after diffuse mixing. The fixed nine-region intervention measures both removal and retain-only responses. A90 is the output-area fraction covering the most concentrated ninety percent of the change, and Spread90 is its ratio to the intervened input-area fraction.

Table A3: Region contribution diagnostic under the fixed nine-region intervention. Removal effects are Clean minus Remove for PSNR loss (dB) and SSIM loss, and Remove minus Clean for LPIPS increase. Mask area and A90 are fractions of the input and output image areas, respectively; A90 covers the most concentrated 90% of output change, and Spread90 is A90 divided by Mask area. Differences use unrounded values. Red and blue mark the largest and second-largest removal effects and A90/Spread90 values, respectively; shaded rows identify R8 and R2.

Region	Mask area	Clean			Remove		
		PSNR ↑	SSIM ↑	LPIPS ↓	PSNR ↑	SSIM ↑	LPIPS ↓
R1	0.1102	20.04	0.6703	0.5148	17.18	0.6082	0.5526
R2	0.1102	20.04	0.6703	0.5148	12.47	0.4845	0.6646
R3	0.1115	20.04	0.6703	0.5148	17.19	0.6130	0.5612
R4	0.1102	20.04	0.6703	0.5148	14.93	0.5564	0.5880
R5	0.1102	20.04	0.6703	0.5148	16.63	0.5861	0.5647
R6	0.1115	20.04	0.6703	0.5148	13.58	0.5421	0.6092
R7	0.1115	20.04	0.6703	0.5148	16.86	0.5962	0.5866
R8	0.1115	20.04	0.6703	0.5148	13.12	0.4829	0.6705
R9	0.1129	20.04	0.6703	0.5148	14.73	0.5604	0.6108

Region	Delta			Retain-only			Spatial footprint	
	PSNR	SSIM	LPIPS	PSNR ↑	SSIM ↑	LPIPS ↓	A90	Spread90
R1	2.85	0.0622	0.0377	6.14	0.2815	0.8420	0.1400	1.2698
R2	**7.57**	0.1859	0.1498	6.61	0.2684	0.7912	0.2305	2.0911
R3	2.84	0.0573	0.0463	6.36	0.2833	0.8750	0.1318	1.1817
R4	5.10	0.1139	0.0732	6.15	0.2701	0.8390	0.1720	1.5604
R5	3.41	0.0842	0.0499	5.98	0.2708	0.7810	0.1706	1.5474
R6	6.46	0.1283	0.0943	6.07	0.2556	0.8356	0.1694	1.5186
R7	3.17	0.0741	0.0718	6.26	0.2748	0.8572	0.1581	1.4174
R8	6.92	**0.1874**	**0.1557**	6.27	0.2991	0.7874	**0.2398**	**2.1503**
R9	5.31	0.1099	0.0959	6.18	0.2610	0.8391	0.1754	1.5540

The removal results expose a distributed evidence field: removing R8, an input mask of about 11%, concentrates 90% of the induced output change within about 24% of the output area, giving a Spread90 ratio of 2.15.

Saunders et al. (2019) recover hidden scenes by interpreting spatial variations in occlusion-encoded reflections. We examine the contribution of wall evidence through paired removal and retain-only interventions. Different regions provide complementary information for the same screen reconstruction: a region with a large removal effect can be especially useful when combined with evidence elsewhere. This joint contribution gives CASR a concrete role in relating dispersed responses before RAL allocates restoration capability.

Nine-Region Visual Evidence

The nine-region evidence study makes the spatial mechanism visible alongside the quantitative diagnostic table: each paired panel places the remove intervention on the left and its retain counterpart on the right for the same case. The three cases use the same fixed 3 x 3 partition, so the visual sequence follows removal loss, isolated contribution, and combined contribution.

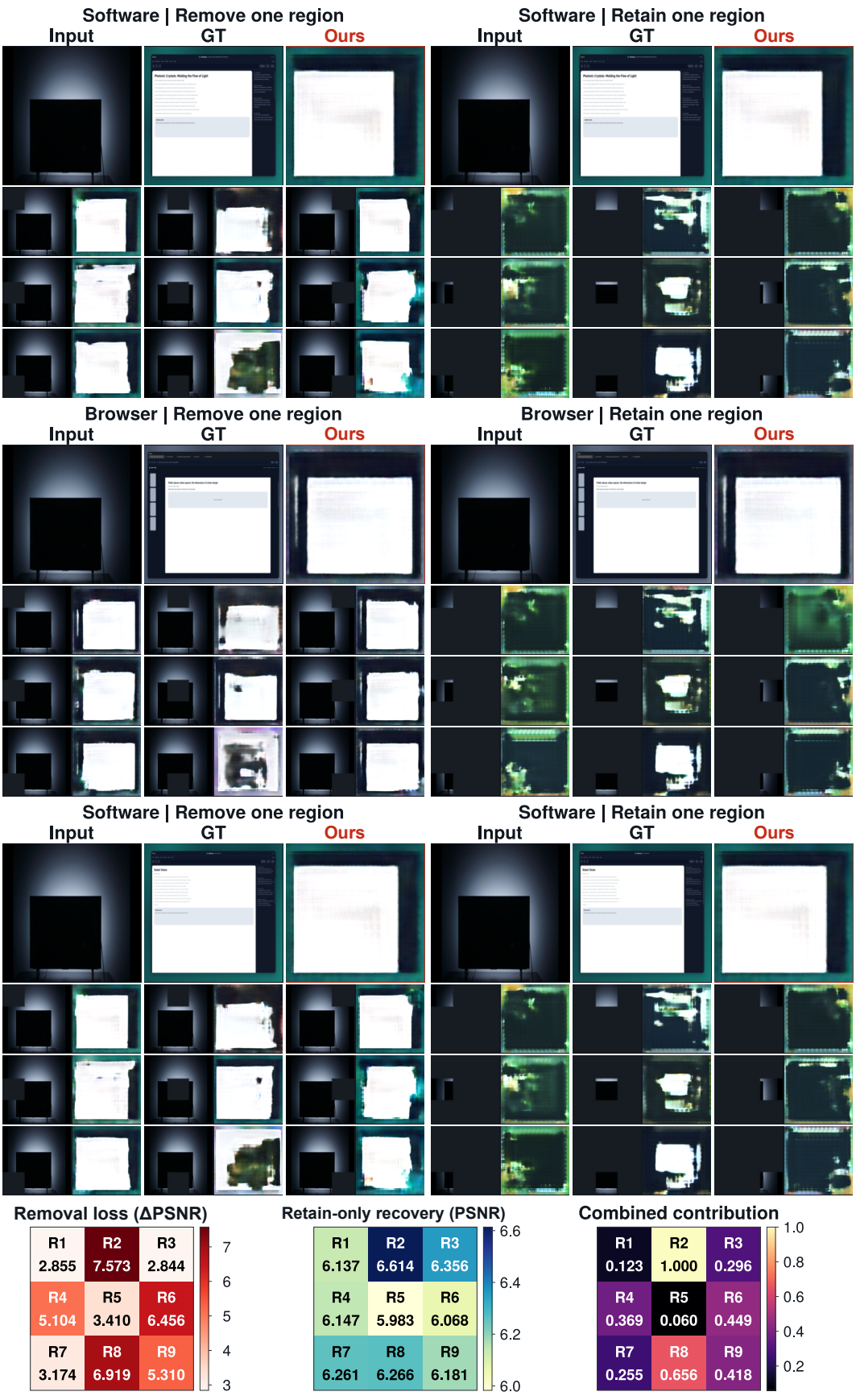

Software | Remove one region
Input
GT
Ours
Software | Retain one region
Input
GT
Ours
Browser | Remove one region
Input
GT
Ours
Browser | Retain one region
Input
GT
Ours
Software | Remove one region
Input
GT
Ours
Software | Retain one region
Input
GT
Ours
Removal loss (ΔPSNR)
R1 2.855
R2 7.573
R3 2.844
R4 5.104
R5 3.410
R6 6.456
R7 3.174
R8 6.919
R9 5.310
7
6
5
4
3
Retain-only recovery (PSNR)
R1 6.137
R2 6.614
R3 6.356
R4 6.147
R5 5.983
R6 6.068
R7 6.261
R8 6.266
R9 6.181
6.6
6.4
6.2
6.0
Combined contribution
R1 0.123
R2 1.000
R3 0.296
R4 0.369
R5 0.060
R6 0.449
R7 0.255
R8 0.656
R9 0.418
1.0
0.8
0.6
0.4
0.2

Figure A5: Nine-region evidence: two Software cases and one Browser; Remove left, Retain right.

The summary maps condense the visual progression into one spatial signature. R2 and R8 carry the largest removal PSNR losses, 7.57 and 6.92 dB, while R2 also provides the highest retain-only PSNR, 6.61 dB; R8's importance is expressed mainly through its collaboration with other positions. This difference between isolated contribution and removal effect supports complementary regional evidence within the wall field.

In Figure A5, rows 1–3 show two software cases and one browser case; in each row Remove is paired at left with Retain at right. Input, GT, and red Ours label the overview; intervention pairs (input left, output right) follow R1–R9 in row-major order, as in the main text. The final panel reports mean removal PSNR loss (dB), retain-only PSNR (dB), and their combination over the same R1–R9 coordinates. The combination averages the two maps after separate min–max normalization across the nine regions.

Total Completion Gain and Final-Region Evidence

Appendix Figure A6 compares the gain from completing the observed wall evidence with CASR's margin over the strongest competing representation. CASR obtains the largest seven-to-nine-region PSNR gains for R2/R8, R1/R9, and R3/R7, approximately 10.2, 7.1, and 5.4 dB, respectively. In panel (b), CASR's gain margin grows as the final region returns for all three pairs, showing its advantage in combining that region with the eight already observed.

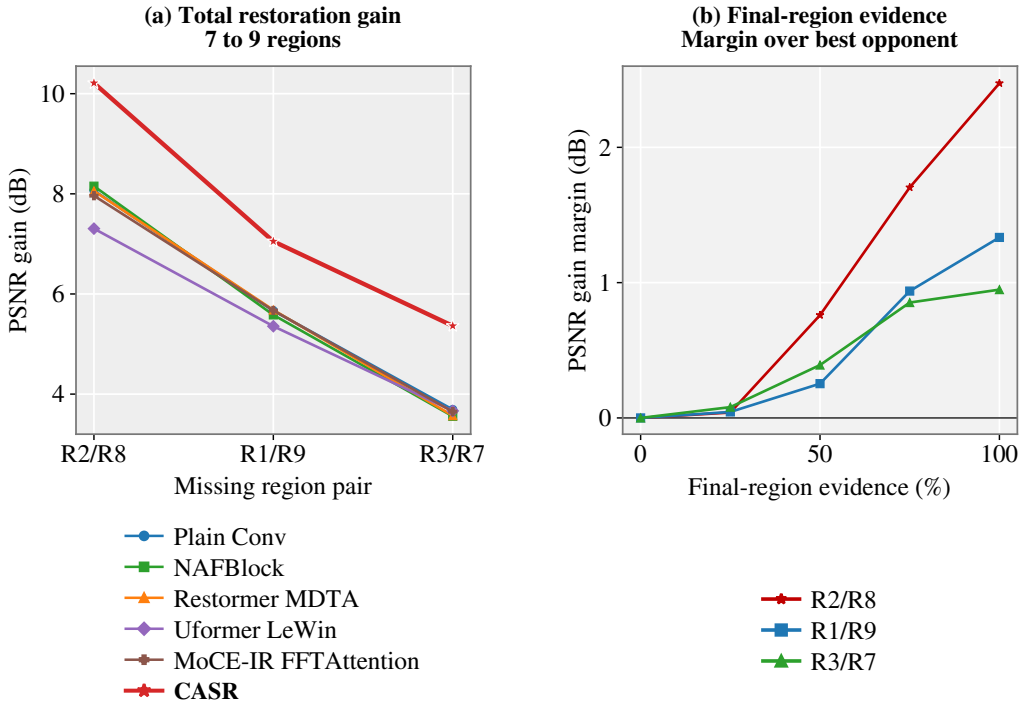


Figure A6: Total restoration gain and final-region evidence. (a) Mean PSNR gain from seven observed regions to all nine for the three missing-region pairs. (b) CASR PSNR recovery gain minus the largest competing gain at each final-region evidence fraction. Recovery gains in (b) are measured from the eight-region input and averaged over the two completion directions within each pair. Values are equally weighted over Browser, Figure, Game, and Software. Colors identify representations in (a) and missing-region pairs in (b).

Two-Stage Completion Increments

At the final completion step, CASR achieves the largest PSNR gain on all six paths (Figure A7). Restoring the final region combines its evidence with all other wall regions, allowing CASR to

organize the complete observation under a shared content reference. This result complements the seven-to-nine-region gains in Figure A6 and supports the joint use of distributed screen cues.

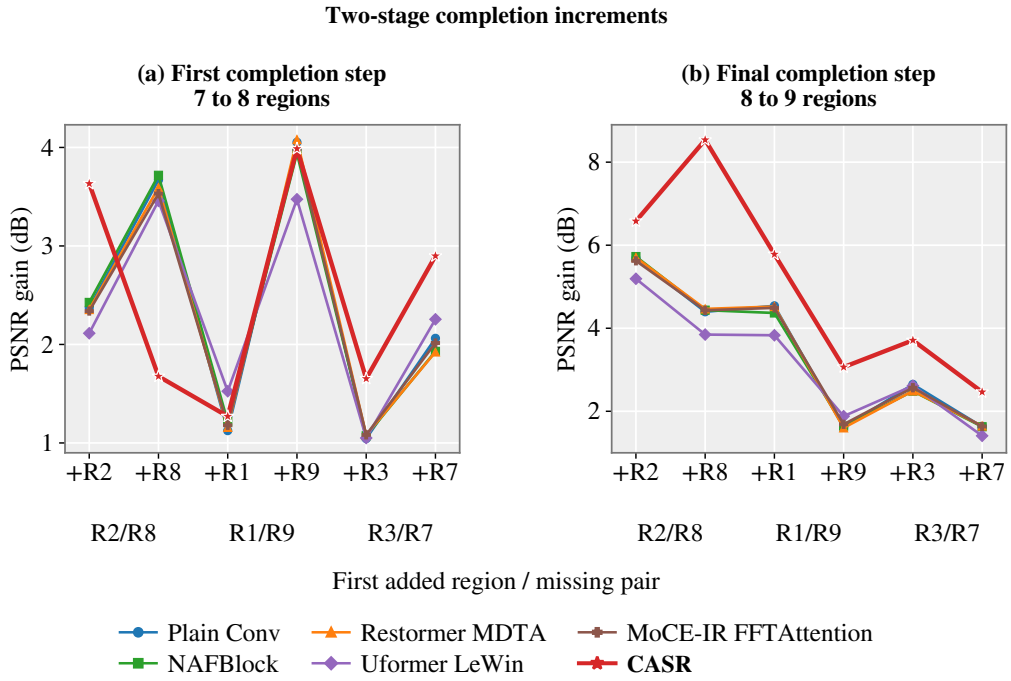


Figure A7: Two-stage completion increments for the six completion paths. (a) PSNR gain from seven to eight observed regions. (b) PSNR gain from eight to nine. The upper tick labels identify the first region restored within the missing pair named below; the final step restores the other region of that pair. Values are equally weighted over Browser, Figure, Game, and Software.

Cross-Category Consistency of Completion Gain

Appendix Figure A8 follows the same completion comparison across the four content categories. CASR obtains the largest total PSNR gain in all twelve category–region-pair combinations.

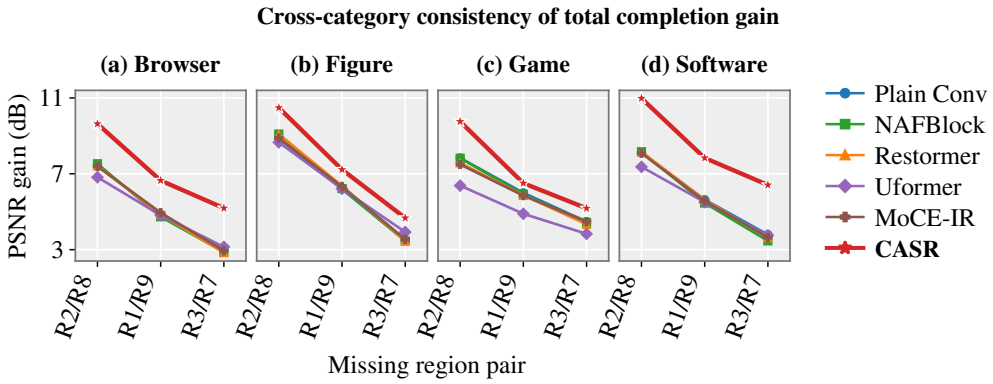


Figure A8: Cross-category consistency of total completion gain. The four panels report PSNR gain from seven observed regions to all nine for Browser, Figure, Game, and Software, respectively. Each panel compares the three missing-region pairs and all six representation outputs. The shared vertical scale and the legend at right support direct comparison across categories. The model labels Restormer, Uformer, and MoCE-IR identify the comparison entries; their representation descriptors are MDTA, LeWin, and FFTAttention, respectively.

Full-Resolution Continuous Recovery

Appendix Figure A9 traces how final-region evidence changes full-resolution recovery. PSNR gains increase as the final region returns, with CASR gaining most at full completion for each missing pair.

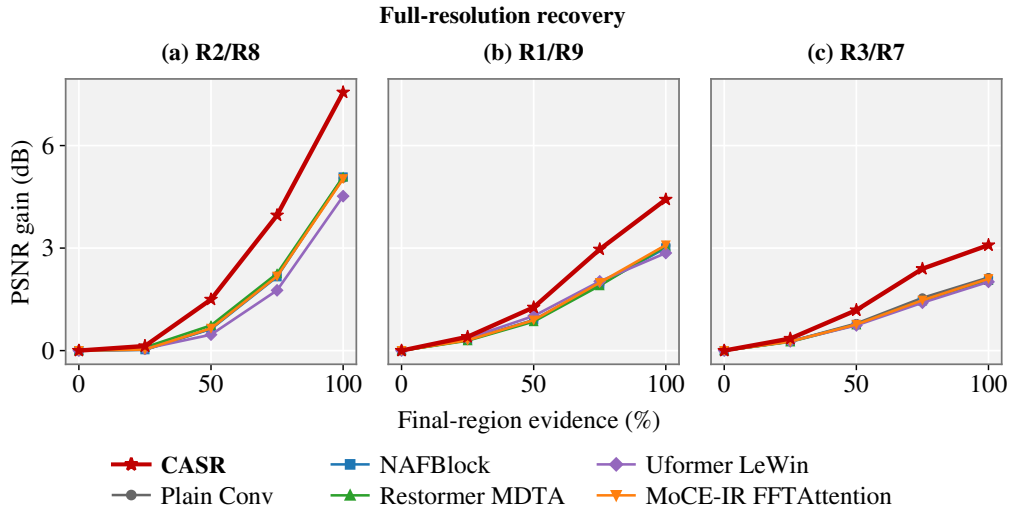


Figure A9: Full-resolution recovery as the final missing region is gradually restored. The panels report PSNR gain relative to the eight-region input for R2/R8, R1/R9, and R3/R7. Curves show the five evidence fractions, 0, 25, 50, 75, and 100%. Values average the two completion directions within each missing pair and weight Browser, Figure, Game, and Software equally.

Coarse-Layout Continuous Recovery

Appendix Figure A10 examines the same recovery at a coarse scale, where brightness regions and layout dominate. CASR also obtains the largest gain at full completion after reducing the prediction and target to 32×32, linking the improvement to coarse screen structure.

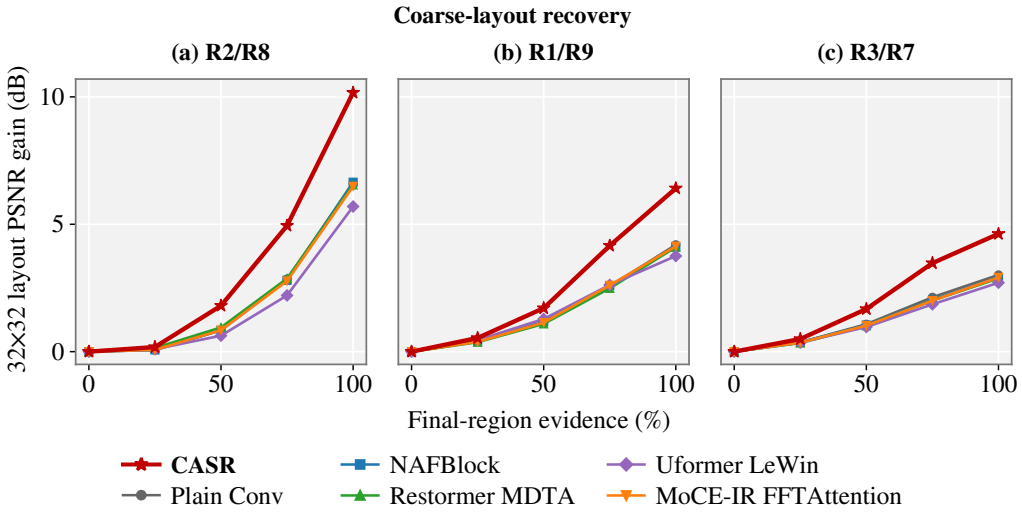


Figure A10: Coarse-layout recovery as the final missing region is gradually restored. The panels report PSNR gain after reducing the reconstruction and target to 32×32 pixels, emphasizing broad brightness regions and screen layout. Gains are relative to the eight-region input. Curves show the five evidence fractions, 0, 25, 50, 75, and 100%. Values average the two completion directions within each missing pair and weight Browser, Figure, Game, and Software equally.

C.3 RAL Ablations and Utility-Guided Refinement

We examine RAL through internal ablations and a paired comparison before and after utility-guided refinement. The internal variants isolate capability differentiation and restoration-utility supervision across Browser, Figure, Game, and Software content.

RAL Internal Ablation

Appendix Tables A4 and A5 test the central allocation claim of RAL: differentiated restoration capabilities become useful when the router learns which capability produces the stronger reconstruction on the same evidence. The variants separate capability structure from utility supervision across Browser, Figure, Game, and Software content.

Table A4: Internal RAL ablation on Browser and Figure. *w/o* denotes *without*, and *capability diff.* denotes *capability differentiation*. Blue marks the best internal variant other than RECALL for each metric, including ties at the displayed precision; variants with at least three blue entries receive a pale-blue background. Across the paired Browser–Figure and Game–Software tables, blue-cell counts use the combined four-category total. Red identifies the complete RECALL model. Values are rounded to six decimals for PSNR and SSIM and seven decimals for LPIPS. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Uniform, random, and hard-winner rows are internal utility-target variants. Local and attention replacements use ResNet (CVPR 2016) (He et al., 2016) and Uformer (CVPR 2022) (Wang et al., 2022), respectively.

Variant	Browser			Figure		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Complete learning design						
w/o RAL	**19.212812**	**0.657814**	**0.4951887**	19.503325	0.656254	0.6263237
Restoration capability differentiation						
w/o capability diff.	19.202965	0.657673	0.4954513	**19.504456**	**0.656355**	**0.6260437**
Context → CNN	18.762643	0.641263	0.5272263	19.299674	0.643396	0.6345756
Context → Attention	18.762615	0.641261	0.5272292	19.299637	0.643397	0.6345753
Both capabilities use context	18.762607	0.641263	0.5272289	19.299582	0.643395	0.6345724
Restoration utility supervision						
w/o utility supervision	18.762638	0.641262	0.5272268	19.299585	0.643394	0.6345696
Uniform utility target	18.762638	0.641262	0.5272268	19.299585	0.643394	0.6345696
Random utility target	18.762638	0.641262	0.5272268	19.299585	0.643394	0.6345696
Hard-winner utility target	18.762638	0.641262	0.5272268	19.299585	0.643394	0.6345696
Reference						
RECALL	**19.524887**	**0.679823**	**0.4616460**	**19.937638**	**0.661546**	**0.6005170**

Table A5: Internal RAL ablation on Game and Software. *w/o* denotes *without*, and *capability diff.* denotes *capability differentiation.* Precision, category grouping, and highlighting follow Table A4.

Variant	Game			Software		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Complete learning design						
w/o RAL	18.570193	0.581699	0.5951680	20.442944	0.735366	0.4114977
Restoration capability differentiation						
w/o capability diff.	**18.571467**	**0.581770**	**0.5948196**	**20.487898**	**0.736146**	**0.4106739**
Context → CNN	18.494250	0.565075	0.6201689	19.753041	0.702497	0.4457170
Context → Attention	18.494248	0.565076	0.6201654	19.753015	0.702495	0.4457205
Both capabilities use context	18.494218	0.565075	0.6201654	19.753061	0.702498	0.4457142
Restoration utility supervision						
w/o utility supervision	18.494159	0.565074	0.6201631	19.752921	0.702494	0.4457179
Uniform utility target	18.494159	0.565074	0.6201631	19.752921	0.702494	0.4457179
Random utility target	18.494159	0.565074	0.6201631	19.752921	0.702494	0.4457179
Hard-winner utility target	18.494159	0.565074	0.6201631	19.752921	0.702494	0.4457179
Reference						
RECALL	**19.175632**	**0.602862**	**0.5894520**	**21.630052**	**0.739512**	**0.4072840**

The internal ablations examine capability differentiation and utility supervision. The four utility-target variants are numerically identical at the displayed precision, showing that these generic assignment targets provide no additional reconstruction gain in this setting. Table A6 follows the same 400 validation images through utility-guided joint refinement, with 100 images from each content category, to measure the resulting change in screen reconstruction.

Table A6: Utility-guided joint refinement on the four-category validation set. Each category contains 100 paired images. The final row reports the macro result over all 400 images. Before utility-guided refinement and After utility-guided refinement (Recall(Ours)) are compared by paired metrics; Gain is the after-minus-before change and Better is the paired-image favorable rate. Positive PSNR/SSIM gain and negative LPIPS change indicate stronger reconstruction. Values are rounded to two decimals for absolute PSNR and four decimals for PSNR gain, SSIM, and LPIPS.

(a) Paired restoration metrics

Dataset	Images	PSNR ↑		SSIM ↑		LPIPS ↓	
		Before	After	Before	After	Before	After
Browser	100	20.01	20.09	0.6997	0.7032	0.4633	0.4570
Figure	100	19.82	19.89	0.6823	0.6841	0.6101	0.6041
Game	100	18.89	18.91	0.6177	0.6195	0.5828	0.5791
Software	100	21.48	21.63	0.7760	0.7797	0.3791	0.3731
Validation macro	400	20.05	20.13	0.6939	0.6966	0.5088	0.5033

(b) Paired improvement

Dataset	Images	PSNR ↑		SSIM ↑		LPIPS ↓	
		Gain	Better	Gain	Better	Change	Better
Browser	100	+0.0792	70%	+0.0035	88%	-0.0063	91%
Figure	100	+0.0695	77%	+0.0018	81%	-0.0060	78%
Game	100	+0.0154	71%	+0.0018	76%	-0.0037	77%
Software	100	+0.1449	75%	+0.0037	80%	-0.0060	88%
Validation macro	400	+0.0772	73.25%	+0.0027	81.25%	-0.0055	83.50%

Figure A11 shows the paired reconstruction gains and their 95% confidence intervals across the four content categories.



Figure A11: Reconstruction gains from utility-guided refinement. The panels report paired PSNR gain, SSIM gain, and LPIPS improvement for Browser, Figure, Game, Software, and their equally weighted macro average. Each category contains 100 paired validation images. Error bars show the paired 95% confidence intervals. PSNR and SSIM gains are After minus Before; LPIPS improvement is Before minus After. SSIM and LPIPS values are displayed in units of 0.001. Positive values indicate improvement.

The complete RAL design achieves the highest PSNR and SSIM and the lowest LPIPS across all four categories in Tables A4 and A5. Capability differentiation supplies distinct local and context-augmented corrections, while the soft utility target teaches the router how their relative reconstruction errors should shape allocation. The tables compare the complete design with the listed variants; the paired refinement in Table A6 further measures output changes from utility-guided joint training.

The paired refinement comparison turns RAL's allocation principle into a controlled output-level progression: all twelve category-metric cells move in the favorable direction after utility-guided refinement. The agreement across PSNR, SSIM, and LPIPS shows that the gain reaches pixel fidelity, structural consistency, and perceptual proximity together. It also recurs across most individual images, with favorable rates of 73.25%, 81.25%, and 83.50%, respectively; the paired 95% intervals for the validation-set changes are $[+0.0514, +0.1037]$ dB, $[+0.0022, +0.0032]$, and $[-0.0062, -0.0048]$.

The refinement starts from a model containing the restoration backbone and differentiated capabilities. The improvements connect restoration-based allocation to a stronger readout of the screen evidence already organized by CASR.

Learning-Variant Comparison

Figure A12 compares RAL with four allocation variants: Hard Winner, Switch-style top-1 (Fedus et al., 2022), V-MoE-style (Riquelme et al., 2021), and MoCE-IR-style (Zamfir et al., 2025). The allocation variants use the same pre-refinement training model and 700 training pairs per category. It is a separate experiment from the utility-guided joint refinement in Table A6.

The three displayed conditions are Clean input, Low–mid-frequency input (retaining Fourier radii up to 60% of the maximum), and Weak-exposure input (-0.75 EV). Switch Transformers and V-MoE combine sparse token routing with auxiliary load-balancing objectives (Fedus et al., 2022; Riquelme et al., 2021); the corresponding allocation variants in our comparison reach 20.1295 and 20.1263 dB on 400 clean-input validation images. RAL learns spatial preferences from relative restoration errors and reaches 20.1354 dB on these images. RAL has the highest mean PSNR under all three displayed conditions; its largest margin is 0.0719 dB over Hard Winner for low–mid-frequency input, with a positive paired 95% confidence interval. The low–mid-frequency result connects graded restoration preferences to improved screen reconstruction as the frequency content of the wall evidence changes.

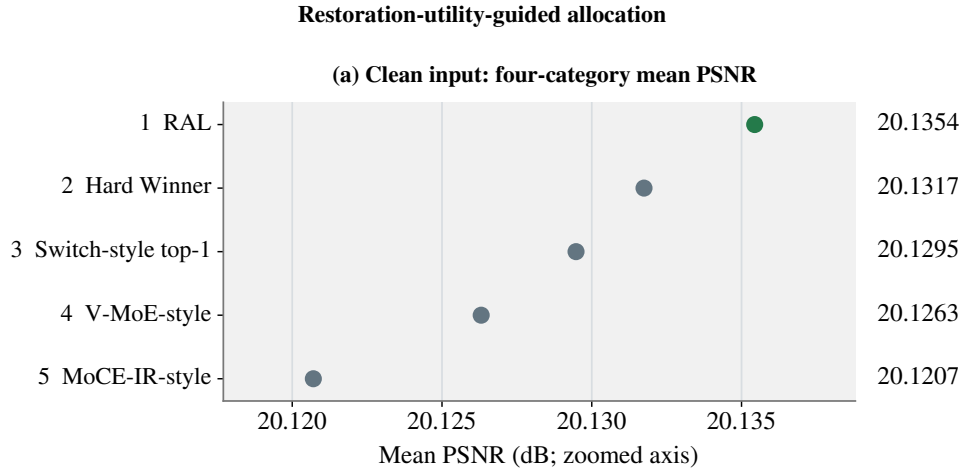


Figure A12: Learning-variant comparison for restoration allocation, panel (a): mean PSNR on 400 Clean input validation images. Panel (b) and the complete comparison details follow on the next page.

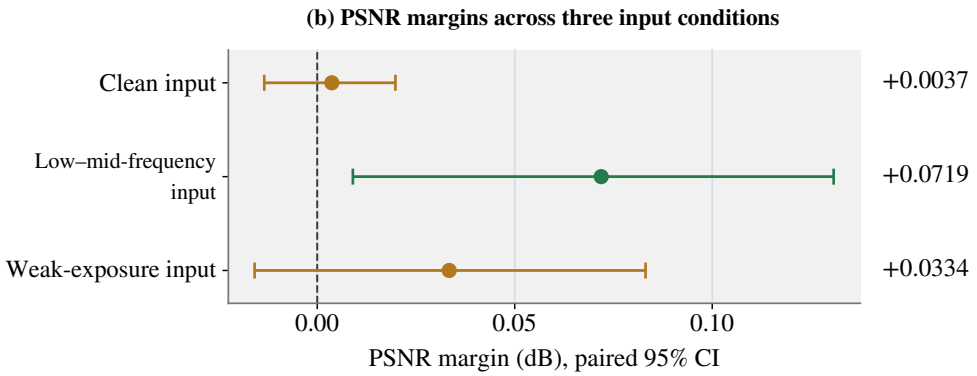


Figure A12: Learning-variant comparison for restoration allocation (continued). (a) Mean PSNR on 400 Clean input validation images: (1) RAL, (2) Hard Winner, (3) Switch-style top-1, (4) V-MoE-style, and (5) MoCE-IR-style. (b) RAL's mean PSNR margin under Clean input, Low–mid-frequency input, and Weak-exposure input; the respective strongest counterparts are Hard Winner, Hard Winner, and MoCE-IR-style. Each content category contributes 100 images. The dashed line marks zero margin, and error bars show paired bootstrap 95% confidence intervals. The Clean and Weak-exposure intervals span zero. Marker labels give means or differences in dB to four decimals.

C.4 Joint Ablation Visualization

The overall ablation visualization complements the quantitative component comparisons in main-text Tables 2 and 3 and Appendix Tables A4 and A5. It connects component choice to recovered screen structure; the complementary qualitative comparison appears in the main text.

In Browser and Figure, the complete model preserves the arrangement of dominant panels and colored regions, while several representation replacements merge neighboring regions (Figure A13). These differences connect the quantitative ablations to the spatial organization of the hidden screen: organizing the evidence and allocating its correction jointly shape the recovered regional boundaries.

Ablation variant definitions for Figure A13.

- **A** CASR removed.
- **B** the spectral relation replaced by local convolution.
- **C** the spectral relation replaced by window attention.
- **D** RAL removed.
- **E** the context capability replaced by local convolution.
- **F** the context capability replaced by attention.
- **G** CASR and RAL removed.
- **H** added-capacity control after removing CASR and RAL.
- **I** the content anchor removed while retaining spectral processing.
- **J** the content anchor shuffled.
- **K** the content anchor replaced by globally averaged internal features.
- **L** spectral processing removed while retaining the content anchor.
- **M** Fourier interaction removed.
- **N** the smooth-layout and residual-detail gate removed.
- **O** the gate driven by raw features.
- **P** teacher distillation removed from the training objective.
- **Q** differentiated capabilities removed while retaining restoration-utility supervision.
- **R** both capabilities use contextual processing.
- **S** restoration-utility supervision removed while retaining differentiated capabilities.
- **T** a uniform assignment target.
- **U** an entropy-matched random assignment target.
- **V** a hard-winner assignment target.

The replacement branches separate the two responsibilities that make this coherence possible. CASR supplies content-anchored smooth-layout and residual-detail evidence, and RAL converts capability-specific restoration utility into differentiated processing of that evidence. Read with the representation table and main-text Figure 3, the visual ablation shows how the complete mechanism advances from a stronger evidence representation to a stronger coarse reconstruction.

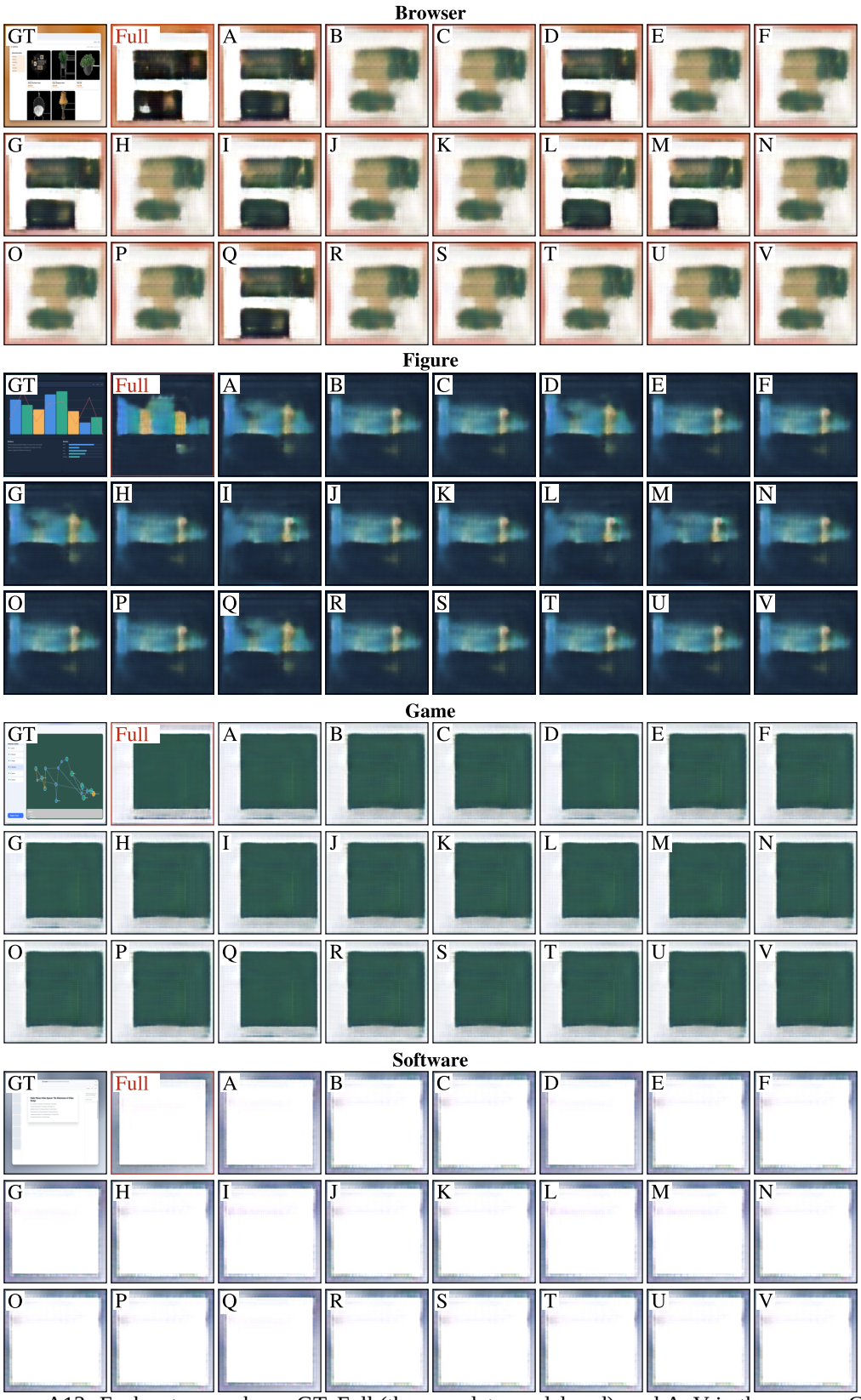


Figure A13: Each category shows GT, Full (the complete model, red), and A–V in three rows: GT, Full, A–F; G–N; O–V.

D Complete One-Factor Robustness Evidence

We evaluate hidden-screen reconstruction under single-factor variations of real wall-light observations. Each sweep varies one observation factor while preserving the paired screen target and the other stated conditions. Results compare Recall(Ours) with 22 external methods across Browser, Figure, Game, and Software where available. Higher PSNR and SSIM and lower LPIPS indicate better reconstruction. N/A marks 234 metric entries from runs that failed; these entries do not participate in ranking. Tables give the condition parameters, and paired curves show the corresponding sweeps. Method sources follow Table 1. In the curves, the method letters are defined below and retained across all sweeps.

In the tables, each condition spans PSNR, SSIM, and LPIPS. PSNR and SSIM are maximized and LPIPS is minimized. PSNR uses two decimals; SSIM and LPIPS use four. Blue marks the best external value, including displayed ties; external rows with at least three blue values in a panel are shaded blue. Recall(Ours) is shaded red. Continuation panels repeat method names and metric headers.

Ours denotes the complete model; A–V denote NAFNet, PromptIR, ConvIR, Ada-Deblur, Uformer, HVI-CIDNet, Retinexformer, DehazeFormer, Restormer, AST, UniProcessor, IRNeXt, Pixel2Pixel, OneRestore, X-Restormer, U-Net, OKNet, DnCNN, DEA-Net, SFHformer, DeepSN-Net, and DarkIR, respectively.

In the five full-page qualitative comparisons, columns show wall input, GT, Ours (red), and A–E (NAFNet, PromptIR, ConvIR, Ada-Deblur, and Uformer). Reference rows identify content categories; the remaining rows identify conditions. The comparisons examine coarse brightness, regional layout, and principal contours.

D.1 Wall-Material Variation

Wall-material variation changes the physical surface that carries the screen's reflected light. Figure A14 shows recorded real captures for a wood wall, a tiled wall, and a frosted white wall, pairing the screen-content scene with the corresponding material view.

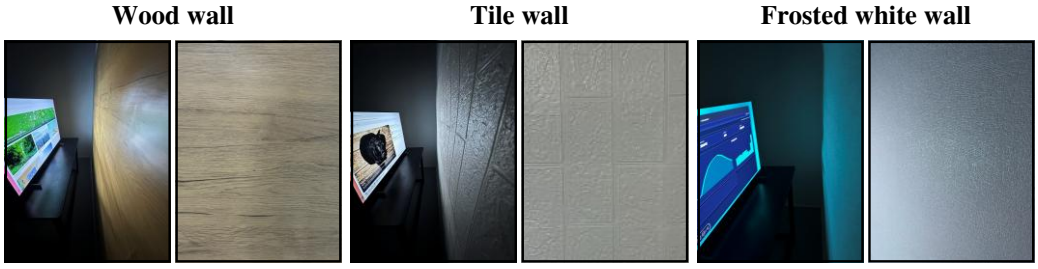


Figure A14: Real captures of three physical wall-material configurations. From left to right, the groups show a wood wall, a tiled wall, and a frosted white wall; within each group, the left image shows the acquisition scene and the right image shows the corresponding wall material.

D.1.1 Wall-Reflectance Variation

Wall-reflectance variation tests coarse recovery on both sides of the reference return strength.

The low-reflectance interval tests how progressively stronger returned wall light clarifies hidden-screen evidence. Browser, Game, and Software each span ten recorded reflectance scales from 0.7x to 0.85x under fixed content and remaining imaging conditions. The aligned sweeps expose the same evidence-strength progression across page sections, a game canvas, and software panels.



Figure A15: Wall-reflectance robustness on Browser, Figure, Game, and Software. Each three-row block shows the reference acquisition at $1.00\times$, $0.85\times$, and $1.18\times$.

Low Wall-Reflectance Interval

Browser Low Wall-Reflectance Interval

Appendix Table A7 and Figure A16 report the Browser sweep.

As returned wall light increases, Browser PSNR improves from 16.632 to 18.911 dB, with SSIM and LPIPS improving jointly; RECALL leads all three metrics at the 10 recorded conditions.

The low-reflectance curves show all three RECALL metrics improving together as the returned light grows, with its leading position already established at the weakest recorded return. The trajectory identifies a graded evidence regime in which stronger wall light progressively clarifies page regions and their principal boundaries.

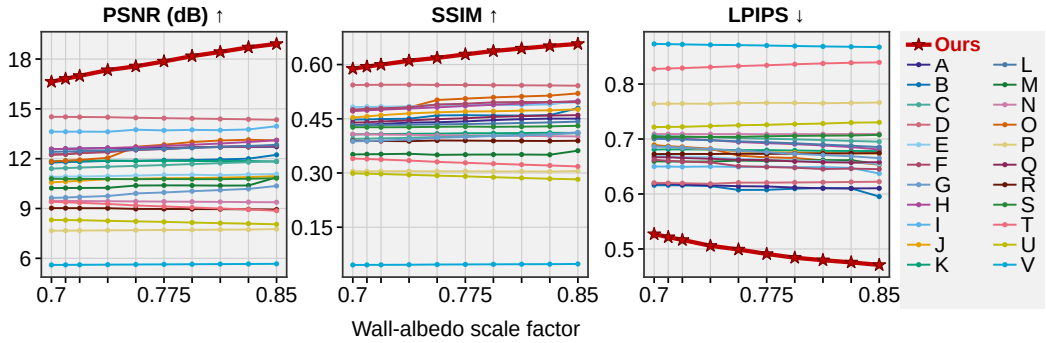


Figure A16: Browser Low Wall-Reflectance Interval curves, generated from the same values as Appendix Table A7. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

Table A7: Full Browser Low Wall-Reflectance Interval results, with 23 methods and 10 conditions.

Method	(0.7x)			(0.7094x)			(0.7188x)			(0.7375x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	11.76	0.4475	**0.6159**	11.80	0.4483	**0.6159**	11.81	0.4491	**0.6157**	11.87	0.4502	**0.6144**
UniProcessor	11.84	0.4065	0.6809	11.87	0.4074	0.6811	11.88	0.4076	0.6812	11.89	0.4084	0.6808
AST	10.57	0.4535	0.6896	10.62	0.4566	0.6866	10.67	0.4599	0.6843	10.76	0.4649	0.6807
OneRestore	9.46	0.4072	0.7089	9.46	0.4068	0.7090	9.45	0.4064	0.7089	9.44	0.4055	0.7089
General restoration backbones												
Restormer	13.63	0.4822	0.6500	13.62	0.4828	0.6499	13.63	0.4830	0.6495	13.62	0.4827	0.6500
X-Restormer	11.82	0.4718	0.6880	11.88	0.4743	0.6868	11.93	0.4764	0.6857	12.05	0.4814	0.6824
NAFNet	12.57	0.4324	0.6191	12.59	0.4339	0.6185	12.61	0.4356	0.6172	12.64	0.4394	0.6157
Pixel2Pixel	10.23	0.3513	0.6595	10.23	0.3519	0.6591	10.24	0.3521	0.6591	10.25	0.3531	0.6589
ConvIR	11.40	0.3945	0.7058	11.43	0.3951	0.7050	11.46	0.3958	0.7044	11.52	0.3974	0.7031
Uformer	10.90	0.4812	0.6695	10.92	0.4822	0.6688	10.93	0.4828	0.6681	10.95	0.4844	0.6670
U-Net	7.66	0.3047	0.7640	7.67	0.3047	0.7642	7.67	0.3048	0.7644	7.68	0.3050	0.7641
Degradation-specific restoration												
Ada-Deblur	**14.52**	**0.5434**	0.6204	**14.52**	**0.5438**	0.6199	**14.51**	**0.5440**	0.6196	**14.50**	**0.5443**	0.6186
DehazeFormer	12.58	0.4716	0.7034	12.59	0.4735	0.7021	12.61	0.4752	0.7006	12.64	0.4782	0.6981
OKNet	12.25	0.4395	0.6669	12.27	0.4401	0.6667	12.35	0.4425	0.6655	12.43	0.4454	0.6641
DnCNN	9.02	0.3890	0.6726	9.02	0.3889	0.6727	9.02	0.3885	0.6728	9.02	0.3880	0.6728
Enhancement-oriented restoration												
Retinexformer	9.64	0.3875	0.6862	9.66	0.3884	0.6855	9.70	0.3898	0.6843	9.75	0.3926	0.6815
HVI-CIDNet	12.24	0.4753	0.6623	12.26	0.4774	0.6604	12.33	0.4788	0.6589	12.39	0.4820	0.6574
IRNeXt	12.41	0.4323	0.7004	12.43	0.4326	0.6998	12.45	0.4329	0.6992	12.50	0.4335	0.6978
DEA-Net	10.79	0.4267	0.7038	10.78	0.4267	0.7037	10.78	0.4265	0.7041	10.78	0.4267	0.7038
SFHformer	9.40	0.3399	0.8274	9.38	0.3388	0.8283	9.35	0.3374	0.8290	9.28	0.3345	0.8308
DeepSN-Net	8.31	0.2990	0.7217	8.30	0.2981	0.7220	8.30	0.2973	0.7222	8.26	0.2949	0.7236
DarkIR	5.60	0.0456	0.8730	5.61	0.0458	0.8726	5.61	0.0459	0.8722	5.62	0.0462	0.8713
Proposed method												
Recall(Ours)	**16.63**	**0.5885**	**0.5270**	**16.81**	**0.5943**	**0.5216**	**16.99**	**0.5996**	**0.5165**	**17.33**	**0.6106**	**0.5058**

Table A7 (continued).

Method	(0.7562x)			(0.775x)			(0.7937x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	11.88	0.4592	**0.6074**	11.91	0.4599	**0.6076**	11.92	0.4592	**0.6096**
UniProcessor	11.86	0.4088	0.6797	11.87	0.4099	0.6797	11.86	0.4100	0.6791
AST	10.79	0.4679	0.6775	10.82	0.4701	0.6759	10.83	0.4707	0.6754
OneRestore	9.43	0.4047	0.7090	9.42	0.4040	0.7087	9.41	0.4033	0.7089
General restoration backbones									
Restormer	13.74	0.4893	0.6492	13.70	0.4898	0.6498	13.74	0.4891	0.6489
X-Restormer	12.72	0.5020	0.6698	12.84	0.5057	0.6666	13.00	0.5092	0.6655
NAFNet	12.63	0.4404	0.6142	12.64	0.4428	0.6137	12.68	0.4463	0.6116
Pixel2Pixel	10.38	0.3502	0.6608	10.39	0.3508	0.6601	10.39	0.3511	0.6608
ConvIR	11.57	0.3995	0.7018	11.62	0.4013	0.7006	11.67	0.4035	0.6994
Uformer	10.98	0.4873	0.6641	11.02	0.4891	0.6625	11.03	0.4903	0.6609
U-Net	7.70	0.3046	0.7655	7.71	0.3048	0.7657	7.71	0.3042	0.7657
Degradation-specific restoration									
Ada-Deblur	**14.46**	**0.5436**	0.6207	**14.44**	**0.5436**	0.6206	**14.42**	**0.5430**	0.6210
DehazeFormer	12.70	0.4816	0.6946	12.77	0.4854	0.6925	12.84	0.4887	0.6907
OKNet	12.53	0.4489	0.6622	12.58	0.4514	0.6616	12.67	0.4552	0.6593
DnCNN	8.98	0.3900	0.6732	8.97	0.3897	0.6731	8.97	0.3891	0.6734
Enhancement-oriented restoration									
Retinexformer	9.91	0.3973	0.6787	9.97	0.3995	0.6761	10.04	0.4024	0.6731
HVI-CIDNet	12.55	0.4894	0.6506	12.59	0.4916	0.6492	12.68	0.4955	0.6478
IRNeXt	12.55	0.4346	0.6959	12.59	0.4354	0.6942	12.65	0.4367	0.6923
DEA-Net	10.77	0.4278	0.7040	10.78	0.4284	0.7050	10.77	0.4278	0.7057
SFHformer	9.18	0.3307	0.8327	9.12	0.3282	0.8342	9.06	0.3257	0.8360
DeepSN-Net	8.22	0.2928	0.7250	8.20	0.2907	0.7259	8.15	0.2884	0.7272
DarkIR	5.63	0.0468	0.8708	5.64	0.0470	0.8701	5.64	0.0474	0.8692
Proposed method									
Recall(Ours)	**17.56**	**0.6183**	**0.4991**	**17.86**	**0.6281**	**0.4909**	**18.18**	**0.6374**	**0.4841**

Table A7 (continued).

Method	(0.8125x)			(0.8313x)			(0.85x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	11.96	0.4588	0.6109	12.00	0.4601	0.6102	12.23	0.4792	**0.5953**
UniProcessor	11.86	0.4105	0.6785	11.86	0.4113	0.6783	11.83	0.4108	0.6782
AST	10.86	0.4725	0.6743	10.89	0.4734	0.6740	10.95	0.4760	0.6735
OneRestore	9.40	0.4027	0.7088	9.39	0.4020	0.7091	9.38	0.4013	0.7093
General restoration backbones									
Restormer	13.72	0.4885	0.6490	13.76	0.4903	0.6474	13.96	0.4987	0.6372
X-Restormer	13.10	0.5117	0.6613	13.14	0.5141	0.6582	13.10	0.5202	0.6534
NAFNet	12.70	0.4490	**0.6103**	12.70	0.4505	**0.6101**	12.72	0.4504	0.6104
Pixel2Pixel	10.38	0.3511	0.6616	10.39	0.3505	0.6615	10.87	0.3617	0.6542
ConvIR	11.73	0.4057	0.6981	11.79	0.4079	0.6965	11.84	0.4100	0.6952
Uformer	11.01	0.4912	0.6593	11.05	0.4930	0.6579	11.08	0.4953	0.6549
U-Net	7.73	0.3044	0.7652	7.73	0.3040	0.7657	7.76	0.3054	0.7664
Degradation-specific restoration									
Ada-Deblur	**14.39**	**0.5426**	0.6214	**14.37**	**0.5422**	0.6218	**14.34**	**0.5415**	0.6223
DehazeFormer	12.91	0.4920	0.6882	13.00	0.4957	0.6853	13.11	0.4990	0.6810
OKNet	12.73	0.4572	0.6578	12.76	0.4590	0.6572	12.77	0.4600	0.6579
DnCNN	8.96	0.3889	0.6737	8.95	0.3886	0.6740	8.93	0.3892	0.6744
Enhancement-oriented restoration									
Retinexformer	10.11	0.4043	0.6709	10.18	0.4064	0.6687	10.36	0.4126	0.6652
HVI-CIDNet	12.70	0.4964	0.6454	12.71	0.4962	0.6462	12.79	0.4964	0.6452
IRNeXt	12.71	0.4383	0.6900	12.76	0.4399	0.6878	12.83	0.4422	0.6854
DEA-Net	10.77	0.4283	0.7061	10.79	0.4290	0.7064	10.82	0.4306	0.7075
SFHformer	9.00	0.3231	0.8375	8.94	0.3208	0.8387	8.87	0.3181	0.8394
DeepSN-Net	8.12	0.2862	0.7282	8.09	0.2841	0.7297	8.05	0.2825	0.7303
DarkIR	5.65	0.0477	0.8685	5.66	0.0478	0.8678	5.67	0.0484	0.8672
Proposed method									
Recall(Ours)	**18.43**	**0.6444**	**0.4795**	**18.70**	**0.6513**	**0.4756**	**18.91**	**0.6571**	**0.4709**

This pattern is consistent with CASR's content-anchored organization of smooth-layout and residual-detail evidence and RAL's allocation of local and context-augmented capabilities by restoration utility.

Game Low Wall-Reflectance Interval

Appendix Table A8 and Figure A17 report the Game sweep.

Stronger returned wall light improves Game PSNR from 16.830 to 18.846 dB, with SSIM and LPIPS improving jointly; RECALL leads all three metrics at the 10 recorded conditions.

The low-reflectance curves show a coordinated improvement across all three metrics as more game evidence returns from the wall, with RECALL leading from the weakest condition onward. This progression maps evidence strength directly to recovery of the broad canvas and principal objects.

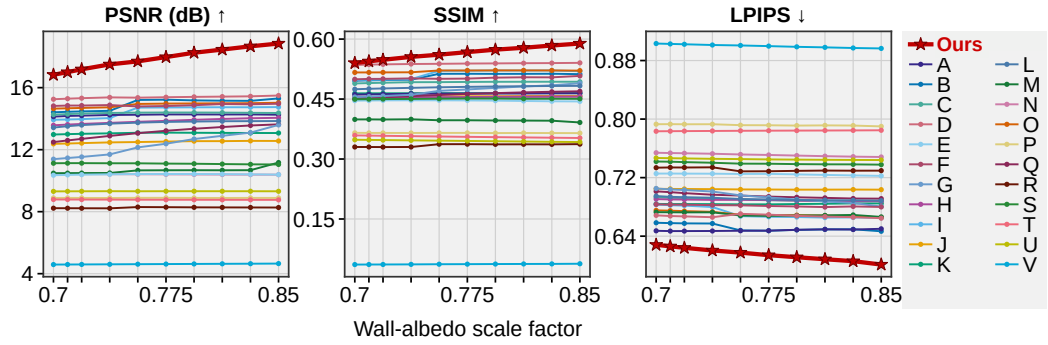


Figure A17: Game Low Wall-Reflectance Interval curves, generated from the same values as Appendix Table A8. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

Table A8: Full Game Low Wall-Reflectance Interval results, with 23 methods and 10 conditions.

Method	(0.7x)			(0.7094x)			(0.7188x)			(0.7375x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	14.41	0.4959	0.6583	14.44	0.4968	0.6579	14.47	0.4974	0.6575	14.51	0.4984	0.6573
UniProcessor	12.98	0.4642	0.6841	13.00	0.4643	0.6839	13.02	0.4644	0.6839	13.05	0.4644	0.6838
AST	12.37	0.4544	0.7047	12.40	0.4550	0.7046	12.42	0.4556	0.7045	12.47	0.4561	0.7043
OneRestore	10.43	0.4563	0.7540	10.43	0.4560	0.7536	10.42	0.4558	0.7533	10.42	0.4552	0.7526
General restoration backbones												
Restormer	13.93	0.4976	0.6832	13.95	0.4983	0.6823	13.97	0.4985	0.6817	14.04	0.4997	0.6798
X-Restormer	14.65	0.5165	0.6753	14.67	0.5166	0.6748	14.69	0.5167	0.6742	14.73	0.5170	0.6733
NAFNet	14.13	0.4613	**0.6473**	14.17	0.4618	**0.6469**	14.19	0.4624	**0.6470**	14.24	0.4633	**0.6471**
Pixel2Pixel	10.48	0.3990	0.6728	10.49	0.3991	0.6727	10.49	0.3989	0.6725	10.50	0.3994	0.6726
ConvIR	14.26	0.4890	0.6932	14.29	0.4900	0.6924	14.33	0.4908	0.6917	14.37	0.4922	0.6911
Uformer	10.35	0.4460	0.7255	10.37	0.4464	0.7256	10.39	0.4467	0.7255	10.41	0.4469	0.7254
U-Net	8.89	0.3655	0.7930	8.89	0.3653	0.7931	8.89	0.3653	0.7929	8.88	0.3652	0.7930
Degradation-specific restoration												
Ada-Deblur	**15.25**	**0.5353**	0.6684	**15.29**	**0.5362**	0.6676	**15.32**	**0.5368**	0.6670	**15.37**	**0.5376**	0.6659
DehazeFormer	13.57	0.4520	0.6906	13.62	0.4526	0.6902	13.66	0.4530	0.6900	13.73	0.4537	0.6896
OKNet	12.49	0.4512	0.7013	12.60	0.4527	0.7001	12.69	0.4544	0.6988	12.89	0.4571	0.6966
DnCNN	8.22	0.3301	0.7336	8.22	0.3301	0.7339	8.22	0.3299	0.7338	8.22	0.3301	0.7341
Enhancement-oriented restoration												
Retinexformer	11.39	0.4551	0.7052	11.46	0.4562	0.7038	11.53	0.4576	0.7031	11.69	0.4605	0.7010
HVI-CIDNet	14.82	0.4994	0.6835	14.85	0.5003	0.6831	14.85	0.5005	0.6830	14.88	0.5017	0.6824
IRNeXt	13.43	0.4745	0.6948	13.51	0.4757	0.6938	13.59	0.4765	0.6933	13.68	0.4780	0.6925
DEA-Net	11.12	0.4495	0.7420	11.13	0.4497	0.7418	11.13	0.4499	0.7412	11.12	0.4503	0.7403
SFHformer	8.79	0.3591	0.7833	8.78	0.3586	0.7835	8.78	0.3581	0.7836	8.78	0.3572	0.7838
DeepSN-Net	9.31	0.3482	0.7469	9.31	0.3478	0.7465	9.32	0.3474	0.7462	9.32	0.3467	0.7457
DarkIR	4.59	0.0360	0.9032	4.59	0.0361	0.9027	4.60	0.0362	0.9022	4.60	0.0365	0.9012
Proposed method												
Recall(Ours)	**16.83**	**0.5402**	**0.6282**	**17.00**	**0.5443**	**0.6261**	**17.18**	**0.5483**	**0.6241**	**17.50**	**0.5555**	**0.6205**

Table A8 (continued).

Method	(0.7562x)			(0.775x)			(0.7937x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.21	0.5132	0.6479	15.22	0.5132	**0.6475**	15.18	0.5130	**0.6486**
UniProcessor	13.09	0.4646	0.6835	13.10	0.4646	0.6835	13.09	0.4645	0.6839
AST	12.49	0.4566	0.7039	12.52	0.4569	0.7037	12.55	0.4570	0.7036
OneRestore	10.41	0.4548	0.7517	10.41	0.4543	0.7510	10.40	0.4537	0.7501
General restoration backbones									
Restormer	14.71	0.5206	0.6674	14.72	0.5210	0.6665	14.73	0.5214	0.6662
X-Restormer	14.95	0.5215	0.6693	14.97	0.5214	0.6687	14.98	0.5217	0.6687
NAFNet	14.25	0.4636	**0.6474**	14.27	0.4639	**0.6475**	14.27	0.4639	0.6487
Pixel2Pixel	10.66	0.3970	0.6682	10.67	0.3969	0.6678	10.67	0.3964	0.6682
ConvIR	14.39	0.4923	0.6900	14.40	0.4928	0.6891	14.40	0.4932	0.6886
Uformer	10.43	0.4469	0.7250	10.43	0.4466	0.7251	10.43	0.4460	0.7244
U-Net	8.89	0.3653	0.7917	8.89	0.3654	0.7916	8.89	0.3649	0.7911
Degradation-specific restoration									
Ada-Deblur	**15.35**	**0.5381**	0.6705	**15.38**	**0.5388**	0.6694	**15.40**	**0.5392**	0.6678
DehazeFormer	13.80	0.4544	0.6897	13.86	0.4548	0.6894	13.93	0.4556	0.6886
OKNet	13.06	0.4602	0.6955	13.22	0.4628	0.6941	13.35	0.4648	0.6931
DnCNN	8.30	0.3371	0.7286	8.29	0.3372	0.7287	8.28	0.3367	0.7293
Enhancement-oriented restoration									
Retinexformer	12.15	0.4705	0.6957	12.38	0.4740	0.6929	12.69	0.4779	0.6901
HVI-CIDNet	14.79	0.5006	0.6821	14.82	0.5012	0.6812	14.87	0.5036	0.6806
IRNeXt	13.74	0.4794	0.6908	13.79	0.4805	0.6902	13.81	0.4815	0.6894
DEA-Net	11.12	0.4509	0.7391	11.10	0.4514	0.7390	11.09	0.4513	0.7385
SFHformer	8.77	0.3563	0.7840	8.77	0.3555	0.7842	8.77	0.3547	0.7843
DeepSN-Net	9.32	0.3459	0.7453	9.32	0.3452	0.7449	9.32	0.3445	0.7446
DarkIR	4.61	0.0369	0.9006	4.62	0.0371	0.8997	4.63	0.0373	0.8987
Proposed method									
Recall(Ours)	**17.70**	**0.5610**	**0.6175**	**17.97**	**0.5674**	**0.6140**	**18.25**	**0.5736**	**0.6112**

Table A8 (continued).

Method	(0.8125x)			(0.8313x)			(0.85x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.16	0.5131	**0.6493**	15.15	0.5133	0.6494	15.30	0.5123	**0.6467**
UniProcessor	13.08	0.4648	0.6843	13.08	0.4647	0.6848	13.07	0.4648	0.6848
AST	12.55	0.4574	0.7036	12.57	0.4578	0.7037	12.56	0.4578	0.7036
OneRestore	10.40	0.4532	0.7493	10.39	0.4527	0.7487	10.39	0.4521	0.7482
General restoration backbones									
Restormer	14.74	0.5213	0.6654	14.73	0.5216	0.6656	14.75	0.5196	0.6651
X-Restormer	14.99	0.5217	0.6682	15.00	0.5215	0.6677	15.03	0.5211	0.6657
NAFNet	14.27	0.4640	**0.6493**	14.27	0.4644	**0.6491**	14.25	0.4644	0.6501
Pixel2Pixel	10.67	0.3962	0.6684	10.68	0.3959	0.6690	11.17	0.3915	0.6663
ConvIR	14.39	0.4933	0.6882	14.38	0.4933	0.6882	14.37	0.4933	0.6882
Uformer	10.42	0.4452	0.7237	10.41	0.4444	0.7230	10.39	0.4441	0.7224
U-Net	8.88	0.3652	0.7914	8.89	0.3650	0.7912	8.89	0.3648	0.7900
Degradation-specific restoration									
Ada-Deblur	**15.42**	**0.5397**	0.6667	**15.44**	**0.5400**	0.6660	**15.49**	**0.5406**	0.6646
DehazeFormer	13.98	0.4560	0.6879	14.03	0.4564	0.6877	14.05	0.4563	0.6878
OKNet	13.46	0.4667	0.6924	13.56	0.4682	0.6915	13.63	0.4694	0.6913
DnCNN	8.27	0.3368	0.7297	8.27	0.3367	0.7295	8.27	0.3373	0.7295

Table A8 (continued).

Method	(0.8125x)			(0.8313x)			(0.85x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Enhancement-oriented restoration									
Retinexformer	12.89	0.4814	0.6874	13.10	0.4844	0.6853	13.60	0.4895	0.6805
HVI-CIDNet	14.94	0.5045	0.6798	14.93	0.5043	0.6806	14.96	0.5079	0.6800
IRNeXt	13.83	0.4821	0.6892	13.84	0.4827	0.6890	13.85	0.4830	0.6885
DEA-Net	11.07	0.4507	0.7382	11.05	0.4508	0.7381	11.04	0.4506	0.7377
SFHformer	8.76	0.3540	0.7844	8.76	0.3533	0.7845	8.76	0.3526	0.7847
DeepSN-Net	9.32	0.3438	0.7443	9.32	0.3430	0.7442	9.31	0.3425	0.7440
DarkIR	4.64	0.0375	0.8980	4.64	0.0377	0.8971	4.65	0.0381	0.8965
Proposed method									
Recall(Ours)	**18.46**	**0.5783**	**0.6085**	**18.67**	**0.5839**	**0.6059**	**18.85**	**0.5889**	**0.6012**

Software Low Wall-Reflectance Interval

Appendix Table A9 and Figure A18 report the Software sweep.

Software recovery improves jointly across all three metrics as more wall light returns, with PSNR rising from 17.038 to 20.572 dB; RECALL leads at the 10 recorded conditions.

The low-reflectance curves show a strong, coordinated improvement as more software-interface evidence returns from the wall, and RECALL leads from the weakest recorded condition. The trajectory links signal strength to increasingly clear panel separation and page hierarchy.

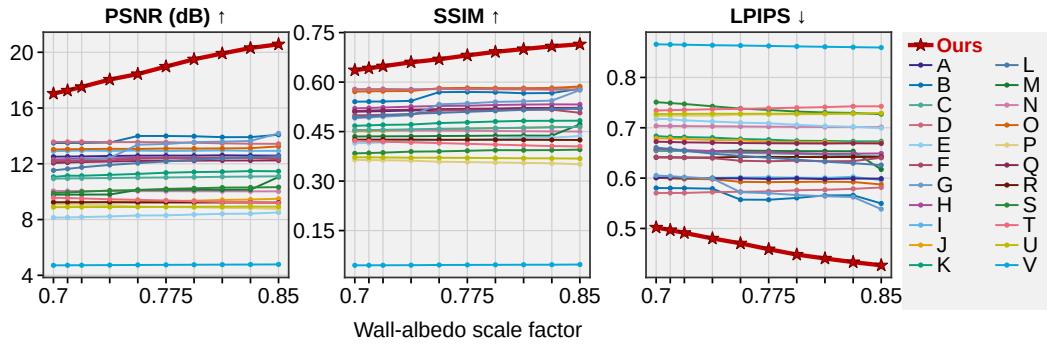


Figure A18: Software Low Wall-Reflectance Interval curves, generated from the same values as Appendix Table A9. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

Table A9: Full Software Low Wall-Reflectance Interval results, with 23 methods and 10 conditions.

Method	(0.7x)			(0.7094x)			(0.7188x)			(0.7375x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	13.49	0.5407	0.5804	13.50	0.5410	0.5801	13.50	0.5412	0.5800	13.52	0.5430	0.5790
UniProcessor	11.06	0.4674	0.6836	11.14	0.4689	0.6818	11.14	0.4703	0.6815	11.21	0.4714	0.6805
AST	9.21	0.4507	0.6789	9.21	0.4512	0.6786	9.23	0.4521	0.6777	9.28	0.4541	0.6757
OneRestore	10.05	0.4552	0.7038	10.05	0.4548	0.7036	10.05	0.4545	0.7034	10.04	0.4538	0.7029
General restoration backbones												
Restormer	12.90	0.5772	0.6006	12.92	0.5777	0.6002	12.94	**0.5789**	0.5982	12.92	**0.5779**	0.6006
X-Restormer	13.03	0.5711	0.6006	13.05	0.5719	0.5996	13.05	0.5725	0.5985	13.07	0.5730	0.5978
NAFNet	12.51	0.5103	0.6009	12.52	0.5111	0.6013	12.53	0.5120	0.6008	12.56	0.5140	0.5998
Pixel2Pixel	9.78	0.4350	0.6547	9.79	0.4354	0.6542	9.79	0.4356	0.6541	9.79	0.4359	0.6535
ConvIR	10.94	0.4535	0.6556	10.95	0.4545	0.6545	10.96	0.4554	0.6535	10.98	0.4569	0.6518
Uformer	8.14	0.4149	0.7178	8.15	0.4155	0.7170	8.18	0.4175	0.7148	8.22	0.4203	0.7124
U-Net	9.09	0.3643	0.7237	9.08	0.3637	0.7237	9.07	0.3631	0.7239	9.04	0.3620	0.7242

Table A9 (continued).

Method	(0.7x)			(0.7094x)			(0.7188x)			(0.7375x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Degradation-specific restoration												
Ada-Deblur	**13.57**	**0.5784**	**0.5705**	**13.57**	**0.5786**	**0.5705**	**13.57**	0.5786	**0.5705**	**13.55**	0.5774	**0.5722**
DehazeFormer	12.31	0.5203	0.6579	12.34	0.5215	0.6570	12.36	0.5230	0.6558	12.39	0.5256	0.6538
OKNet	12.06	0.5122	0.6725	12.09	0.5136	0.6717	12.12	0.5148	0.6710	12.16	0.5164	0.6705
DnCNN	9.24	0.4255	0.6412	9.24	0.4256	0.6412	9.24	0.4256	0.6410	9.24	0.4256	0.6408
Enhancement-oriented restoration												
Retinexformer	12.20	0.4910	0.6052	12.23	0.4926	0.6038	12.29	0.4952	0.6020	12.42	0.4995	0.5992
HVI-CIDNet	12.19	0.4992	0.6418	12.20	0.4999	0.6413	12.21	0.5011	0.6405	12.24	0.5023	0.6397
IRNeXt	11.53	0.4930	0.6607	11.64	0.4955	0.6580	11.75	0.4987	0.6544	11.92	0.5037	0.6486
DEA-Net	9.90	0.3839	0.7509	9.94	0.3851	0.7490	9.99	0.3862	0.7473	10.08	0.3892	0.7427
SFHformer	9.56	0.4222	0.7342	9.54	0.4211	0.7350	9.51	0.4197	0.7356	9.46	0.4172	0.7369
DeepSN-Net	8.89	0.3721	0.7272	8.89	0.3718	0.7273	8.90	0.3716	0.7275	8.90	0.3709	0.7278
DarkIR	4.72	0.0447	0.8658	4.72	0.0448	0.8653	4.72	0.0449	0.8649	4.73	0.0451	0.8640
Proposed method												
Recall(Ours)	**17.04**	**0.6360**	**0.5020**	**17.26**	**0.6417**	**0.4969**	**17.51**	**0.6479**	**0.4913**	**18.04**	**0.6600**	**0.4802**

Table A9 (continued).

Method	(0.7562x)			(0.775x)			(0.7937x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	**13.99**	0.5696	**0.5572**	**13.99**	0.5701	**0.5570**	**13.97**	0.5693	**0.5606**
UniProcessor	11.27	0.4758	0.6778	11.36	0.4780	0.6764	11.41	0.4806	0.6742
AST	9.27	0.4550	0.6752	9.34	0.4589	0.6720	9.35	0.4601	0.6716
OneRestore	10.04	0.4531	0.7027	10.04	0.4525	0.7022	10.03	0.4519	0.7020
General restoration backbones									
Restormer	12.94	0.5791	0.6012	12.92	0.5782	0.6016	12.93	0.5798	0.6009
X-Restormer	13.07	**0.5815**	0.5926	13.10	**0.5824**	0.5921	13.09	**0.5817**	0.5925
NAFNet	12.58	0.5160	0.5995	12.59	0.5178	0.5984	12.59	0.5186	0.5994
Pixel2Pixel	10.13	0.4366	0.6547	10.13	0.4370	0.6540	10.14	0.4376	0.6536
ConvIR	11.00	0.4586	0.6501	11.02	0.4595	0.6491	11.04	0.4606	0.6479
Uformer	8.29	0.4242	0.7101	8.30	0.4248	0.7089	8.36	0.4281	0.7059
U-Net	8.93	0.3585	0.7262	8.90	0.3575	0.7263	8.87	0.3562	0.7267
Degradation-specific restoration									
Ada-Deblur	13.56	0.5790	0.5729	13.54	0.5791	0.5736	13.51	0.5782	0.5758
DehazeFormer	12.42	0.5276	0.6519	12.43	0.5285	0.6516	12.44	0.5305	0.6497
OKNet	12.20	0.5181	0.6697	12.21	0.5192	0.6692	12.22	0.5198	0.6689
DnCNN	9.23	0.4252	0.6423	9.23	0.4252	0.6422	9.22	0.4251	0.6420
Enhancement-oriented restoration									
Retinexformer	13.37	0.5327	0.5721	13.42	0.5354	0.5700	13.55	0.5400	0.5663
HVI-CIDNet	12.36	0.5135	0.6345	12.38	0.5147	0.6335	12.39	0.5142	0.6346
IRNeXt	12.05	0.5067	0.6441	12.17	0.5098	0.6404	12.28	0.5129	0.6368
DEA-Net	10.12	0.3900	0.7382	10.20	0.3918	0.7354	10.24	0.3937	0.7323
SFHformer	9.41	0.4152	0.7374	9.36	0.4129	0.7388	9.31	0.4106	0.7398
DeepSN-Net	8.90	0.3707	0.7278	8.91	0.3703	0.7279	8.92	0.3697	0.7279
DarkIR	4.74	0.0457	0.8634	4.75	0.0459	0.8626	4.76	0.0462	0.8616
Proposed method									
Recall(Ours)	**18.44**	**0.6691**	**0.4704**	**18.98**	**0.6810**	**0.4588**	**19.50**	**0.6917**	**0.4481**

Table A9 (continued).

Method	(0.8125x)			(0.8313x)			(0.85x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	**13.91**	0.5662	0.5657	**13.91**	0.5669	0.5660	14.08	0.5798	0.5496
UniProcessor	11.43	0.4824	0.6739	11.48	0.4827	0.6730	11.46	0.4830	0.6730
AST	9.40	0.4615	0.6719	9.44	0.4637	0.6701	9.49	0.4642	0.6704
OneRestore	10.03	0.4513	0.7014	10.02	0.4507	0.7015	10.02	0.4501	0.7013

Table A9 (continued).

Method	(0.8125x)			(0.8313x)			(0.85x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones									
Restormer	12.96	0.5797	0.6005	12.93	0.5782	0.6026	12.93	0.5853	0.5959
X-Restormer	13.10	**0.5816**	0.5930	13.12	**0.5823**	0.5923	13.25	**0.5868**	0.5874
NAFNet	12.61	0.5199	0.5981	12.59	0.5199	0.5991	12.59	0.5197	0.5990
Pixel2Pixel	10.13	0.4380	0.6535	10.14	0.4376	0.6534	11.05	0.4720	0.6173
ConvIR	11.07	0.4617	0.6465	11.08	0.4629	0.6451	11.10	0.4643	0.6432
Uformer	8.41	0.4310	0.7033	8.42	0.4314	0.7021	8.51	0.4367	0.6993
U-Net	8.84	0.3550	0.7271	8.82	0.3538	0.7275	8.75	0.3511	0.7285
Degradation-specific restoration									
Ada-Deblur	13.47	0.5778	0.5768	13.44	0.5771	0.5786	13.43	0.5770	0.5814
DehazeFormer	12.44	0.5318	0.6484	12.44	0.5325	0.6486	12.40	0.5322	0.6490
OKNet	12.23	0.5213	0.6688	12.23	0.5218	0.6692	12.24	0.5221	0.6688
DnCNN	9.22	0.4251	0.6418	9.22	0.4249	0.6420	9.22	0.4246	0.6421
Enhancement-oriented restoration									
Retinexformer	13.59	0.5417	**0.5641**	13.64	0.5438	**0.5623**	**14.18**	0.5758	**0.5384**
HVI-CIDNet	12.43	0.5164	0.6335	12.44	0.5164	0.6339	12.32	0.5069	0.6404
IRNeXt	12.39	0.5158	0.6326	12.47	0.5179	0.6295	12.55	0.5203	0.6260
DEA-Net	10.29	0.3935	0.7304	10.30	0.3938	0.7295	10.32	0.3953	0.7271
SFHformer	9.26	0.4084	0.7411	9.22	0.4061	0.7426	9.18	0.4051	0.7426
DeepSN-Net	8.93	0.3691	0.7280	8.93	0.3688	0.7283	8.92	0.3681	0.7291
DarkIR	4.77	0.0464	0.8609	4.77	0.0465	0.8601	4.78	0.0471	0.8594
Proposed method									
Recall(Ours)	**19.91**	**0.7001**	**0.4404**	**20.31**	**0.7084**	**0.4331**	**20.57**	**0.7145**	**0.4268**

High Wall-Reflectance Interval

The same qualitative comparison includes both reflectance intervals in Figure A15.

The high-reflectance interval tests stable coarse recovery as strong returned light approaches the reference condition. Browser, Game, and Software each span ten recorded reflectance scales from 1.429x to 1.176x with content and the remaining imaging conditions fixed. The shared interval connects webpage regions, the low-light game canvas, and dense software hierarchy under the same return-strength change.

Browser High Wall-Reflectance Interval

Appendix Table A10 and Figure A19 report the Browser sweep.

Approaching the reference condition from the high-return side improves Browser PSNR from 16.624 to 18.645 dB, while RECALL leads all three metrics at the 10 recorded conditions.

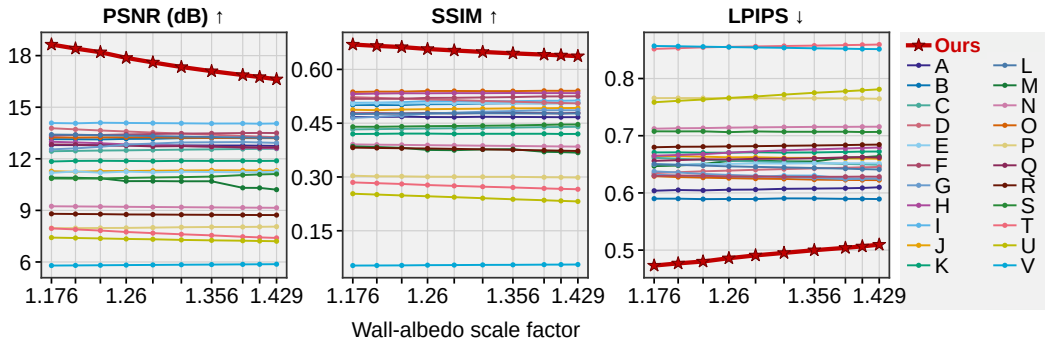


Figure A19: Browser High Wall-Reflectance Interval curves, generated from the same values as Appendix Table A10. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

The high-reflectance curves reveal a second side of evidence strength: reconstruction improves as the excessive return approaches the reference condition, and RECALL leads throughout the transition. Page-level regions and their boundaries therefore remain recoverable across both low- and high-reflectance intervals.

Table A10: Full Browser High Wall-Reflectance Interval results, with 23 methods and 10 conditions.

Method	(1.429x)			(1.41x)			(1.391x)			(1.356x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	13.21	0.5063	**0.5893**	13.20	0.5057	**0.5896**	13.20	0.5055	**0.5896**	13.21	0.5056	**0.5903**
UniProcessor	11.88	0.4200	0.6724	11.87	0.4200	0.6722	11.88	0.4205	0.6716	11.88	0.4205	0.6707
AST	11.31	0.4924	0.6597	11.32	0.4921	0.6600	11.33	0.4917	0.6602	11.33	0.4913	0.6613
OneRestore	9.15	0.3847	0.7158	9.16	0.3851	0.7157	9.16	0.3856	0.7155	9.17	0.3865	0.7154
General restoration backbones												
Restormer	**14.05**	0.5133	0.6248	**14.04**	0.5125	0.6251	**14.05**	0.5126	0.6254	**14.05**	0.5112	0.6303
X-Restormer	13.20	**0.5403**	0.6223	13.21	**0.5403**	0.6225	13.21	**0.5404**	0.6227	13.22	**0.5395**	0.6232
NAFNet	12.75	0.4669	0.6099	12.76	0.4667	0.6087	12.77	0.4670	0.6081	12.77	0.4674	0.6076
Pixel2Pixel	10.21	0.3677	0.6643	10.31	0.3694	0.6624	10.31	0.3702	0.6620	10.69	0.3774	0.6550
ConvIR	12.59	0.4400	0.6492	12.58	0.4394	0.6501	12.57	0.4389	0.6507	12.55	0.4378	0.6523
Uformer	11.25	0.5066	0.6516	11.22	0.5060	0.6519	11.21	0.5060	0.6518	11.23	0.5058	0.6518
U-Net	8.06	0.2985	0.7646	8.04	0.2990	0.7650	8.04	0.2993	0.7652	8.03	0.3004	0.7655
Degradation-specific restoration												
Ada-Deblur	13.26	0.5051	0.6455	13.29	0.5063	0.6447	13.33	0.5075	0.6440	13.40	0.5100	0.6428
DehazeFormer	12.61	0.5338	0.6794	12.63	0.5340	0.6786	12.65	0.5338	0.6777	12.71	0.5342	0.6761
OKNet	12.67	0.4787	0.6617	12.66	0.4774	0.6625	12.68	0.4780	0.6621	12.71	0.4782	0.6605
DnCNN	8.73	0.3725	0.6845	8.73	0.3733	0.6842	8.73	0.3742	0.6836	8.74	0.3757	0.6829
Enhancement-oriented restoration												
Retinexformer	12.93	0.4859	0.6248	12.95	0.4861	0.6245	12.97	0.4860	0.6241	12.96	0.4838	0.6263
HVI-CIDNet	13.50	0.5251	0.6283	13.50	0.5248	0.6285	13.50	0.5246	0.6282	13.48	0.5228	0.6282
IRNeXt	13.22	0.4771	0.6410	13.23	0.4772	0.6416	13.24	0.4773	0.6424	13.27	0.4775	0.6436
DEA-Net	11.12	0.4465	0.7067	11.09	0.4463	0.7064	11.05	0.4453	0.7070	10.97	0.4437	0.7069
SFHformer	7.40	0.2658	0.8594	7.43	0.2669	0.8589	7.47	0.2681	0.8584	7.55	0.2707	0.8576
DeepSN-Net	7.21	0.2318	0.7812	7.22	0.2334	0.7794	7.24	0.2352	0.7777	7.26	0.2378	0.7751
DarkIR	5.87	0.0559	0.8514	5.87	0.0557	0.8517	5.86	0.0556	0.8522	5.85	0.0550	0.8528
Proposed method												
Recall(Ours)	**16.62**	**0.6369**	**0.5096**	**16.76**	**0.6392**	**0.5065**	**16.87**	**0.6412**	**0.5040**	**17.10**	**0.6447**	**0.4998**

Table A10 (continued).

Method	(1.322x)			(1.29x)			(1.26x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	13.20	0.5050	**0.5904**	13.16	0.5032	**0.5893**	13.16	0.5029	**0.5894**
UniProcessor	11.88	0.4205	0.6705	11.86	0.4202	0.6711	11.87	0.4210	0.6703
AST	11.32	0.4905	0.6613	11.30	0.4898	0.6624	11.29	0.4891	0.6622
OneRestore	9.19	0.3872	0.7150	9.20	0.3880	0.7146	9.21	0.3887	0.7141
General restoration backbones									
Restormer	**14.06**	0.5113	0.6303	**14.07**	0.5112	0.6275	**14.08**	0.5115	0.6284
X-Restormer	13.22	**0.5396**	0.6244	13.25	**0.5398**	0.6249	13.25	**0.5397**	0.6258
NAFNet	12.78	0.4678	0.6071	12.78	0.4669	0.6058	12.78	0.4672	0.6056
Pixel2Pixel	10.69	0.3769	0.6552	10.70	0.3747	0.6564	10.70	0.3754	0.6559
ConvIR	12.53	0.4369	0.6535	12.51	0.4359	0.6549	12.49	0.4351	0.6563
Uformer	11.24	0.5061	0.6513	11.21	0.5053	0.6516	11.25	0.5057	0.6507
U-Net	8.02	0.3004	0.7652	8.00	0.3006	0.7656	7.98	0.3008	0.7654
Degradation-specific restoration									
Ada-Deblur	13.47	0.5122	0.6416	13.53	0.5144	0.6404	13.59	0.5164	0.6390
DehazeFormer	12.74	0.5337	0.6744	12.80	0.5339	0.6724	12.84	0.5334	0.6704
OKNet	12.74	0.4786	0.6597	12.72	0.4773	0.6596	12.77	0.4782	0.6584
DnCNN	8.75	0.3771	0.6824	8.76	0.3784	0.6817	8.76	0.3794	0.6813

Table A10 (continued).

Method	(1.322x)			(1.29x)			(1.26x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Enhancement-oriented restoration									
Retinexformer	12.95	0.4819	0.6276	12.88	0.4793	0.6299	12.83	0.4767	0.6314
HVI-CIDNet	13.47	0.5218	0.6283	13.44	0.5208	0.6286	13.42	0.5206	0.6288
IRNeXt	13.29	0.4777	0.6446	13.32	0.4775	0.6455	13.35	0.4773	0.6464
DEA-Net	10.93	0.4429	0.7069	10.91	0.4422	0.7075	10.89	0.4416	0.7063
SFHformer	7.61	0.2729	0.8569	7.68	0.2752	0.8561	7.74	0.2775	0.8554
DeepSN-Net	7.28	0.2409	0.7719	7.32	0.2437	0.7686	7.34	0.2462	0.7660
DarkIR	5.84	0.0548	0.8537	5.83	0.0544	0.8543	5.82	0.0541	0.8550
Proposed method									
Recall(Ours)	**17.34**	**0.6487**	**0.4951**	**17.60**	**0.6528**	**0.4908**	**17.87**	**0.6569**	**0.4858**

Table A10 (continued).

Method	(1.231x)			(1.203x)			(1.176x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	13.13	0.5007	**0.5891**	13.13	0.5009	**0.5899**	13.14	0.5007	**0.5899**
UniProcessor	11.88	0.4210	0.6703	11.88	0.4203	0.6709	11.84	0.4199	0.6708
AST	11.28	0.4881	0.6634	11.24	0.4863	0.6643	11.28	0.4874	0.6643
OneRestore	9.22	0.3895	0.7133	9.23	0.3900	0.7130	9.24	0.3908	0.7123
General restoration backbones									
Restormer	**14.10**	0.5084	0.6276	**14.06**	0.5072	0.6301	**14.08**	0.5069	0.6321
X-Restormer	13.25	**0.5380**	0.6267	13.24	**0.5380**	0.6277	13.24	**0.5371**	0.6292
NAFNet	12.78	0.4681	0.6044	12.80	0.4673	0.6051	12.80	0.4673	0.6038
Pixel2Pixel	10.87	0.3812	0.6505	10.90	0.3836	0.6479	10.90	0.3854	0.6469
ConvIR	12.48	0.4342	0.6580	12.46	0.4335	0.6597	12.44	0.4326	0.6614
Uformer	11.19	0.5045	0.6504	11.26	0.5058	0.6497	11.18	0.5043	0.6503
U-Net	7.98	0.3018	0.7658	7.97	0.3020	0.7659	7.96	0.3034	0.7657
Degradation-specific restoration									
Ada-Deblur	13.65	0.5185	0.6378	13.71	0.5205	0.6362	13.78	0.5226	0.6346
DehazeFormer	12.91	0.5334	0.6678	12.95	0.5325	0.6663	12.99	0.5314	0.6651
OKNet	12.78	0.4771	0.6587	12.82	0.4777	0.6573	12.83	0.4775	0.6561
DnCNN	8.78	0.3801	0.6808	8.79	0.3809	0.6807	8.80	0.3818	0.6798
Enhancement-oriented restoration									
Retinexformer	12.70	0.4711	0.6332	12.61	0.4677	0.6357	12.55	0.4649	0.6377
HVI-CIDNet	13.38	0.5182	0.6299	13.39	0.5179	0.6305	13.33	0.5177	0.6300
IRNeXt	13.37	0.4768	0.6478	13.40	0.4762	0.6489	13.41	0.4755	0.6504
DEA-Net	10.86	0.4408	0.7077	10.85	0.4400	0.7076	10.86	0.4400	0.7077
SFHformer	7.83	0.2805	0.8545	7.89	0.2827	0.8530	7.95	0.2849	0.8517
DeepSN-Net	7.37	0.2486	0.7632	7.39	0.2510	0.7610	7.42	0.2533	0.7585
DarkIR	5.81	0.0535	0.8556	5.80	0.0532	0.8564	5.79	0.0530	0.8569
Proposed method									
Recall(Ours)	**18.20**	**0.6623**	**0.4801**	**18.41**	**0.6655**	**0.4768**	**18.64**	**0.6693**	**0.4730**

Game High Wall-Reflectance Interval

Appendix Table A11 and Figure A20 report the Game sweep.

Game PSNR improves from 16.959 to 18.502 dB as the stronger return approaches the reference condition, while RECALL leads all three metrics at the 10 recorded conditions.

The high-reflectance curves complete the game intensity evidence by tracing recovery as an excessive return approaches the reference condition. RECALL leads at every point, and the joint metric improvement shows that stronger agreement emerges in both overall quality and structural similarity.

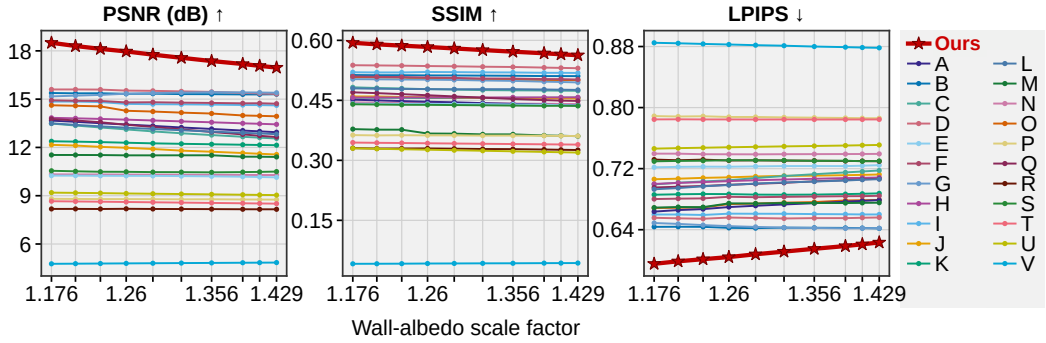


Figure A20: Game High Wall-Reflectance Interval curves, generated from the same values as Appendix Table A11. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

Table A11: Full Game High Wall-Reflectance Interval results, with 23 methods and 10 conditions.

Method	(1.429x)			(1.41x)			(1.391x)			(1.356x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	15.30	0.5106	**0.6417**	15.29	0.5107	0.6421	15.29	0.5107	0.6423	15.31	0.5114	0.6425
UniProcessor	12.14	0.4565	0.6876	12.15	0.4564	0.6871	12.17	0.4561	0.6866	12.20	0.4560	0.6860
AST	11.56	0.4545	0.7123	11.61	0.4549	0.7118	11.65	0.4553	0.7114	11.73	0.4559	0.7108
OneRestore	10.28	0.4407	0.7393	10.29	0.4410	0.7392	10.29	0.4413	0.7391	10.30	0.4420	0.7390
General restoration backbones												
Restormer	14.61	0.5185	0.6600	14.63	0.5188	0.6600	14.64	0.5188	0.6602	14.66	0.5197	0.6605
X-Restormer	13.93	0.5005	0.6790	13.96	0.5006	0.6786	13.99	0.5009	0.6783	14.11	0.5017	0.6762
NAFNet	12.95	0.4373	0.6787	13.00	0.4383	0.6778	13.05	0.4391	0.6767	13.15	0.4412	0.6747
Pixel2Pixel	11.41	0.3603	0.6754	11.42	0.3616	0.6752	11.43	0.3623	0.6749	11.51	0.3649	0.6750
ConvIR	12.56	0.4739	0.7176	12.61	0.4742	0.7163	12.66	0.4746	0.7150	12.77	0.4750	0.7127
Uformer	10.14	0.4371	0.7246	10.16	0.4380	0.7238	10.18	0.4388	0.7233	10.20	0.4396	0.7234
U-Net	8.76	0.3607	0.7860	8.76	0.3610	0.7861	8.77	0.3613	0.7864	8.78	0.3619	0.7868
Degradation-specific restoration												
Ada-Deblur	15.32	**0.5303**	0.6560	15.36	**0.5311**	0.6556	15.39	**0.5319**	0.6551	**15.45**	**0.5334**	0.6551
DehazeFormer	13.43	0.4575	0.7084	13.47	0.4575	0.7079	13.50	0.4574	0.7076	13.56	0.4573	0.7067
OKNet	12.65	0.4486	0.7067	12.72	0.4493	0.7060	12.81	0.4507	0.7049	12.96	0.4534	0.7034
DnCNN	8.16	0.3258	0.7296	8.16	0.3264	0.7300	8.16	0.3271	0.7300	8.17	0.3280	0.7305
Enhancement-oriented restoration												
Retinexformer	**15.40**	0.4947	0.6419	**15.41**	0.4959	**0.6419**	**15.42**	0.4967	**0.6418**	15.43	0.4986	**0.6423**
HVI-CIDNet	14.72	0.5021	0.6844	14.75	0.5029	0.6840	14.74	0.5032	0.6839	14.76	0.5044	0.6835
IRNeXt	12.82	0.4761	0.7062	12.87	0.4766	0.7055	12.91	0.4772	0.7044	12.99	0.4779	0.7031
DEA-Net	10.50	0.4361	0.7300	10.48	0.4364	0.7296	10.47	0.4362	0.7304	10.45	0.4369	0.7301
SFHformer	8.51	0.3393	0.7845	8.52	0.3397	0.7844	8.53	0.3401	0.7844	8.55	0.3407	0.7844
DeepSN-Net	9.04	0.3194	0.7510	9.05	0.3203	0.7507	9.06	0.3211	0.7503	9.09	0.3226	0.7497
DarkIR	4.85	0.0432	0.8783	4.84	0.0431	0.8787	4.84	0.0430	0.8792	4.82	0.0426	0.8800
Proposed method												
Recall(Ours)	**16.96**	**0.5627**	**0.6233**	**17.07**	**0.5651**	**0.6209**	**17.18**	**0.5677**	**0.6186**	**17.37**	**0.5716**	**0.6150**

Table A11 (continued).

Method	(1.322x)			(1.29x)			(1.26x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.31	0.5118	**0.6427**	15.34	0.5122	**0.6421**	15.33	0.5123	**0.6424**
UniProcessor	12.22	0.4559	0.6858	12.25	0.4560	0.6860	12.29	0.4562	0.6866
AST	11.80	0.4562	0.7105	11.90	0.4573	0.7097	11.98	0.4580	0.7086
OneRestore	10.30	0.4424	0.7389	10.31	0.4430	0.7388	10.31	0.4435	0.7388

Table A11 (continued).

Method	(1.322x)			(1.29x)			(1.26x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones									
Restormer	14.68	0.5200	0.6609	14.69	0.5206	0.6609	14.70	0.5209	0.6610
X-Restormer	14.16	0.5022	0.6754	14.23	0.5029	0.6742	14.28	0.5037	0.6736
NAFNet	13.24	0.4430	0.6731	13.34	0.4451	0.6714	13.42	0.4466	0.6697
Pixel2Pixel	11.51	0.3649	0.6750	11.51	0.3667	0.6743	11.51	0.3670	0.6745
ConvIR	12.88	0.4756	0.7103	13.00	0.4768	0.7077	13.12	0.4779	0.7047
Uformer	10.22	0.4405	0.7234	10.23	0.4410	0.7230	10.23	0.4410	0.7225
U-Net	8.77	0.3618	0.7872	8.78	0.3623	0.7877	8.79	0.3624	0.7877
Degradation-specific restoration									
Ada-Deblur	**15.48**	**0.5341**	0.6547	**15.52**	**0.5351**	0.6553	**15.53**	**0.5357**	0.6559
DehazeFormer	13.62	0.4571	0.7057	13.68	0.4573	0.7048	13.73	0.4574	0.7036
OKNet	13.12	0.4566	0.7014	13.27	0.4598	0.7001	13.41	0.4628	0.6988
DnCNN	8.17	0.3283	0.7305	8.18	0.3292	0.7309	8.19	0.3298	0.7307
Enhancement-oriented restoration									
Retinexformer	15.41	0.4996	0.6428	15.38	0.5010	0.6436	15.34	0.5016	0.6447
HVI-CIDNet	14.78	0.5045	0.6830	14.81	0.5061	0.6826	14.80	0.5070	0.6831
IRNeXt	13.07	0.4779	0.7019	13.15	0.4776	0.7005	13.23	0.4780	0.6985
DEA-Net	10.46	0.4376	0.7308	10.47	0.4382	0.7308	10.48	0.4387	0.7310
SFHformer	8.57	0.3414	0.7845	8.59	0.3420	0.7844	8.61	0.3426	0.7845
DeepSN-Net	9.11	0.3240	0.7492	9.12	0.3253	0.7486	9.14	0.3265	0.7480
DarkIR	4.82	0.0425	0.8811	4.81	0.0422	0.8818	4.80	0.0420	0.8827
Proposed method									
Recall(Ours)	**17.57**	**0.5758**	**0.6113**	**17.76**	**0.5797**	**0.6078**	**17.96**	**0.5835**	**0.6041**

Table A11 (continued).

Method	(1.231x)			(1.203x)			(1.176x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.36	0.5128	**0.6437**	15.36	0.5128	**0.6439**	15.38	0.5133	**0.6437**
UniProcessor	12.33	0.4566	0.6868	12.36	0.4567	0.6864	12.38	0.4567	0.6858
AST	12.03	0.4585	0.7079	12.12	0.4597	0.7068	12.16	0.4598	0.7061
OneRestore	10.32	0.4440	0.7389	10.32	0.4443	0.7396	10.33	0.4450	0.7396
General restoration backbones									
Restormer	14.82	0.5198	0.6593	14.85	0.5198	0.6599	14.85	0.5202	0.6599
X-Restormer	14.55	0.5067	0.6691	14.59	0.5072	0.6688	14.62	0.5078	0.6684
NAFNet	13.50	0.4481	0.6670	13.59	0.4500	0.6657	13.66	0.4516	0.6637
Pixel2Pixel	11.53	0.3766	0.6696	11.53	0.3767	0.6697	11.53	0.3781	0.6689
ConvIR	13.24	0.4797	0.7032	13.36	0.4808	0.7016	13.48	0.4826	0.6993
Uformer	10.24	0.4410	0.7226	10.25	0.4413	0.7223	10.25	0.4417	0.7218
U-Net	8.79	0.3628	0.7887	8.80	0.3623	0.7883	8.81	0.3631	0.7889
Degradation-specific restoration									
Ada-Deblur	**15.59**	**0.5367**	0.6543	**15.60**	**0.5373**	0.6549	**15.60**	**0.5378**	0.6556
DehazeFormer	13.77	0.4572	0.7024	13.81	0.4572	0.7013	13.84	0.4571	0.7000
OKNet	13.56	0.4655	0.6973	13.68	0.4680	0.6963	13.77	0.4700	0.6953
DnCNN	8.18	0.3296	0.7318	8.18	0.3296	0.7310	8.18	0.3306	0.7319
Enhancement-oriented restoration									
Retinexformer	15.26	0.5021	0.6460	15.22	0.5025	0.6476	15.17	0.5029	0.6488
HVI-CIDNet	14.89	0.5082	0.6810	14.90	0.5087	0.6807	14.93	0.5098	0.6802
IRNeXt	13.31	0.4784	0.6969	13.40	0.4790	0.6945	13.50	0.4798	0.6930
DEA-Net	10.49	0.4388	0.7304	10.52	0.4395	0.7301	10.55	0.4402	0.7296
SFHformer	8.63	0.3433	0.7845	8.64	0.3438	0.7846	8.66	0.3444	0.7845
DeepSN-Net	9.16	0.3277	0.7474	9.18	0.3289	0.7469	9.19	0.3300	0.7462
DarkIR	4.79	0.0416	0.8834	4.78	0.0414	0.8843	4.77	0.0413	0.8849
Proposed method									
Recall(Ours)	**18.12**	**0.5867**	**0.6014**	**18.30**	**0.5900**	**0.5986**	**18.50**	**0.5939**	**0.5953**

Software High Wall-Reflectance Interval

Appendix Table A12 and Figure A21 report the Software sweep.

Software PSNR improves from 17.407 to 20.099 dB as the stronger return approaches the reference condition, while RECALL leads all three metrics at the 10 recorded conditions.

The high-reflectance results show progressively stronger software-interface recovery as the excessive return approaches the reference condition, while RECALL leads every recorded point. Read with the low interval, they show that dense panel hierarchy remains available across two distinct wall-response regimes.

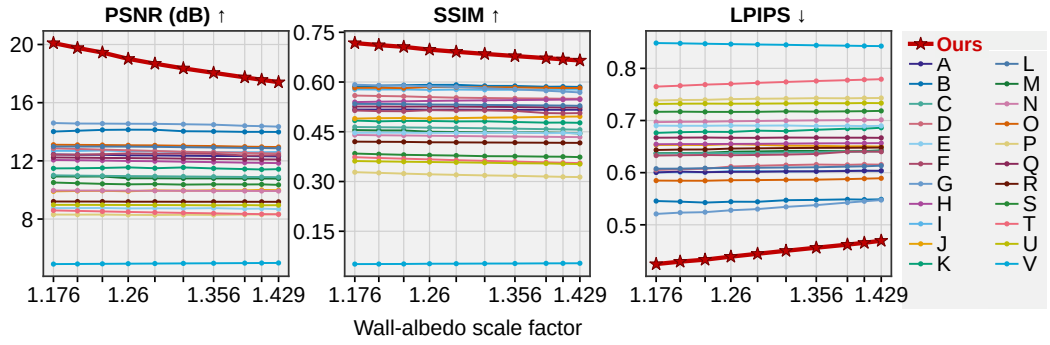


Figure A21: Software High Wall-Reflectance Interval curves, generated from the same values as Appendix Table A12. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

Table A12: Full Software High Wall-Reflectance Interval results, with 23 methods and 10 conditions.

Method	(1.429x)			(1.41x)			(1.391x)			(1.356x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	13.99	**0.5852**	0.5489	13.99	**0.5862**	0.5484	13.99	**0.5858**	0.5488	14.02	**0.5882**	0.5478
UniProcessor	11.43	0.4770	0.6861	11.41	0.4777	0.6844	11.43	0.4775	0.6843	11.48	0.4795	0.6822
AST	9.98	0.4960	0.6501	10.00	0.4956	0.6506	9.97	0.4946	0.6505	9.97	0.4933	0.6515
OneRestore	9.93	0.4339	0.7013	9.93	0.4343	0.7011	9.93	0.4348	0.7007	9.93	0.4356	0.7003
General restoration backbones												
Restormer	12.61	0.5773	0.6031	12.59	0.5772	0.6038	12.59	0.5775	0.6038	12.60	0.5767	0.6027
X-Restormer	12.95	0.5821	0.5892	12.96	0.5820	0.5885	12.98	0.5824	0.5876	13.02	0.5839	0.5866
NAFNet	12.30	0.5164	0.6037	12.32	0.5163	0.6036	12.33	0.5164	0.6032	12.34	0.5160	0.6025
Pixel2Pixel	10.78	0.4450	0.6428	10.78	0.4469	0.6414	10.78	0.4476	0.6410	10.79	0.4484	0.6417
ConvIR	10.88	0.4563	0.6410	10.89	0.4571	0.6404	10.89	0.4579	0.6400	10.91	0.4593	0.6393
Uformer	8.68	0.4451	0.6898	8.71	0.4463	0.6893	8.71	0.4459	0.6898	8.75	0.4479	0.6893
U-Net	8.34	0.3134	0.7431	8.31	0.3141	0.7430	8.31	0.3151	0.7426	8.28	0.3172	0.7428
Degradation-specific restoration												
Ada-Deblur	12.50	0.5496	0.6154	12.52	0.5496	0.6158	12.55	0.5502	0.6150	12.59	0.5509	0.6156
DehazeFormer	11.85	0.5473	0.6567	11.86	0.5468	0.6564	11.88	0.5464	0.6564	11.91	0.5456	0.6562
OKNet	12.10	0.5231	0.6667	12.10	0.5233	0.6670	12.11	0.5239	0.6671	12.13	0.5246	0.6672
DnCNN	9.18	0.4165	0.6481	9.19	0.4167	0.6479	9.19	0.4170	0.6477	9.19	0.4173	0.6475
Enhancement-oriented restoration												
Retinexformer	**14.35**	0.5687	**0.5475**	**14.39**	0.5713	**0.5451**	**14.41**	0.5738	**0.5427**	**14.49**	0.5782	**0.5378**
HVI-CIDNet	12.39	0.5063	0.6401	12.38	0.5057	0.6404	12.37	0.5063	0.6401	12.49	0.5128	0.6359
IRNeXt	12.86	0.5283	0.6133	12.88	0.5291	0.6122	12.89	0.5294	0.6116	12.92	0.5303	0.6104
DEA-Net	10.35	0.3736	0.7185	10.38	0.3748	0.7179	10.38	0.3750	0.7176	10.39	0.3761	0.7171
SFHformer	8.32	0.3556	0.7792	8.34	0.3566	0.7783	8.35	0.3578	0.7774	8.39	0.3601	0.7757
DeepSN-Net	8.95	0.3527	0.7333	8.95	0.3534	0.7335	8.96	0.3545	0.7331	8.94	0.3552	0.7331
DarkIR	4.98	0.0535	0.8427	4.98	0.0533	0.8430	4.97	0.0532	0.8435	4.96	0.0527	0.8442
Proposed method												
Recall(Ours)	**17.41**	**0.6650**	**0.4695**	**17.57**	**0.6685**	**0.4655**	**17.74**	**0.6720**	**0.4620**	**18.05**	**0.6784**	**0.4561**

Table A12 (continued).

Method	(1.322x)			(1.29x)			(1.26x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.04	**0.5884**	0.5472	14.14	**0.5916**	0.5441	14.14	**0.5915**	0.5443
UniProcessor	11.55	0.4816	0.6797	11.49	0.4813	0.6805	11.55	0.4825	0.6781
AST	9.95	0.4925	0.6518	9.97	0.4912	0.6534	9.91	0.4901	0.6546
OneRestore	9.94	0.4364	0.6997	9.94	0.4372	0.6991	9.95	0.4380	0.6985
General restoration backbones									
Restormer	12.61	0.5765	0.6023	12.65	0.5773	0.6029	12.66	0.5763	0.6030
X-Restormer	13.04	0.5842	0.5863	13.07	0.5845	0.5858	13.07	0.5849	0.5855
NAFNet	12.35	0.5163	0.6025	12.37	0.5168	0.6017	12.38	0.5167	0.6016
Pixel2Pixel	10.79	0.4484	0.6416	10.80	0.4492	0.6407	10.80	0.4501	0.6402
ConvIR	10.93	0.4606	0.6385	10.94	0.4616	0.6378	10.95	0.4623	0.6377
Uformer	8.73	0.4467	0.6904	8.74	0.4469	0.6901	8.73	0.4466	0.6903
U-Net	8.29	0.3184	0.7421	8.28	0.3201	0.7417	8.29	0.3217	0.7410
Degradation-specific restoration									
Ada-Deblur	12.63	0.5518	0.6145	12.68	0.5528	0.6133	12.73	0.5545	0.6117
DehazeFormer	11.94	0.5448	0.6557	11.98	0.5440	0.6553	11.99	0.5430	0.6551
OKNet	12.15	0.5252	0.6673	12.18	0.5259	0.6668	12.19	0.5260	0.6669
DnCNN	9.19	0.4177	0.6472	9.19	0.4180	0.6467	9.19	0.4184	0.6462
Enhancement-oriented restoration									
Retinexformer	**14.52**	0.5813	**0.5344**	**14.54**	0.5852	**0.5301**	**14.55**	0.5870	**0.5279**
HVI-CIDNet	12.50	0.5144	0.6347	12.49	0.5141	0.6339	12.51	0.5151	0.6335
IRNeXt	12.94	0.5309	0.6099	12.96	0.5318	0.6094	12.98	0.5322	0.6091
DEA-Net	10.37	0.3764	0.7175	10.40	0.3783	0.7167	10.39	0.3793	0.7165
SFHformer	8.42	0.3623	0.7739	8.45	0.3643	0.7722	8.49	0.3667	0.7703
DeepSN-Net	8.96	0.3567	0.7327	8.96	0.3578	0.7324	8.97	0.3588	0.7322
DarkIR	4.95	0.0526	0.8451	4.94	0.0522	0.8457	4.93	0.0520	0.8465
Proposed method									
Recall(Ours)	**18.36**	**0.6849**	**0.4502**	**18.68**	**0.6913**	**0.4445**	**19.01**	**0.6977**	**0.4390**

Table A12 (continued).

Method	(1.231x)			(1.203x)			(1.176x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.13	**0.5904**	0.5426	14.07	0.5888	0.5444	14.01	0.5864	0.5456
UniProcessor	11.51	0.4828	0.6784	11.49	0.4815	0.6776	11.48	0.4838	0.6763
AST	9.94	0.4914	0.6530	9.93	0.4910	0.6532	9.90	0.4897	0.6531
OneRestore	9.95	0.4388	0.6977	9.96	0.4395	0.6975	9.96	0.4403	0.6969
General restoration backbones									
Restormer	12.72	0.5776	0.6007	12.69	0.5774	0.6009	12.69	0.5777	0.6005
X-Restormer	13.09	0.5817	0.5845	13.10	0.5825	0.5846	13.11	0.5824	0.5848
NAFNet	12.42	0.5171	0.6009	12.42	0.5169	0.6021	12.44	0.5170	0.6004
Pixel2Pixel	10.92	0.4540	0.6380	10.92	0.4542	0.6377	10.92	0.4551	0.6373
ConvIR	10.97	0.4631	0.6373	10.99	0.4636	0.6370	11.00	0.4643	0.6367
Uformer	8.76	0.4471	0.6899	8.75	0.4471	0.6899	8.75	0.4467	0.6902
U-Net	8.31	0.3238	0.7396	8.30	0.3261	0.7393	8.31	0.3281	0.7384
Degradation-specific restoration									
Ada-Deblur	12.77	0.5568	0.6076	12.82	0.5579	0.6066	12.86	0.5592	0.6052
DehazeFormer	12.03	0.5417	0.6548	12.05	0.5407	0.6548	12.06	0.5395	0.6545
OKNet	12.20	0.5259	0.6674	12.22	0.5261	0.6672	12.23	0.5261	0.6670
DnCNN	9.20	0.4195	0.6445	9.20	0.4198	0.6443	9.21	0.4202	0.6435
Enhancement-oriented restoration									
Retinexformer	**14.56**	0.5891	**0.5243**	**14.57**	**0.5899**	**0.5234**	**14.60**	**0.5920**	**0.5209**
HVI-CIDNet	12.46	0.5118	0.6338	12.43	0.5123	0.6334	12.43	0.5141	0.6328
IRNeXt	12.98	0.5334	0.6086	12.98	0.5339	0.6077	12.98	0.5340	0.6076
DEA-Net	10.42	0.3805	0.7166	10.46	0.3823	0.7170	10.51	0.3843	0.7167
SFHformer	8.52	0.3689	0.7688	8.56	0.3709	0.7667	8.59	0.3733	0.7650
DeepSN-Net	8.97	0.3597	0.7324	8.97	0.3607	0.7323	8.98	0.3617	0.7318
DarkIR	4.92	0.0514	0.8472	4.91	0.0511	0.8480	4.90	0.0510	0.8485

Table A12 (continued).

Method	(1.231x)			(1.203x)			(1.176x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Proposed method									
Recall(Ours)	**19.45**	**0.7061**	**0.4332**	**19.76**	**0.7114**	**0.4294**	**20.10**	**0.7175**	**0.4247**

D.1.2 Wall-Texture Variation

Wall-texture variation tests whether screen structure remains readable as wall texture occupies the same frequency range as the dispersed content evidence. Browser, Game, and Software span ten recorded log-gain standard deviations from 0.02 to 0.15; Figure uses its recorded ten-level interval from 0.002 to 0.02. Content and the remaining imaging conditions stay fixed within every sweep.

Browser Wall-Texture Variation

Appendix Table A13 and Figure A22 report the Browser sweep.

As wall texture intensifies, Browser PSNR decreases from 19.486 to 18.350 dB, while RECALL leads all three metrics at the 10 recorded conditions.

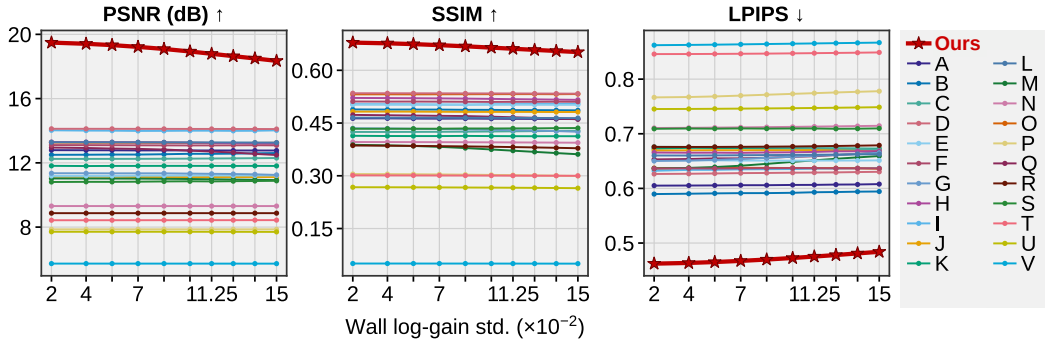


Figure A22: Browser Wall-Texture Variation curves, generated from the same values as Appendix Table A13. Higher PSNR and SSIM and lower LPIPS indicate better restoration. The axis expresses the tabulated dimensionless log-gain standard deviation in 10^{-2} units. Method letters follow Section D.

Table A13: Full Browser Wall-Texture Variation results, with 23 methods and 10 conditions.

Method	(0.02)			(0.04)			(0.055)			(0.07)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	12.50	0.4887	**0.5896**	12.51	0.4883	**0.5903**	12.52	0.4884	**0.5909**	12.52	0.4883	**0.5913**
UniProcessor	11.81	0.4138	0.6727	11.80	0.4131	0.6742	11.81	0.4130	0.6740	11.81	0.4129	0.6738
AST	11.14	0.4824	0.6693	11.15	0.4826	0.6697	11.14	0.4824	0.6699	11.12	0.4821	0.6699
OneRestore	9.31	0.3961	0.7106	9.31	0.3959	0.7109	9.31	0.3958	0.7113	9.31	0.3956	0.7117
General restoration backbones												
Restormer	14.03	0.5037	0.6322	14.01	0.5034	0.6339	14.00	0.5033	0.6340	13.99	0.5026	0.6348
X-Restormer	13.26	0.5315	0.6372	13.25	0.5317	0.6374	13.26	0.5315	0.6376	13.25	0.5317	0.6377
NAFNet	12.79	0.4632	0.6051	12.78	0.4633	0.6053	12.78	0.4627	0.6055	12.77	0.4624	0.6059
Pixel2Pixel	11.03	0.3881	0.6365	11.03	0.3865	0.6375	11.02	0.3848	0.6391	11.02	0.3823	0.6415
ConvIR	12.25	0.4246	0.6761	12.25	0.4247	0.6759	12.25	0.4248	0.6757	12.25	0.4251	0.6753
Uformer	11.18	0.5022	0.6518	11.19	0.5023	0.6514	11.18	0.5022	0.6514	11.20	0.5024	0.6510
U-Net	7.86	0.3050	0.7666	7.86	0.3048	0.7673	7.86	0.3045	0.7683	7.86	0.3039	0.7699
Degradation-specific restoration												
Ada-Deblur	**14.12**	**0.5347**	0.6264	**14.12**	**0.5347**	0.6268	**14.12**	**0.5346**	0.6273	**14.12**	**0.5345**	0.6280
DehazeFormer	13.29	0.5214	0.6656	13.29	0.5210	0.6653	13.29	0.5206	0.6654	13.28	0.5201	0.6651
OKNet	12.95	0.4732	0.6531	12.93	0.4721	0.6538	12.89	0.4713	0.6549	12.87	0.4705	0.6550
DnCNN	8.87	0.3860	0.6759	8.87	0.3855	0.6759	8.87	0.3850	0.6759	8.87	0.3843	0.6761

Table A13 (continued).

Method	(0.02)			(0.04)			(0.055)			(0.07)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Enhancement-oriented restoration												
Retinexformer	11.35	0.4350	0.6502	11.35	0.4344	0.6509	11.35	0.4335	0.6523	11.35	0.4329	0.6538
HVI-CIDNet	13.11	0.5112	0.6364	13.10	0.5110	0.6367	13.10	0.5111	0.6364	13.09	0.5108	0.6366
IRNeXt	13.29	0.4653	0.6602	13.28	0.4652	0.6602	13.28	0.4651	0.6604	13.28	0.4650	0.6607
DEA-Net	10.81	0.4338	0.7091	10.82	0.4339	0.7096	10.82	0.4339	0.7093	10.83	0.4340	0.7098
SFHformer	8.43	0.3013	0.8459	8.43	0.3011	0.8460	8.43	0.3010	0.8462	8.43	0.3009	0.8464
DeepSN-Net	7.71	0.2674	0.7453	7.71	0.2673	0.7454	7.71	0.2672	0.7457	7.71	0.2669	0.7460
DarkIR	5.73	0.0505	0.8621	5.73	0.0505	0.8626	5.73	0.0505	0.8631	5.73	0.0504	0.8637
Proposed method												
Recall(Ours)	**19.49**	**0.6787**	**0.4623**	**19.41**	**0.6767**	**0.4636**	**19.33**	**0.6745**	**0.4652**	**19.22**	**0.6715**	**0.4673**

Table A13 (continued).

Method	(0.085)			(0.1)			(0.1125)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.54	0.4876	**0.5914**	12.56	0.4875	**0.5920**	12.56	0.4868	**0.5930**
UniProcessor	11.81	0.4134	0.6733	11.81	0.4129	0.6731	11.81	0.4126	0.6728
AST	11.12	0.4818	0.6699	11.12	0.4817	0.6699	11.12	0.4818	0.6701
OneRestore	9.31	0.3954	0.7121	9.31	0.3952	0.7126	9.31	0.3949	0.7131
General restoration backbones									
Restormer	13.99	0.5024	0.6351	14.00	0.5034	0.6354	14.00	0.5038	0.6361
X-Restormer	13.25	0.5319	0.6375	13.24	0.5321	0.6373	13.24	0.5322	0.6371
NAFNet	12.77	0.4627	0.6059	12.77	0.4623	0.6063	12.77	0.4620	0.6064
Pixel2Pixel	11.01	0.3788	0.6449	10.99	0.3748	0.6485	10.98	0.3714	0.6514
ConvIR	12.25	0.4255	0.6749	12.26	0.4260	0.6743	12.27	0.4264	0.6738
Uformer	11.20	0.5022	0.6509	11.21	0.5021	0.6508	11.21	0.5021	0.6509
U-Net	7.86	0.3033	0.7715	7.86	0.3025	0.7730	7.86	0.3019	0.7743
Degradation-specific restoration									
Ada-Deblur	**14.11**	**0.5343**	0.6283	**14.11**	**0.5342**	0.6288	**14.11**	**0.5341**	0.6290
DehazeFormer	13.27	0.5195	0.6657	13.26	0.5187	0.6661	13.24	0.5179	0.6668
OKNet	12.83	0.4698	0.6560	12.76	0.4681	0.6578	12.70	0.4664	0.6589
DnCNN	8.87	0.3835	0.6764	8.87	0.3826	0.6767	8.87	0.3817	0.6771
Enhancement-oriented restoration									
Retinexformer	11.35	0.4321	0.6560	11.33	0.4308	0.6580	11.32	0.4294	0.6598
HVI-CIDNet	13.09	0.5105	0.6370	13.08	0.5101	0.6372	13.09	0.5103	0.6371
IRNeXt	13.28	0.4649	0.6610	13.28	0.4647	0.6613	13.27	0.4646	0.6616
DEA-Net	10.84	0.4345	0.7094	10.85	0.4345	0.7097	10.84	0.4348	0.7097
SFHformer	8.43	0.3007	0.8467	8.43	0.3006	0.8472	8.43	0.3004	0.8476
DeepSN-Net	7.71	0.2667	0.7464	7.71	0.2663	0.7468	7.71	0.2660	0.7472
DarkIR	5.73	0.0504	0.8643	5.73	0.0504	0.8649	5.73	0.0503	0.8654
Proposed method									
Recall(Ours)	**19.09**	**0.6682**	**0.4698**	**18.93**	**0.6645**	**0.4727**	**18.79**	**0.6613**	**0.4753**

Table A13 (continued).

Method	(0.125)			(0.1375)			(0.15)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.57	0.4867	**0.5934**	12.59	0.4865	**0.5940**	12.61	0.4861	**0.5943**
UniProcessor	11.81	0.4125	0.6731	11.81	0.4126	0.6730	11.81	0.4125	0.6728
AST	11.12	0.4816	0.6702	11.12	0.4813	0.6702	11.12	0.4814	0.6703
OneRestore	9.31	0.3947	0.7136	9.31	0.3944	0.7141	9.31	0.3941	0.7146
General restoration backbones									
Restormer	13.99	0.5040	0.6365	14.00	0.5041	0.6370	14.02	0.5047	0.6372
X-Restormer	13.24	0.5322	0.6371	13.24	0.5320	0.6368	13.25	0.5324	0.6361
NAFNet	12.77	0.4619	0.6070	12.77	0.4615	0.6072	12.77	0.4612	0.6079
Pixel2Pixel	10.96	0.3680	0.6542	10.95	0.3646	0.6568	10.93	0.3613	0.6593
ConvIR	12.28	0.4269	0.6731	12.29	0.4275	0.6723	12.30	0.4280	0.6714
Uformer	11.21	0.5019	0.6510	11.22	0.5018	0.6510	11.22	0.5017	0.6513
U-Net	7.86	0.3011	0.7756	7.86	0.3004	0.7768	7.86	0.2996	0.7779

Table A13 (continued).

Method	(0.125)			(0.1375)			(0.15)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Degradation-specific restoration									
Ada-Deblur	**14.11**	**0.5339**	0.6293	**14.11**	**0.5337**	0.6299	**14.10**	**0.5335**	0.6304
DehazeFormer	13.23	0.5173	0.6678	13.21	0.5166	0.6680	13.19	0.5160	0.6683
OKNet	12.64	0.4649	0.6611	12.56	0.4629	0.6633	12.49	0.4608	0.6658
DnCNN	8.87	0.3807	0.6776	8.87	0.3796	0.6782	8.87	0.3784	0.6788
Enhancement-oriented restoration									
Retinexformer	11.30	0.4284	0.6613	11.29	0.4272	0.6631	11.25	0.4252	0.6655
HVI-CIDNet	13.09	0.5104	0.6367	13.10	0.5107	0.6367	13.09	0.5105	0.6366
IRNeXt	13.27	0.4644	0.6619	13.26	0.4642	0.6622	13.26	0.4641	0.6625
DEA-Net	10.86	0.4349	0.7091	10.87	0.4354	0.7093	10.88	0.4358	0.7098
SFHformer	8.43	0.3002	0.8480	8.43	0.3001	0.8484	8.43	0.3000	0.8489
DeepSN-Net	7.71	0.2657	0.7476	7.70	0.2653	0.7481	7.70	0.2648	0.7487
DarkIR	5.73	0.0503	0.8659	5.73	0.0502	0.8664	5.73	0.0502	0.8668
Proposed method									
Recall(Ours)	**18.64**	**0.6581**	**0.4781**	**18.50**	**0.6550**	**0.4810**	**18.35**	**0.6518**	**0.4840**

The wall-texture curves pose a frequency competition: stable wall edges grow stronger while webpage boundaries remain weak and dispersed. RECALL preserves its lead throughout the interval, supporting recovery of page layout as competing wall texture intensifies.

CASR relates frequency responses to the global content anchor and organizes dispersed screen evidence alongside wall texture. The paired trajectory extends the complete model's advantage in coarse webpage recovery across every recorded texture level.

Figure-Content Wall-Texture Variation

Appendix Table A14 and Figure A23 report the Figure sweep.

Figure PSNR remains nearly level as wall texture intensifies, from 19.938 to 19.889 dB, while RECALL leads all three metrics at the 10 recorded conditions.

Chart axes, curves, and small color regions supply weak, compact screen cues alongside wall texture. RECALL's nearly level trajectory and leading rank support stable recovery of overall chart brightness, color, and layout as wall texture becomes more prominent.

The paired result extends the comparison from broad webpage regions to the compact brightness, color, and layout of chart content.

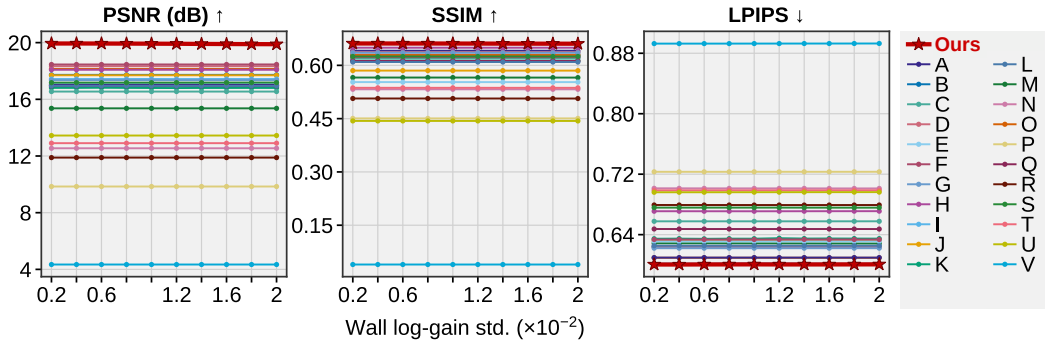


Figure A23: Figure-Content Wall-Texture Variation curves, generated from the same values as Appendix Table A14. Higher PSNR and SSIM and lower LPIPS indicate better restoration. The axis expresses the tabulated dimensionless log-gain standard deviation in 10^{-2} units. Method letters follow Section D.

Table A14: Full Figure-Content Wall-Texture Variation results, with 23 methods and 10 conditions.

Method	(0.002)			(0.004)			(0.006)			(0.008)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	17.73	0.6283	0.6240	17.73	0.6283	0.6240	17.73	0.6283	0.6240	17.73	0.6283	0.6240
UniProcessor	16.81	0.6132	0.6346	16.81	0.6133	0.6347	16.82	0.6134	0.6345	16.81	0.6133	0.6347
AST	17.70	0.5853	0.6322	17.70	0.5853	0.6323	17.70	0.5852	0.6322	17.70	0.5852	0.6323
OneRestore	12.54	0.5326	0.7013	12.54	0.5326	0.7013	12.54	0.5326	0.7012	12.54	0.5326	0.7012
General restoration backbones												
Restormer	17.43	0.6231	**0.6017**	17.43	0.6231	**0.6018**	17.43	0.6230	**0.6015**	17.43	0.6231	**0.6020**
X-Restormer	18.14	0.6291	0.6094	18.14	0.6291	0.6094	18.14	0.6291	0.6094	18.14	0.6291	0.6094
NAFNet	17.02	0.6411	0.6096	17.02	0.6411	0.6096	17.02	0.6411	0.6096	17.02	0.6411	0.6096
Pixel2Pixel	15.36	0.5657	0.6285	15.36	0.5657	0.6285	15.36	0.5657	0.6285	15.36	0.5657	0.6285
ConvIR	16.55	0.6196	0.6576	16.55	0.6196	0.6576	16.55	0.6196	0.6576	16.55	0.6196	0.6576
Uformer	17.15	0.5529	0.6311	17.15	0.5529	0.6311	17.15	0.5529	0.6311	17.15	0.5528	0.6311
U-Net	9.85	0.4507	0.7231	9.85	0.4507	0.7231	9.85	0.4507	0.7231	9.85	0.4507	0.7231
Degradation-specific restoration												
Ada-Deblur	18.33	0.6368	0.6236	18.33	0.6368	0.6236	18.33	0.6368	0.6236	18.34	0.6369	0.6236
DehazeFormer	18.08	**0.6497**	0.6710	18.08	**0.6497**	0.6710	18.09	**0.6497**	0.6710	18.08	**0.6497**	0.6709
OKNet	16.94	0.6124	0.6475	16.94	0.6124	0.6474	16.94	0.6123	0.6474	16.94	0.6123	0.6475
DnCNN	11.89	0.5067	0.6792	11.89	0.5067	0.6792	11.89	0.5067	0.6792	11.89	0.5067	0.6792
Enhancement-oriented restoration												
Retinexformer	17.35	0.6354	0.6221	17.35	0.6354	0.6221	17.35	0.6354	0.6221	17.35	0.6354	0.6221
HVI-CIDNet	**18.46**	0.6231	0.6335	**18.46**	0.6231	0.6335	**18.46**	0.6231	0.6335	**18.46**	0.6231	0.6336
IRNeXt	16.95	0.6094	0.6253	16.95	0.6094	0.6253	16.95	0.6094	0.6253	16.95	0.6094	0.6253
DEA-Net	17.18	0.6250	0.6758	17.18	0.6250	0.6758	17.18	0.6250	0.6758	17.18	0.6250	0.6758
SFHformer	12.91	0.5368	0.6986	12.91	0.5368	0.6986	12.91	0.5368	0.6986	12.91	0.5368	0.6987
DeepSN-Net	13.44	0.4436	0.6961	13.44	0.4436	0.6961	13.44	0.4436	0.6961	13.44	0.4436	0.6961
DarkIR	4.34	0.0394	0.8928	4.34	0.0394	0.8927	4.34	0.0394	0.8928	4.34	0.0394	0.8928
Proposed method												
Recall(Ours)	**19.94**	**0.6615**	**0.6005**	**19.94**	**0.6615**	**0.6005**	**19.94**	**0.6615**	**0.6006**	**19.93**	**0.6615**	**0.6006**

Table A14 (continued).

Method	(0.01)			(0.012)			(0.014)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	17.73	0.6282	0.6241	17.73	0.6282	0.6241	17.73	0.6282	0.6241
UniProcessor	16.80	0.6133	0.6347	16.80	0.6132	0.6353	16.80	0.6131	0.6348
AST	17.70	0.5852	0.6323	17.70	0.5852	0.6323	17.70	0.5852	0.6323
OneRestore	12.54	0.5326	0.7012	12.54	0.5326	0.7012	12.54	0.5326	0.7012
General restoration backbones									
Restormer	17.43	0.6231	**0.6020**	17.43	0.6233	**0.6021**	17.43	0.6233	**0.6018**
X-Restormer	18.14	0.6291	0.6094	18.14	0.6291	0.6094	18.14	0.6291	0.6094
NAFNet	17.02	0.6411	0.6096	17.02	0.6411	0.6096	17.02	0.6411	0.6096
Pixel2Pixel	15.36	0.5657	0.6285	15.36	0.5656	0.6284	15.36	0.5656	0.6284
ConvIR	16.55	0.6196	0.6576	16.55	0.6196	0.6576	16.55	0.6196	0.6576
Uformer	17.15	0.5528	0.6311	17.15	0.5528	0.6311	17.15	0.5528	0.6311
U-Net	9.85	0.4507	0.7232	9.85	0.4507	0.7232	9.85	0.4507	0.7232
Degradation-specific restoration									
Ada-Deblur	18.34	0.6369	0.6236	18.34	0.6369	0.6236	18.34	0.6368	0.6237
DehazeFormer	18.08	**0.6497**	0.6709	18.08	**0.6497**	0.6710	18.08	**0.6497**	0.6710
OKNet	16.94	0.6124	0.6474	16.94	0.6123	0.6474	16.95	0.6124	0.6475
DnCNN	11.89	0.5067	0.6792	11.89	0.5067	0.6792	11.89	0.5067	0.6792
Enhancement-oriented restoration									
Retinexformer	17.35	0.6354	0.6221	17.35	0.6354	0.6221	17.35	0.6354	0.6221
HVI-CIDNet	**18.46**	0.6231	0.6335	**18.46**	0.6231	0.6336	**18.46**	0.6231	0.6336
IRNeXt	16.95	0.6093	0.6253	16.95	0.6093	0.6253	16.95	0.6093	0.6253
DEA-Net	17.18	0.6250	0.6758	17.18	0.6250	0.6758	17.18	0.6250	0.6757
SFHformer	12.91	0.5368	0.6987	12.91	0.5367	0.6986	12.91	0.5367	0.6987
DeepSN-Net	13.44	0.4436	0.6961	13.44	0.4435	0.6962	13.44	0.4435	0.6962
DarkIR	4.34	0.0394	0.8928	4.34	0.0394	0.8928	4.34	0.0394	0.8928

Table A14 (continued).

Method	(0.01)			(0.012)			(0.014)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Proposed method									
Recall(Ours)	**19.93**	**0.6614**	**0.6007**	**19.92**	**0.6613**	**0.6006**	**19.91**	**0.6611**	**0.6006**

Table A14 (continued).

Method	(0.016)			(0.018)			(0.02)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	17.73	0.6282	0.6241	17.73	0.6282	0.6241	17.73	0.6282	0.6241
UniProcessor	16.80	0.6133	0.6349	16.81	0.6134	0.6348	16.80	0.6132	0.6347
AST	17.70	0.5852	0.6323	17.70	0.5852	0.6324	17.70	0.5852	0.6324
OneRestore	12.54	0.5326	0.7012	12.54	0.5326	0.7011	12.54	0.5326	0.7012
General restoration backbones									
Restormer	17.43	0.6233	**0.6017**	17.43	0.6231	**0.6015**	17.43	0.6233	**0.6017**
X-Restormer	18.14	0.6291	0.6094	18.14	0.6291	0.6094	18.14	0.6291	0.6094
NAFNet	17.02	0.6411	0.6096	17.02	0.6411	0.6096	17.02	0.6411	0.6096
Pixel2Pixel	15.36	0.5656	0.6283	15.36	0.5656	0.6283	15.36	0.5655	0.6282
ConvIR	16.55	0.6196	0.6576	16.55	0.6196	0.6577	16.55	0.6196	0.6577
Uformer	17.15	0.5528	0.6311	17.15	0.5528	0.6311	17.15	0.5528	0.6311
U-Net	9.85	0.4507	0.7232	9.85	0.4507	0.7232	9.85	0.4507	0.7232
Degradation-specific restoration									
Ada-Deblur	18.34	0.6369	0.6237	18.34	0.6368	0.6237	18.34	0.6369	0.6237
DehazeFormer	18.08	**0.6497**	0.6710	18.08	**0.6497**	0.6710	18.08	**0.6497**	0.6711
OKNet	16.95	0.6124	0.6475	16.94	0.6123	0.6474	16.94	0.6123	0.6474
DnCNN	11.89	0.5067	0.6792	11.89	0.5066	0.6792	11.89	0.5066	0.6792
Enhancement-oriented restoration									
Retinexformer	17.35	0.6354	0.6221	17.35	0.6354	0.6221	17.35	0.6354	0.6221
HVI-CIDNet	**18.46**	0.6231	0.6336	**18.46**	0.6231	0.6336	**18.46**	0.6231	0.6336
IRNeXt	16.95	0.6093	0.6253	16.95	0.6093	0.6253	16.95	0.6093	0.6254
DEA-Net	17.18	0.6250	0.6757	17.18	0.6250	0.6757	17.18	0.6250	0.6757
SFHformer	12.91	0.5367	0.6987	12.91	0.5367	0.6987	12.91	0.5367	0.6987
DeepSN-Net	13.44	0.4435	0.6962	13.44	0.4435	0.6962	13.44	0.4435	0.6963
DarkIR	4.34	0.0394	0.8929	4.34	0.0394	0.8929	4.34	0.0394	0.8929
Proposed method									
Recall(Ours)	**19.90**	**0.6611**	**0.6006**	**19.89**	**0.6610**	**0.6006**	**19.89**	**0.6609**	**0.6007**

Game Wall-Texture Variation

Appendix Table A15 and Figure A24 report the Game sweep.

Game PSNR decreases from 19.145 to 18.267 dB as wall texture intensifies, while RECALL leads all three metrics at the 10 recorded conditions.

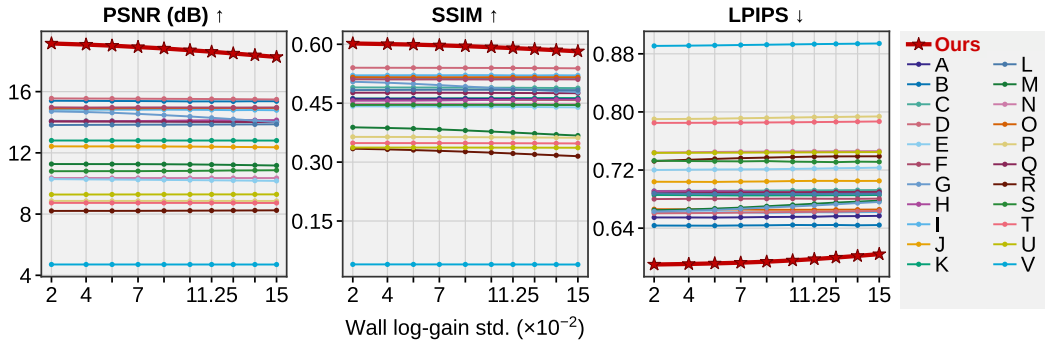


Figure A24: Game Wall-Texture Variation curves, generated from the same values as Appendix Table A15. Higher PSNR and SSIM and lower LPIPS indicate better restoration. The axis expresses the tabulated dimensionless log-gain standard deviation in 10^{-2} units. Method letters follow Section D.

Increasing wall texture intensifies competition between weak object-contour cues and stable local wall edges, and RECALL retains its lead as that competition intensifies. The recovered structure therefore stays aligned with the canvas and principal objects across the recorded texture range.

RECALL preserves the strongest coarse game reconstruction across the recorded wall-texture range.

Table A15: Full Game Wall-Texture Variation results, with 23 methods and 10 conditions.

Method	(0.02)			(0.04)			(0.055)			(0.07)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	15.40	0.5154	**0.6436**	15.40	0.5151	**0.6435**	15.39	0.5149	**0.6434**	15.38	0.5148	**0.6437**
UniProcessor	12.81	0.4618	0.6857	12.81	0.4620	0.6854	12.81	0.4620	0.6851	12.81	0.4622	0.6850
AST	12.43	0.4586	0.7039	12.42	0.4584	0.7038	12.42	0.4585	0.7036	12.42	0.4586	0.7041
OneRestore	10.36	0.4483	0.7440	10.36	0.4482	0.7445	10.36	0.4481	0.7449	10.36	0.4480	0.7452
General restoration backbones												
Restormer	14.82	0.5209	0.6617	14.82	0.5210	0.6613	14.82	0.5212	0.6617	14.82	0.5211	0.6618
X-Restormer	14.91	0.5162	0.6661	14.91	0.5159	0.6659	14.91	0.5158	0.6659	14.92	0.5158	0.6656
NAFNet	14.08	0.4612	0.6547	14.07	0.4612	0.6547	14.07	0.4611	0.6546	14.07	0.4612	0.6549
Pixel2Pixel	11.27	0.3886	0.6647	11.27	0.3869	0.6658	11.27	0.3854	0.6669	11.26	0.3832	0.6683
ConvIR	14.09	0.4901	0.6912	14.08	0.4899	0.6914	14.08	0.4899	0.6914	14.07	0.4898	0.6915
Uformer	10.28	0.4421	0.7201	10.27	0.4417	0.7205	10.26	0.4416	0.7207	10.24	0.4415	0.7209
U-Net	8.86	0.3642	0.7901	8.86	0.3641	0.7904	8.86	0.3639	0.7907	8.86	0.3637	0.7913
Degradation-specific restoration												
Ada-Deblur	**15.56**	**0.5403**	0.6604	**15.55**	**0.5401**	0.6606	**15.54**	**0.5400**	0.6609	**15.54**	**0.5399**	0.6614
DehazeFormer	14.07	0.4563	0.6910	14.07	0.4564	0.6910	14.07	0.4566	0.6910	14.08	0.4570	0.6906
OKNet	14.05	0.4766	0.6883	14.05	0.4767	0.6887	14.04	0.4766	0.6888	14.04	0.4765	0.6889
DnCNN	8.21	0.3341	0.7323	8.21	0.3323	0.7342	8.21	0.3306	0.7353	8.21	0.3287	0.7364
Enhancement-oriented restoration												
Retinexformer	14.71	0.5045	0.6631	14.67	0.5021	0.6641	14.62	0.4993	0.6651	14.55	0.4960	0.6667
HVI-CIDNet	14.97	0.5108	0.6800	14.96	0.5104	0.6803	14.96	0.5104	0.6804	14.97	0.5105	0.6805
IRNeXt	13.82	0.4834	0.6880	13.83	0.4836	0.6873	13.83	0.4839	0.6871	13.84	0.4842	0.6869
DEA-Net	10.80	0.4455	0.7329	10.80	0.4456	0.7324	10.81	0.4457	0.7322	10.81	0.4455	0.7319
SFHformer	8.73	0.3484	0.7849	8.73	0.3484	0.7850	8.73	0.3484	0.7851	8.73	0.3483	0.7853
DeepSN-Net	9.28	0.3370	0.7437	9.28	0.3370	0.7437	9.28	0.3370	0.7438	9.28	0.3370	0.7440
DarkIR	4.71	0.0396	0.8909	4.71	0.0396	0.8913	4.71	0.0395	0.8916	4.71	0.0395	0.8921
Proposed method												
Recall(Ours)	**19.15**	**0.6020**	**0.5899**	**19.07**	**0.6005**	**0.5907**	**19.00**	**0.5991**	**0.5915**	**18.91**	**0.5973**	**0.5925**

Table A15 (continued).

Method	(0.085)			(0.1)			(0.1125)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.38	0.5146	**0.6439**	15.36	0.5147	**0.6444**	15.36	0.5146	**0.6442**
UniProcessor	12.81	0.4625	0.6850	12.81	0.4627	0.6851	12.81	0.4628	0.6851
AST	12.42	0.4585	0.7043	12.41	0.4585	0.7048	12.40	0.4583	0.7051
OneRestore	10.36	0.4479	0.7454	10.36	0.4477	0.7456	10.35	0.4476	0.7457
General restoration backbones									
Restormer	14.82	0.5214	0.6612	14.81	0.5213	0.6615	14.80	0.5208	0.6619
X-Restormer	14.92	0.5159	0.6653	14.93	0.5160	0.6653	14.93	0.5160	0.6654
NAFNet	14.07	0.4611	0.6553	14.07	0.4608	0.6555	14.08	0.4607	0.6557
Pixel2Pixel	11.26	0.3806	0.6701	11.24	0.3777	0.6721	11.23	0.3752	0.6736
ConvIR	14.07	0.4897	0.6917	14.06	0.4894	0.6919	14.05	0.4892	0.6920
Uformer	10.23	0.4414	0.7211	10.22	0.4411	0.7216	10.21	0.4407	0.7219
U-Net	8.86	0.3635	0.7918	8.86	0.3632	0.7923	8.86	0.3629	0.7927
Degradation-specific restoration									
Ada-Deblur	**15.53**	**0.5398**	0.6619	**15.52**	**0.5397**	0.6622	**15.52**	**0.5396**	0.6625
DehazeFormer	14.09	0.4577	0.6899	14.11	0.4582	0.6893	14.13	0.4585	0.6891
OKNet	14.03	0.4764	0.6891	14.03	0.4762	0.6894	14.02	0.4760	0.6897
DnCNN	8.22	0.3265	0.7371	8.22	0.3241	0.7379	8.23	0.3219	0.7385

Table A15 (continued).

Method	(0.085)			(0.1)			(0.1125)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Enhancement-oriented restoration									
Retinexformer	14.46	0.4925	0.6684	14.38	0.4888	0.6698	14.29	0.4861	0.6713
HVI-CIDNet	14.97	0.5105	0.6805	14.96	0.5103	0.6807	14.96	0.5107	0.6805
IRNeXt	13.84	0.4841	0.6870	13.85	0.4840	0.6870	13.85	0.4839	0.6871
DEA-Net	10.82	0.4456	0.7323	10.82	0.4456	0.7315	10.83	0.4456	0.7313
SFHformer	8.73	0.3482	0.7855	8.73	0.3481	0.7858	8.73	0.3480	0.7860
DeepSN-Net	9.28	0.3370	0.7441	9.29	0.3369	0.7442	9.29	0.3368	0.7443
DarkIR	4.71	0.0395	0.8925	4.71	0.0394	0.8930	4.71	0.0394	0.8933
Proposed method									
Recall(Ours)	**18.82**	**0.5952**	**0.5938**	**18.71**	**0.5925**	**0.5956**	**18.61**	**0.5902**	**0.5975**

Table A15 (continued).

Method	(0.125)			(0.1375)			(0.15)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.36	0.5148	**0.6444**	15.37	0.5149	**0.6440**	15.37	0.5150	**0.6443**
UniProcessor	12.81	0.4630	0.6853	12.80	0.4631	0.6853	12.80	0.4630	0.6857
AST	12.39	0.4582	0.7051	12.38	0.4581	0.7050	12.36	0.4578	0.7051
OneRestore	10.35	0.4475	0.7459	10.35	0.4473	0.7460	10.35	0.4471	0.7461
General restoration backbones									
Restormer	14.79	0.5207	0.6618	14.80	0.5211	0.6620	14.78	0.5208	0.6622
X-Restormer	14.93	0.5161	0.6654	14.93	0.5161	0.6655	14.93	0.5161	0.6657
NAFNet	14.07	0.4604	0.6564	14.07	0.4603	0.6566	14.07	0.4601	0.6569
Pixel2Pixel	11.21	0.3727	0.6752	11.19	0.3701	0.6765	11.17	0.3675	0.6779
ConvIR	14.05	0.4890	0.6922	14.04	0.4887	0.6924	14.03	0.4884	0.6924
Uformer	10.20	0.4403	0.7225	10.18	0.4397	0.7228	10.17	0.4393	0.7233
U-Net	8.86	0.3626	0.7931	8.86	0.3623	0.7935	8.86	0.3620	0.7938
Degradation-specific restoration									
Ada-Deblur	**15.51**	**0.5393**	0.6627	**15.50**	**0.5391**	0.6632	**15.49**	**0.5388**	0.6636
DehazeFormer	14.14	0.4587	0.6889	14.14	0.4587	0.6888	14.14	0.4587	0.6889
OKNet	14.02	0.4758	0.6898	14.01	0.4756	0.6898	14.01	0.4754	0.6900
DnCNN	8.23	0.3196	0.7388	8.24	0.3173	0.7389	8.24	0.3150	0.7389
Enhancement-oriented restoration									
Retinexformer	14.20	0.4833	0.6729	14.10	0.4806	0.6745	14.01	0.4781	0.6761
HVI-CIDNet	14.96	0.5106	0.6804	14.96	0.5107	0.6804	14.96	0.5105	0.6806
IRNeXt	13.86	0.4837	0.6872	13.86	0.4834	0.6873	13.86	0.4833	0.6873
DEA-Net	10.85	0.4456	0.7309	10.86	0.4454	0.7315	10.86	0.4453	0.7313
SFHformer	8.73	0.3478	0.7863	8.73	0.3477	0.7866	8.73	0.3475	0.7869
DeepSN-Net	9.29	0.3367	0.7445	9.29	0.3367	0.7446	9.29	0.3365	0.7447
DarkIR	4.71	0.0394	0.8937	4.71	0.0393	0.8939	4.71	0.0393	0.8942
Proposed method									
Recall(Ours)	**18.49**	**0.5876**	**0.5995**	**18.38**	**0.5849**	**0.6018**	**18.27**	**0.5821**	**0.6042**

Software Wall-Texture Variation

Appendix Table A16 and Figure A25 report the Software sweep.

Increasing wall texture lowers Software PSNR from 21.548 to 19.569 dB, while RECALL leads all three metrics at the 10 recorded conditions.

Increasing wall texture places cues from many interface boundaries in direct competition with stable wall edges, and RECALL preserves the leading trajectory as texture intensifies. Dense panels and tool regions therefore remain tied to the screen hierarchy across the recorded frequency interference.

The sweep extends the complete model's advantage to a densely partitioned screen under increasing wall texture.

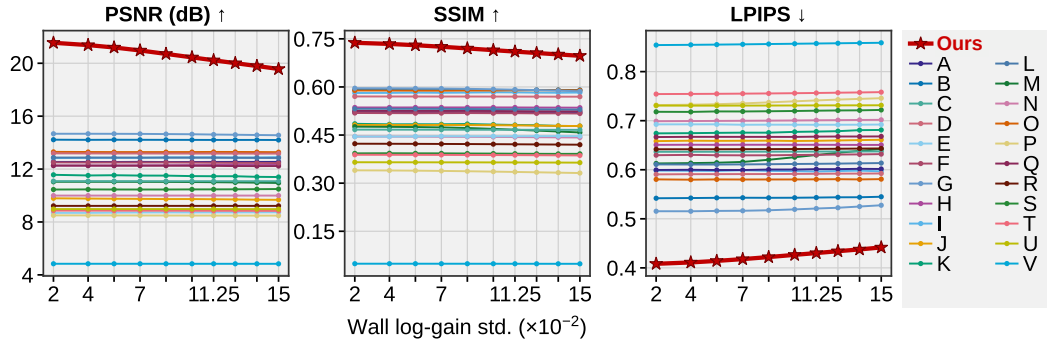


Figure A25: Software Wall-Texture Variation curves, generated from the same values as Appendix Table A16. Higher PSNR and SSIM and lower LPIPS indicate better restoration. The axis expresses the tabulated dimensionless log-gain standard deviation in 10^{-2} units. Method letters follow Section D.

Table A16: Full Software Wall-Texture Variation results, with 23 methods and 10 conditions.

Method	(0.02)			(0.04)			(0.055)			(0.07)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	14.22	0.5906	0.5419	14.21	0.5904	0.5423	14.22	0.5902	0.5428	14.21	0.5903	0.5430
UniProcessor	11.57	0.4851	0.6742	11.52	0.4835	0.6746	11.54	0.4837	0.6752	11.51	0.4836	0.6756
AST	9.79	0.4815	0.6584	9.77	0.4815	0.6592	9.76	0.4812	0.6589	9.75	0.4815	0.6591
OneRestore	10.00	0.4454	0.6989	10.00	0.4452	0.6993	10.00	0.4450	0.6995	10.00	0.4447	0.6998
General restoration backbones												
Restormer	12.83	0.5812	0.5982	12.84	0.5816	0.5978	12.85	0.5823	0.5975	12.85	0.5818	0.5989
X-Restormer	13.30	0.5889	0.5804	13.29	0.5888	0.5797	13.28	0.5886	0.5803	13.28	0.5884	0.5801
NAFNet	12.54	0.5210	0.5995	12.54	0.5210	0.5999	12.54	0.5208	0.5994	12.54	0.5209	0.5994
Pixel2Pixel	11.04	0.4762	0.6129	11.04	0.4756	0.6135	11.04	0.4750	0.6143	11.03	0.4740	0.6159
ConvIR	11.08	0.4670	0.6366	11.08	0.4669	0.6366	11.08	0.4668	0.6367	11.08	0.4667	0.6368
Uformer	8.69	0.4453	0.6925	8.69	0.4452	0.6926	8.71	0.4456	0.6926	8.72	0.4463	0.6917
U-Net	8.50	0.3400	0.7318	8.50	0.3396	0.7326	8.49	0.3390	0.7336	8.49	0.3382	0.7352
Degradation-specific restoration												
Ada-Deblur	13.19	0.5703	0.5906	13.18	0.5703	0.5910	13.18	0.5702	0.5910	13.18	0.5702	0.5912
DehazeFormer	12.26	0.5360	0.6508	12.27	0.5360	0.6510	12.27	0.5361	0.6508	12.28	0.5361	0.6510
OKNet	12.27	0.5255	0.6667	12.26	0.5255	0.6671	12.26	0.5253	0.6670	12.25	0.5253	0.6670
DnCNN	9.22	0.4230	0.6418	9.22	0.4228	0.6418	9.22	0.4226	0.6418	9.22	0.4223	0.6419
Enhancement-oriented restoration												
Retinexformer	**14.67**	**0.5960**	**0.5154**	**14.67**	**0.5957**	**0.5154**	**14.67**	**0.5954**	**0.5161**	**14.66**	**0.5950**	**0.5164**
HVI-CIDNet	12.51	0.5188	0.6297	12.50	0.5184	0.6303	12.50	0.5181	0.6296	12.50	0.5183	0.6294
IRNeXt	12.87	0.5319	0.6109	12.87	0.5319	0.6107	12.87	0.5317	0.6106	12.87	0.5316	0.6109
DEA-Net	10.45	0.3929	0.7181	10.46	0.3933	0.7179	10.46	0.3930	0.7189	10.45	0.3929	0.7188
SFHformer	8.86	0.3885	0.7543	8.86	0.3884	0.7545	8.86	0.3882	0.7548	8.85	0.3880	0.7551
DeepSN-Net	8.97	0.3652	0.7307	8.97	0.3651	0.7307	8.98	0.3650	0.7306	8.97	0.3649	0.7308
DarkIR	4.84	0.0488	0.8541	4.84	0.0488	0.8546	4.84	0.0488	0.8551	4.84	0.0488	0.8556
Proposed method												
Recall(Ours)	**21.55**	**0.7377**	**0.4083**	**21.38**	**0.7342**	**0.4111**	**21.19**	**0.7302**	**0.4142**	**20.97**	**0.7254**	**0.4178**

Table A16 (continued).

Method	(0.085)			(0.1)			(0.1125)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.21	0.5902	0.5428	14.21	0.5904	0.5430	14.20	0.5903	0.5433
UniProcessor	11.51	0.4844	0.6756	11.47	0.4827	0.6772	11.46	0.4814	0.6778
AST	9.73	0.4811	0.6593	9.73	0.4807	0.6587	9.72	0.4802	0.6591
OneRestore	10.00	0.4444	0.7001	10.00	0.4440	0.7005	10.00	0.4437	0.7008

Table A16 (continued).

Method	(0.085)			(0.1)			(0.1125)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones									
Restormer	12.88	0.5824	0.5977	12.89	0.5833	0.5971	12.89	0.5830	0.5964
X-Restormer	13.29	0.5889	0.5802	13.29	0.5888	0.5802	13.29	0.5894	0.5805
NAFNet	12.53	0.5202	0.6004	12.53	0.5202	0.6005	12.54	0.5201	0.6012
Pixel2Pixel	11.03	0.4720	0.6204	11.02	0.4693	0.6256	11.01	0.4667	0.6300
ConvIR	11.08	0.4666	0.6369	11.08	0.4665	0.6369	11.08	0.4664	0.6370
Uformer	8.72	0.4462	0.6919	8.72	0.4462	0.6918	8.72	0.4463	0.6917
U-Net	8.49	0.3372	0.7373	8.49	0.3360	0.7395	8.48	0.3350	0.7413
Degradation-specific restoration									
Ada-Deblur	13.17	0.5701	0.5912	13.17	0.5700	0.5915	13.17	0.5699	0.5917
DehazeFormer	12.29	0.5361	0.6510	12.30	0.5361	0.6509	12.31	0.5360	0.6509
OKNet	12.25	0.5252	0.6670	12.25	0.5251	0.6669	12.24	0.5248	0.6675
DnCNN	9.22	0.4220	0.6421	9.22	0.4216	0.6422	9.22	0.4212	0.6425
Enhancement-oriented restoration									
Retinexformer	**14.65**	**0.5941**	**0.5174**	**14.63**	**0.5928**	**0.5192**	**14.61**	**0.5915**	**0.5210**
HVI-CIDNet	12.50	0.5186	0.6294	12.49	0.5182	0.6300	12.48	0.5182	0.6304
IRNeXt	12.86	0.5312	0.6113	12.86	0.5308	0.6118	12.86	0.5306	0.6121
DEA-Net	10.46	0.3925	0.7192	10.46	0.3922	0.7198	10.47	0.3918	0.7204
SFHformer	8.85	0.3878	0.7555	8.85	0.3876	0.7560	8.85	0.3874	0.7565
DeepSN-Net	8.97	0.3648	0.7309	8.97	0.3647	0.7310	8.97	0.3646	0.7312
DarkIR	4.84	0.0488	0.8562	4.84	0.0487	0.8568	4.84	0.0487	0.8573
Proposed method									
Recall(Ours)	**20.71**	**0.7201**	**0.4220**	**20.45**	**0.7147**	**0.4266**	**20.23**	**0.7103**	**0.4302**

Table A16 (continued).

Method	(0.125)			(0.1375)			(0.15)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.20	**0.5906**	0.5439	14.20	**0.5906**	0.5439	14.20	**0.5905**	0.5450
UniProcessor	11.46	0.4806	0.6786	11.41	0.4786	0.6807	11.40	0.4780	0.6811
AST	9.70	0.4795	0.6597	9.69	0.4785	0.6604	9.67	0.4782	0.6611
OneRestore	10.00	0.4433	0.7011	10.00	0.4429	0.7014	9.99	0.4424	0.7017
General restoration backbones									
Restormer	12.88	0.5823	0.5974	12.88	0.5820	0.5982	12.91	0.5825	0.5967
X-Restormer	13.29	0.5897	0.5807	13.29	0.5898	0.5803	13.28	0.5895	0.5809
NAFNet	12.54	0.5199	0.6012	12.54	0.5198	0.6019	12.54	0.5196	0.6016
Pixel2Pixel	10.99	0.4639	0.6346	10.97	0.4610	0.6385	10.95	0.4581	0.6423
ConvIR	11.08	0.4664	0.6371	11.08	0.4663	0.6372	11.08	0.4662	0.6373
Uformer	8.72	0.4466	0.6917	8.72	0.4467	0.6918	8.73	0.4467	0.6921
U-Net	8.48	0.3339	0.7430	8.48	0.3327	0.7444	8.48	0.3316	0.7458
Degradation-specific restoration									
Ada-Deblur	13.17	0.5699	0.5921	13.17	0.5697	0.5922	13.17	0.5696	0.5924
DehazeFormer	12.32	0.5358	0.6508	12.33	0.5356	0.6506	12.34	0.5354	0.6506
OKNet	12.23	0.5244	0.6678	12.22	0.5243	0.6678	12.23	0.5243	0.6679
DnCNN	9.22	0.4208	0.6428	9.22	0.4204	0.6431	9.22	0.4199	0.6434
Enhancement-oriented restoration									
Retinexformer	**14.60**	0.5902	**0.5226**	**14.58**	0.5885	**0.5251**	**14.56**	0.5864	**0.5276**
HVI-CIDNet	12.47	0.5176	0.6309	12.47	0.5177	0.6313	12.46	0.5172	0.6319
IRNeXt	12.85	0.5303	0.6125	12.85	0.5299	0.6131	12.84	0.5295	0.6136
DEA-Net	10.47	0.3915	0.7209	10.48	0.3913	0.7211	10.49	0.3914	0.7219
SFHformer	8.84	0.3871	0.7570	8.84	0.3868	0.7576	8.84	0.3864	0.7582
DeepSN-Net	8.97	0.3644	0.7312	8.97	0.3642	0.7313	8.97	0.3640	0.7314
DarkIR	4.84	0.0486	0.8578	4.84	0.0486	0.8583	4.84	0.0485	0.8588
Proposed method									
Recall(Ours)	**20.01**	**0.7058**	**0.4340**	**19.79**	**0.7015**	**0.4376**	**19.57**	**0.6971**	**0.4417**

Across Browser, Game, and Software, the paired sweeps show that screen organization remains recoverable with both weaker and stronger wall returns. These experiments vary the strength of

transported screen evidence. The wall-texture sweeps further examine how texture changes its spatial pattern and overlaps with frequencies carrying screen structure.

D.2 Camera-Position Variation

Camera-position variation changes the view of the reflected wall light while the display faces the wall, testing recovery of the same screen content from different observation geometries. Figures A26–A39 provide recorded real-capture evidence for the angle, height, and distance configurations used below.

D.2.1 Horizontal Camera Viewpoint Variation

One-Side Camera Viewpoint Variation

One-side viewpoint variation tests whether content relationships can be recovered after the wall-light pattern moves with camera rotation. Game spans ten recorded angles from 0.3 to 3 degrees, and Software spans ten angles from 3 to 6 degrees. Each sweep fixes its screen content and remaining imaging conditions while varying the camera rotation toward one side.

Horizontal viewpoint variation tests whether page sections and block boundaries remain recoverable as the wall projection shifts laterally. The Browser sweep spans ten recorded horizontal angles from 3 to 15 degrees while screen content and the remaining imaging conditions stay fixed.

Angle



Figure A26: Real captures of the physical acquisition scene under three camera-angle configurations. The display faces the wall and the camera remains behind the display; the views show the corresponding changes in the observed wall-light geometry.

Browser Horizontal Viewpoint Variation

Appendix Table A17 and Figure A27 report the Browser sweep.

Increasing the horizontal viewing angle lowers Browser PSNR from 18.177 to 15.311 dB, with SSIM decreasing and LPIPS increasing; RECALL leads all three metrics at the 10 recorded conditions.

The horizontal-viewpoint curves record a directional progression in which all three metrics trace the changing projection and RECALL retains the leading position. The result shows that webpage regions and their principal boundaries remain recoverable as their evidence migrates laterally across the wall.

The agreement between horizontal and vertical sweeps broadens the evidence for coarse layout recovery across two recorded viewpoint directions. Under each changed observation, CASR derives its content anchor from the complete wall image, and RAL allocates local and context-augmented processing by restoration utility.

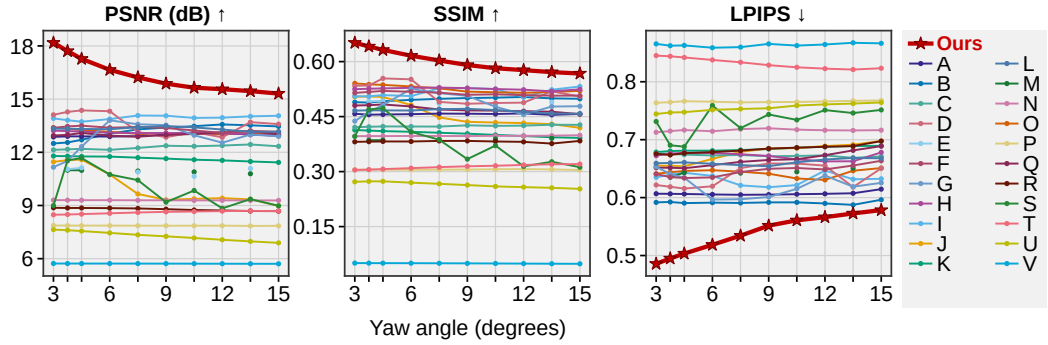


Figure A27: Browser Horizontal Viewpoint Variation curves, generated from the same values as Appendix Table A17. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

Table A17: Full Browser Horizontal Viewpoint Variation results, with 23 methods and 10 conditions.

Method	(3 deg)			(3.75 deg)			(4.5 deg)			(6 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	12.50	0.4893	**0.5917**	12.55	0.4883	**0.5925**	12.71	0.4918	**0.5905**	13.05	0.4957	**0.5913**
UniProcessor	11.79	0.4135	0.6785	11.78	0.4119	0.6803	11.77	0.4104	0.6810	11.76	0.4086	0.6810
AST	11.46	0.5040	0.6552	11.56	0.5050	0.6549	11.59	0.5037	0.6540	10.75	0.4814	0.6669
OneRestore	9.30	0.3966	0.7128	9.30	0.3968	0.7148	9.30	0.3968	0.7167	9.30	0.3972	0.7145
General restoration backbones												
Restormer	13.91	0.5056	0.6350	13.81	0.5052	0.6397	13.72	0.5087	0.6429	13.87	0.5060	0.6375
X-Restormer	13.39	**0.5407**	0.6411	13.33	**0.5379**	0.6438	13.25	0.5366	0.6460	13.15	0.5322	0.6473
NAFNet	12.87	0.4578	0.6067	12.90	0.4552	0.6065	12.90	0.4557	0.6062	12.89	0.4566	0.6054
Pixel2Pixel	N/A	N/A	N/A	10.99	0.3857	0.6351	10.98	0.3857	0.6432	N/A	N/A	N/A
ConvIR	12.14	0.4210	0.6766	12.17	0.4222	0.6755	12.19	0.4232	0.6742	12.14	0.4230	0.6728
Uformer	N/A	N/A	N/A	11.04	0.4914	0.6515	11.12	0.4929	0.6515	N/A	N/A	N/A
U-Net	7.87	0.3050	0.7637	7.87	0.3053	0.7648	7.87	0.3055	0.7664	7.87	0.3049	0.7655
Degradation-specific restoration												
Ada-Deblur	**14.12**	0.5340	0.6218	**14.28**	0.5349	0.6186	**14.36**	**0.5542**	0.6156	**14.32**	**0.5517**	0.6196
DehazeFormer	13.22	0.5246	0.6724	13.20	0.5261	0.6760	13.17	0.5269	0.6773	13.10	0.5284	0.6770
OKNet	12.95	0.4802	0.6516	12.98	0.4812	0.6516	13.09	0.4831	0.6507	12.94	0.4777	0.6560
DnCNN	8.87	0.3812	0.6756	8.86	0.3817	0.6737	8.86	0.3822	0.6767	8.85	0.3821	0.6786
Enhancement-oriented restoration												
Retinexformer	11.16	0.4377	0.6532	11.51	0.4626	0.6408	12.32	0.4813	0.6343	13.81	0.5255	0.5966
HVI-CIDNet	13.38	0.5146	0.6406	13.46	0.5174	0.6354	13.50	0.5201	0.6338	13.39	0.5177	0.6349
IRNeXt	13.33	0.4663	0.6593	13.33	0.4672	0.6599	13.31	0.4670	0.6608	13.30	0.4666	0.6584
DEA-Net	9.00	0.3960	0.7313	11.55	0.4697	0.6903	11.67	0.4728	0.6879	10.75	0.4084	0.7589
SFHformer	8.48	0.3045	0.8452	8.49	0.3054	0.8439	8.51	0.3068	0.8419	8.56	0.3094	0.8376
DeepSN-Net	7.64	0.2721	0.7444	7.61	0.2734	0.7469	7.56	0.2735	0.7475	7.45	0.2698	0.7515
DarkIR	5.73	0.0504	0.8654	5.73	0.0504	0.8622	5.73	0.0503	0.8627	5.72	0.0502	0.8587
Proposed method												
Recall(Ours)	**18.18**	**0.6513**	**0.4857**	**17.71**	**0.6413**	**0.4950**	**17.27**	**0.6319**	**0.5034**	**16.65**	**0.6160**	**0.5186**

Table A17 (continued).

Method	(7.5 deg)			(9 deg)			(10.5 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	13.29	0.4984	**0.5908**	13.39	0.5006	**0.5918**	13.47	0.5017	**0.5918**
UniProcessor	11.70	0.4059	0.6821	11.64	0.4034	0.6838	11.58	0.4001	0.6861
AST	9.65	0.4477	0.6790	9.32	0.4357	0.6848	9.37	0.4338	0.6855
OneRestore	9.29	0.3971	0.7182	9.29	0.3969	0.7196	9.29	0.3975	0.7173

Table A17 (continued).

Method	(7.5 deg)			(9 deg)			(10.5 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones									
Restormer	**14.08**	0.5274	0.6211	**14.06**	**0.5277**	0.6179	**13.94**	0.5251	0.6216
X-Restormer	13.04	0.5272	0.6447	12.96	0.5181	0.6412	13.06	0.5164	0.6330
NAFNet	12.91	0.4582	0.6048	13.01	0.4579	0.6051	13.12	0.4571	0.6059
Pixel2Pixel	10.94	0.3869	0.6423	N/A	N/A	N/A	10.89	0.3890	0.6446
ConvIR	12.25	0.4228	0.6736	12.37	0.4262	0.6714	12.34	0.4247	0.6719
Uformer	10.88	0.4854	0.6577	N/A	N/A	N/A	10.65	0.4819	0.6631
U-Net	7.86	0.3053	0.7644	7.86	0.3056	0.7649	7.86	0.3064	0.7651
Degradation-specific restoration									
Ada-Deblur	13.14	0.4900	0.6511	12.85	0.4850	0.6589	13.14	0.4871	0.6588
DehazeFormer	13.09	**0.5292**	0.6749	13.09	0.5276	0.6719	13.08	**0.5252**	0.6661
OKNet	12.88	0.4694	0.6617	12.98	0.4669	0.6650	13.03	0.4664	0.6662
DnCNN	8.83	0.3836	0.6810	8.79	0.3837	0.6846	8.75	0.3822	0.6862
Enhancement-oriented restoration									
Retinexformer	13.58	0.5141	0.5972	13.53	0.5067	0.6010	12.96	0.4769	0.6152
HVI-CIDNet	13.43	0.5153	0.6441	13.37	0.5095	0.6498	13.23	0.5108	0.6511
IRNeXt	13.42	0.4703	0.6561	13.48	0.4712	0.6542	13.41	0.4678	0.6610
DEA-Net	10.43	0.3868	0.7199	9.19	0.3341	0.7435	9.84	0.3709	0.7341
SFHformer	8.61	0.3122	0.8336	8.64	0.3145	0.8286	8.66	0.3160	0.8249
DeepSN-Net	7.35	0.2667	0.7530	7.26	0.2632	0.7542	7.17	0.2595	0.7589
DarkIR	5.72	0.0499	0.8598	5.72	0.0497	0.8654	5.72	0.0494	0.8624
Proposed method									
Recall(Ours)	**16.22**	**0.6030**	**0.5343**	**15.87**	**0.5907**	**0.5516**	**15.64**	**0.5819**	**0.5608**

Table A17 (continued).

Method	(12 deg)			(13.5 deg)			(15 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	13.57	0.5035	**0.5899**	13.52	0.4997	**0.5875**	13.46	0.4986	**0.5963**
UniProcessor	11.54	0.3971	0.6878	11.48	0.3937	0.6891	11.43	0.3918	0.6894
AST	9.41	0.4324	0.6890	9.35	0.4294	0.6912	8.98	0.4195	0.6979
OneRestore	9.29	0.3974	0.7162	9.29	0.3980	0.7160	9.29	0.3991	0.7164
General restoration backbones									
Restormer	**13.96**	0.5036	0.6467	**14.03**	**0.5233**	0.6317	**14.06**	**0.5322**	0.6324
X-Restormer	13.01	0.5149	0.6306	13.08	0.5169	0.6464	13.07	0.5203	0.6510
NAFNet	13.11	0.4587	0.6065	12.99	0.4548	0.6075	12.95	0.4572	0.6146
Pixel2Pixel	N/A	N/A	N/A	10.79	0.3908	0.6509	N/A	N/A	N/A
ConvIR	12.38	0.4254	0.6729	12.44	0.4278	0.6686	12.34	0.4275	0.6711
Uformer	N/A	N/A	N/A	11.09	0.4895	0.6616	N/A	N/A	N/A
U-Net	7.86	0.3068	0.7660	7.85	0.3060	0.7670	7.85	0.3043	0.7676
Degradation-specific restoration									
Ada-Deblur	12.85	0.4881	0.6552	13.70	0.5186	0.6182	13.59	0.5048	0.6506
DehazeFormer	13.06	**0.5233**	0.6625	13.03	0.5190	0.6627	12.93	0.5243	0.6781
OKNet	13.12	0.4648	0.6731	13.19	0.4633	0.6815	13.02	0.4567	0.6888
DnCNN	8.72	0.3811	0.6878	8.69	0.3765	0.6889	8.68	0.3837	0.6975
Enhancement-oriented restoration									
Retinexformer	12.54	0.4555	0.6380	13.00	0.4774	0.6188	12.91	0.4783	0.6255
HVI-CIDNet	13.09	0.5086	0.6486	13.21	0.5071	0.6554	13.15	0.5073	0.6636
IRNeXt	13.28	0.4631	0.6657	13.16	0.4583	0.6685	13.16	0.4580	0.6679
DEA-Net	8.84	0.3143	0.7510	9.36	0.3269	0.7460	8.98	0.3121	0.7514
SFHformer	8.68	0.3181	0.8226	8.70	0.3201	0.8210	8.68	0.3205	0.8233
DeepSN-Net	7.07	0.2576	0.7609	6.98	0.2558	0.7623	6.89	0.2528	0.7642
DarkIR	5.72	0.0491	0.8643	5.71	0.0487	0.8673	5.71	0.0485	0.8663
Proposed method									
Recall(Ours)	**15.56**	**0.5768**	**0.5662**	**15.45**	**0.5713**	**0.5726**	**15.31**	**0.5675**	**0.5785**

Game One-Side Camera Viewpoint Variation

Appendix Table A18 and Figure A28 report the Game sweep.

As the one-side viewing angle increases, Game PSNR decreases from 19.144 to 17.536 dB, with SSIM decreasing and LPIPS increasing; RECALL leads all three metrics at the 10 recorded conditions.

The one-side viewpoint variation relocates the observed low-light game pattern, with RECALL remaining the leading method throughout the recorded offset. The trajectory demonstrates that the canvas and principal objects remain identifiable while their wall support moves in one direction.

The method follows the game content through viewpoint motion while preserving its coarse spatial relationships.

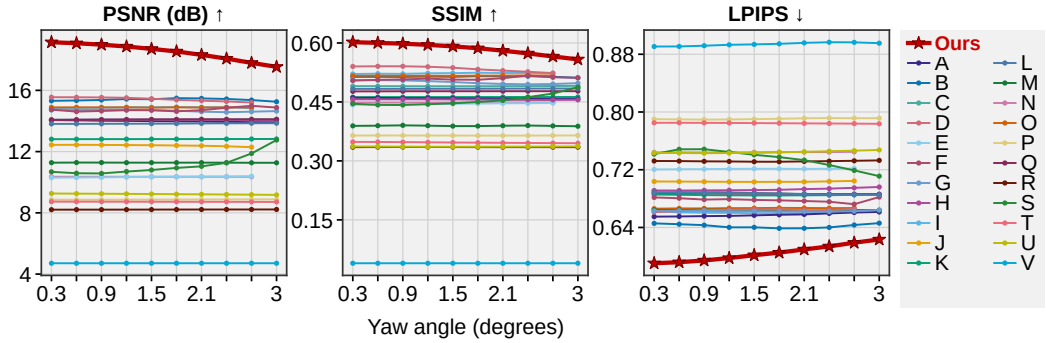


Figure A28: Game One-Side Camera Viewpoint Variation curves, generated from the same values as Appendix Table A18. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

Table A18: Full Game One-Side Camera Viewpoint Variation results, with 23 methods and 10 conditions.

Method	(0.3 deg)			(0.6 deg)			(0.9 deg)			(1.2 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	15.32	0.5138	**0.6457**	15.34	0.5139	**0.6445**	15.37	0.5137	**0.6432**	15.43	0.5146	**0.6402**
UniProcessor	12.81	0.4621	0.6856	12.81	0.4623	0.6853	12.81	0.4624	0.6848	12.82	0.4624	0.6846
AST	12.44	0.4590	0.7037	12.44	0.4592	0.7036	12.44	0.4590	0.7035	12.43	0.4587	0.7032
OneRestore	10.36	0.4483	0.7440	10.36	0.4482	0.7440	10.36	0.4482	0.7439	10.36	0.4482	0.7440
General restoration backbones												
Restormer	14.82	0.5211	0.6625	14.85	0.5219	0.6609	14.87	0.5214	0.6603	14.90	0.5229	0.6602
X-Restormer	14.89	0.5165	0.6661	14.89	0.5170	0.6664	14.89	0.5164	0.6664	14.89	0.5166	0.6668
NAFNet	14.06	0.4608	0.6550	14.04	0.4603	0.6553	14.02	0.4597	0.6557	14.01	0.4596	0.6560
Pixel2Pixel	11.28	0.3891	0.6644	11.28	0.3896	0.6642	11.28	0.3905	0.6647	11.28	0.3896	0.6643
ConvIR	14.09	0.4902	0.6911	14.09	0.4902	0.6906	14.09	0.4901	0.6898	14.09	0.4899	0.6887
Uformer	10.30	0.4429	0.7204	10.31	0.4433	0.7207	10.32	0.4439	0.7208	10.34	0.4445	0.7212
U-Net	8.86	0.3645	0.7901	8.86	0.3648	0.7897	8.86	0.3647	0.7895	8.86	0.3645	0.7897
Degradation-specific restoration												
Ada-Deblur	**15.55**	**0.5403**	0.6613	**15.55**	**0.5407**	0.6625	**15.54**	**0.5408**	0.6641	**15.51**	**0.5395**	0.6645
DehazeFormer	14.07	0.4566	0.6910	14.08	0.4567	0.6912	14.09	0.4567	0.6914	14.09	0.4567	0.6916
OKNet	14.06	0.4769	0.6879	14.07	0.4770	0.6877	14.08	0.4772	0.6875	14.09	0.4772	0.6871
DnCNN	8.21	0.3349	0.7321	8.21	0.3352	0.7320	8.21	0.3353	0.7316	8.21	0.3354	0.7315
Enhancement-oriented restoration												
Retinexformer	14.72	0.5057	0.6630	14.72	0.5054	0.6633	14.73	0.5049	0.6629	14.73	0.5031	0.6623
HVI-CIDNet	14.74	0.5042	0.6816	14.61	0.5062	0.6805	14.65	0.5074	0.6787	14.71	0.5093	0.6792
IRNeXt	13.81	0.4833	0.6882	13.81	0.4833	0.6881	13.82	0.4834	0.6879	13.82	0.4835	0.6874
DEA-Net	10.68	0.4454	0.7417	10.59	0.4424	0.7483	10.57	0.4422	0.7484	10.70	0.4442	0.7446
SFHformer	8.73	0.3483	0.7850	8.73	0.3482	0.7851	8.73	0.3478	0.7850	8.73	0.3473	0.7848
DeepSN-Net	9.26	0.3367	0.7434	9.25	0.3365	0.7432	9.25	0.3363	0.7429	9.24	0.3360	0.7431
DarkIR	4.71	0.0396	0.8907	4.71	0.0396	0.8909	4.71	0.0396	0.8918	4.71	0.0396	0.8931
Proposed method												
Recall(Ours)	**19.14**	**0.6019**	**0.5904**	**19.08**	**0.6003**	**0.5919**	**18.98**	**0.5982**	**0.5943**	**18.86**	**0.5952**	**0.5976**

Table A18 (continued).

Method	(1.5 deg)			(1.8 deg)			(2.1 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.42	0.5139	**0.6402**	**15.49**	0.5155	**0.6388**	**15.47**	0.5152	**0.6388**
UniProcessor	12.82	0.4624	0.6844	12.82	0.4624	0.6844	12.82	0.4625	0.6846
AST	12.42	0.4583	0.7031	12.40	0.4578	0.7032	12.38	0.4572	0.7033
OneRestore	10.36	0.4482	0.7442	10.36	0.4482	0.7443	10.36	0.4483	0.7444
General restoration backbones									
Restormer	14.89	0.5233	0.6598	14.91	0.5244	0.6597	14.89	0.5236	0.6597
X-Restormer	14.87	0.5163	0.6669	14.89	0.5169	0.6671	14.88	0.5170	0.6670
NAFNet	13.99	0.4592	0.6568	13.98	0.4587	0.6576	13.96	0.4582	0.6581
Pixel2Pixel	11.28	0.3885	0.6639	11.28	0.3886	0.6631	11.28	0.3895	0.6630
ConvIR	14.09	0.4899	0.6878	14.10	0.4900	0.6871	14.10	0.4901	0.6865
Uformer	10.35	0.4452	0.7213	10.36	0.4458	0.7213	10.37	0.4465	0.7211
U-Net	8.87	0.3645	0.7901	8.87	0.3644	0.7906	8.87	0.3644	0.7913
Degradation-specific restoration									
Ada-Deblur	**15.45**	**0.5372**	0.6650	15.38	**0.5330**	0.6648	15.33	**0.5297**	0.6639
DehazeFormer	14.09	0.4564	0.6918	14.08	0.4560	0.6922	14.08	0.4555	0.6932
OKNet	14.10	0.4772	0.6870	14.10	0.4773	0.6868	14.11	0.4773	0.6862
DnCNN	8.21	0.3352	0.7311	8.22	0.3350	0.7311	8.22	0.3351	0.7315
Enhancement-oriented restoration									
Retinexformer	14.71	0.5006	0.6625	14.67	0.4977	0.6620	14.61	0.4958	0.6620
HVI-CIDNet	14.70	0.5068	0.6782	14.63	0.5064	0.6776	14.71	0.5104	0.6767
IRNeXt	13.82	0.4836	0.6869	13.83	0.4837	0.6868	13.84	0.4839	0.6862
DEA-Net	10.80	0.4465	0.7407	10.94	0.4500	0.7375	11.04	0.4539	0.7333
SFHformer	8.73	0.3468	0.7846	8.72	0.3464	0.7844	8.72	0.3460	0.7842
DeepSN-Net	9.23	0.3360	0.7435	9.22	0.3360	0.7441	9.21	0.3362	0.7448
DarkIR	4.71	0.0396	0.8937	4.71	0.0396	0.8945	4.71	0.0396	0.8958
Proposed method									
Recall(Ours)	**18.71**	**0.5914**	**0.6016**	**18.54**	**0.5867**	**0.6052**	**18.32**	**0.5804**	**0.6095**

Table A18 (continued).

Method	(2.4 deg)			(2.7 deg)			(3 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	**15.44**	0.5155	**0.6400**	**15.37**	0.5141	**0.6434**	**15.26**	**0.5115**	**0.6460**
UniProcessor	12.82	0.4625	0.6847	12.82	0.4625	0.6851	12.82	0.4626	0.6854
AST	12.35	0.4560	0.7039	12.29	0.4546	0.7045	N/A	N/A	N/A
OneRestore	10.36	0.4483	0.7445	10.36	0.4483	0.7448	N/A	N/A	N/A
General restoration backbones									
Restormer	14.90	0.5237	0.6605	14.83	0.5231	0.6624	N/A	N/A	N/A
X-Restormer	14.89	0.5174	0.6668	14.88	0.5172	0.6669	N/A	N/A	N/A
NAFNet	13.94	0.4578	0.6595	13.92	0.4574	0.6607	13.92	0.4573	0.6615
Pixel2Pixel	11.28	0.3900	0.6633	11.27	0.3890	0.6642	11.27	0.3881	0.6640
ConvIR	14.10	0.4903	0.6861	14.11	0.4905	0.6858	14.11	0.4908	0.6857
Uformer	10.37	0.4468	0.7214	10.39	0.4472	0.7217	N/A	N/A	N/A
U-Net	8.88	0.3644	0.7916	8.88	0.3646	0.7914	8.88	0.3648	0.7914
Degradation-specific restoration									
Ada-Deblur	15.28	**0.5268**	0.6640	15.21	**0.5234**	0.6657	N/A	N/A	N/A
DehazeFormer	14.07	0.4553	0.6938	14.07	0.4553	0.6949	14.07	0.4554	0.6961
OKNet	14.11	0.4773	0.6862	14.11	0.4773	0.6862	14.11	0.4774	0.6862
DnCNN	8.22	0.3350	0.7319	8.22	0.3350	0.7324	8.22	0.3350	0.7329
Enhancement-oriented restoration									
Retinexformer	14.57	0.4948	0.6619	14.61	0.4956	0.6626	14.65	0.4978	0.6642
HVI-CIDNet	14.86	0.5171	0.6757	14.99	0.5127	0.6723	14.88	0.5114	0.6822
IRNeXt	13.85	0.4840	0.6858	13.85	0.4842	0.6856	13.85	0.4842	0.6855
DEA-Net	11.27	0.4622	0.7265	11.88	0.4713	0.7190	12.76	0.4874	0.7111
SFHformer	8.72	0.3456	0.7841	8.72	0.3453	0.7839	8.71	0.3450	0.7836
DeepSN-Net	9.20	0.3363	0.7456	9.19	0.3366	0.7464	9.17	0.3369	0.7474
DarkIR	4.71	0.0396	0.8967	4.71	0.0396	0.8965	4.71	0.0396	0.8953

Table A18 (continued).

Method	(2.4 deg)			(2.7 deg)			(3 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Proposed method									
Recall(Ours)	**18.07**	**0.5735**	**0.6138**	**17.79**	**0.5657**	**0.6189**	**17.54**	**0.5583**	**0.6234**

Software One-Side Camera Viewpoint Variation

Appendix Table A19 and Figure A29 report the Software sweep.

Software PSNR decreases from 19.131 to 16.636 dB with increasing one-side viewing angle, with SSIM decreasing and LPIPS increasing; RECALL leads all three metrics at the 10 recorded conditions.

The one-side viewpoint variation shifts the entire observed software evidence pattern while RECALL remains the leading method at each offset. The result shows that dense panel and tool relationships can be recovered from a laterally displaced wall projection.

The trajectory supports coarse interface recovery under directional viewpoint change.

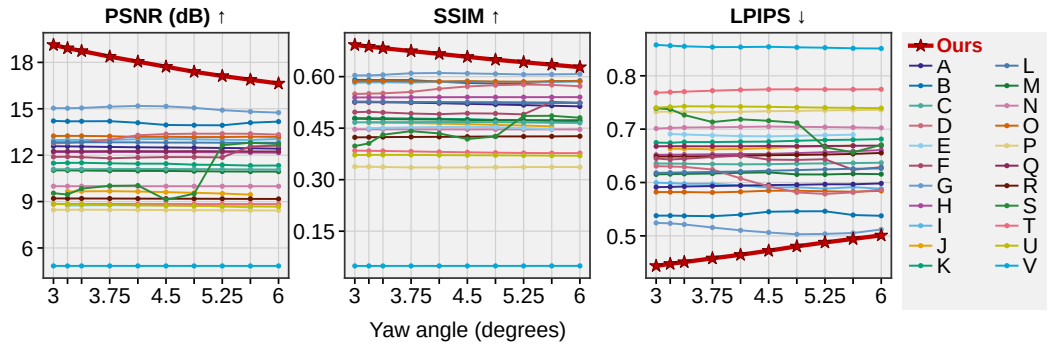


Figure A29: Software One-Side Camera Viewpoint Variation curves, generated from the same values as Appendix Table A19. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

Table A19: Full Software One-Side Camera Viewpoint Variation results, with 23 methods and 10 conditions.

Method	(3 deg)			(3.1875 deg)			(3.375 deg)			(3.75 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	14.22	0.5907	0.5378	14.19	0.5902	0.5380	14.19	0.5900	0.5375	14.20	0.5900	0.5369
UniProcessor	11.48	0.4793	0.6748	11.50	0.4792	0.6744	11.51	0.4789	0.6758	11.47	0.4781	0.6758
AST	N/A	N/A	N/A	9.65	0.4663	0.6634	9.66	0.4659	0.6631	9.67	0.4648	0.6623
OneRestore	9.99	0.4467	0.7011	9.99	0.4466	0.7022	9.99	0.4466	0.7030	9.99	0.4464	0.7035
General restoration backbones												
Restormer	12.97	0.5823	0.5996	12.99	0.5830	0.5988	12.98	0.5837	0.5976	12.98	0.5826	0.5977
X-Restormer	13.24	0.5863	0.5821	13.25	0.5869	0.5820	13.25	0.5872	0.5821	13.23	0.5863	0.5814
NAFNet	12.58	0.5267	0.5913	12.57	0.5267	0.5917	12.56	0.5260	0.5925	12.53	0.5245	0.5934
Pixel2Pixel	11.02	0.4774	0.6152	11.01	0.4767	0.6157	11.01	0.4762	0.6162	10.99	0.4757	0.6168
ConvIR	11.09	0.4668	0.6357	11.09	0.4671	0.6354	11.09	0.4673	0.6352	11.10	0.4677	0.6345
Uformer	N/A	N/A	N/A	8.73	0.4498	0.6910	8.75	0.4508	0.6900	8.76	0.4523	0.6884
U-Net	8.47	0.3380	0.7326	8.47	0.3376	0.7328	8.47	0.3369	0.7326	8.47	0.3357	0.7317
Degradation-specific restoration												
Ada-Deblur	12.76	0.5496	0.6307	12.79	0.5505	0.6300	12.83	0.5514	0.6292	13.00	0.5554	0.6243
DehazeFormer	12.20	0.5394	0.6519	12.20	0.5395	0.6521	12.20	0.5395	0.6523	12.21	0.5397	0.6529
OKNet	12.25	0.5255	0.6678	12.25	0.5254	0.6680	12.25	0.5252	0.6679	12.26	0.5256	0.6678
DnCNN	9.20	0.4231	0.6486	9.20	0.4236	0.6487	9.20	0.4240	0.6487	9.20	0.4244	0.6492

Table A19 (continued).

Method	(3 deg)			(3.1875 deg)			(3.375 deg)			(3.75 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Enhancement-oriented restoration												
Retinexformer	**15.04**	**0.6037**	**0.5242**	**15.03**	**0.6037**	**0.5235**	**15.05**	**0.6054**	**0.5214**	**15.14**	**0.6098**	**0.5156**
HVI-CIDNet	11.89	0.4967	0.6450	11.90	0.4976	0.6431	11.87	0.4958	0.6444	11.80	0.4926	0.6478
IRNeXt	12.84	0.5269	0.6180	12.84	0.5268	0.6185	12.83	0.5266	0.6190	12.83	0.5261	0.6198
DEA-Net	9.54	0.3978	0.7390	9.45	0.4058	0.7374	9.84	0.4308	0.7265	10.02	0.4412	0.7133
SFHformer	8.84	0.3846	0.7683	8.84	0.3841	0.7694	8.84	0.3836	0.7703	8.84	0.3823	0.7721
DeepSN-Net	8.84	0.3717	0.7402	8.83	0.3722	0.7417	8.81	0.3723	0.7428	8.78	0.3720	0.7427
DarkIR	4.84	0.0489	0.8579	4.84	0.0489	0.8565	4.84	0.0489	0.8553	4.84	0.0489	0.8538
Proposed method												
Recall(Ours)	**19.13**	**0.6924**	**0.4437**	**18.92**	**0.6874**	**0.4476**	**18.74**	**0.6830**	**0.4509**	**18.37**	**0.6745**	**0.4579**

Table A19 (continued).

Method	(4.125 deg)			(4.5 deg)			(4.875 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.10	0.5854	0.5397	13.95	0.5814	0.5452	13.94	0.5804	0.5460
UniProcessor	11.45	0.4771	0.6763	11.45	0.4762	0.6767	11.39	0.4740	0.6782
AST	9.65	0.4632	0.6627	9.61	0.4617	0.6645	9.57	0.4595	0.6669
OneRestore	9.99	0.4463	0.7041	9.99	0.4463	0.7049	9.99	0.4464	0.7043
General restoration backbones									
Restormer	13.03	0.5849	0.5947	13.04	0.5868	0.5905	13.02	0.5846	0.5911
X-Restormer	13.18	0.5861	0.5826	13.19	0.5868	0.5846	13.17	0.5858	0.5846
NAFNet	12.51	0.5227	0.5942	12.50	0.5208	0.5952	12.49	0.5190	0.5957
Pixel2Pixel	10.98	0.4751	0.6182	10.98	0.4739	0.6189	10.96	0.4731	0.6152
ConvIR	11.10	0.4678	0.6341	11.10	0.4679	0.6343	11.10	0.4674	0.6352
Uformer	8.76	0.4534	0.6870	8.76	0.4537	0.6865	8.75	0.4530	0.6874
U-Net	8.46	0.3356	0.7325	8.45	0.3357	0.7337	8.45	0.3360	0.7341
Degradation-specific restoration									
Ada-Deblur	13.29	0.5648	0.6077	13.37	0.5714	0.5930	13.39	0.5751	0.5814
DehazeFormer	12.21	0.5401	0.6533	12.20	0.5403	0.6537	12.19	0.5402	0.6551
OKNet	12.26	0.5251	0.6678	12.25	0.5248	0.6684	12.26	0.5248	0.6681
DnCNN	9.19	0.4247	0.6500	9.19	0.4253	0.6511	9.18	0.4259	0.6517
Enhancement-oriented restoration									
Retinexformer	**15.18**	**0.6107**	**0.5104**	**15.16**	**0.6093**	**0.5063**	**15.06**	**0.6081**	**0.5029**
HVI-CIDNet	11.85	0.4908	0.6501	11.88	0.4932	0.6429	11.87	0.4925	0.6423
IRNeXt	12.83	0.5254	0.6206	12.81	0.5248	0.6221	12.81	0.5244	0.6232
DEA-Net	10.04	0.4347	0.7184	9.12	0.4183	0.7157	9.51	0.4258	0.7120
SFHformer	8.84	0.3809	0.7736	8.84	0.3797	0.7745	8.84	0.3787	0.7747
DeepSN-Net	8.76	0.3715	0.7423	8.74	0.3712	0.7419	8.72	0.3710	0.7410
DarkIR	4.84	0.0489	0.8539	4.84	0.0489	0.8544	4.84	0.0489	0.8533
Proposed method									
Recall(Ours)	**18.05**	**0.6664**	**0.4646**	**17.72**	**0.6577**	**0.4721**	**17.39**	**0.6494**	**0.4803**

Table A19 (continued).

Method	(5.25 deg)			(5.625 deg)			(6 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	13.93	0.5805	0.5462	14.10	0.5863	0.5391	14.17	0.5879	0.5376
UniProcessor	11.37	0.4731	0.6796	11.33	0.4712	0.6802	11.33	0.4704	0.6814
AST	9.52	0.4576	0.6676	9.45	0.4554	0.6692	N/A	N/A	N/A
OneRestore	9.99	0.4464	0.7039	9.99	0.4464	0.7033	9.99	0.4463	0.7024
General restoration backbones									
Restormer	13.00	0.5850	0.5885	12.99	0.5839	0.5913	13.04	0.5861	0.5884
X-Restormer	13.17	0.5852	0.5835	13.19	0.5869	0.5828	13.18	0.5871	0.5843
NAFNet	12.47	0.5172	0.5967	12.45	0.5153	0.5966	12.42	0.5133	0.5983
Pixel2Pixel	10.95	0.4729	0.6151	10.94	0.4732	0.6163	10.94	0.4730	0.6157
ConvIR	11.09	0.4667	0.6359	11.08	0.4658	0.6365	11.07	0.4653	0.6370
Uformer	8.69	0.4500	0.6886	8.63	0.4474	0.6897	N/A	N/A	N/A
U-Net	8.44	0.3367	0.7351	8.43	0.3369	0.7358	8.42	0.3368	0.7361

Table A19 (continued).

Method	(5.25 deg)			(5.625 deg)			(6 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Degradation-specific restoration									
Ada-Deblur	13.39	0.5770	0.5785	13.39	0.5758	0.5815	13.33	0.5721	0.5868
DehazeFormer	12.18	0.5402	0.6567	12.17	0.5403	0.6585	12.16	0.5404	0.6608
OKNet	12.25	0.5245	0.6684	12.24	0.5241	0.6688	12.24	0.5237	0.6692
DnCNN	9.18	0.4260	0.6524	9.17	0.4261	0.6536	9.17	0.4266	0.6554
Enhancement-oriented restoration									
Retinexformer	**14.91**	**0.6064**	**0.5037**	**14.81**	**0.6065**	**0.5053**	**14.75**	**0.6076**	**0.5120**
HVI-CIDNet	11.86	0.4903	0.6436	12.57	0.5265	0.6239	12.61	0.5236	0.6286
IRNeXt	12.80	0.5238	0.6246	12.80	0.5235	0.6258	12.80	0.5230	0.6263
DEA-Net	12.65	0.4856	0.6661	12.80	0.4860	0.6565	12.72	0.4803	0.6706
SFHformer	8.84	0.3778	0.7746	8.84	0.3774	0.7745	8.84	0.3773	0.7747
DeepSN-Net	8.70	0.3705	0.7403	8.69	0.3700	0.7399	8.67	0.3695	0.7394
DarkIR	4.84	0.0490	0.8527	4.84	0.0490	0.8515	4.84	0.0490	0.8512
Proposed method									
Recall(Ours)	**17.12**	**0.6420**	**0.4876**	**16.88**	**0.6348**	**0.4943**	**16.64**	**0.6277**	**0.5009**

Opposite-Side Camera Viewpoint Variation

Opposite-side viewpoint variation tests whether the same content relationships remain readable after camera rotation moves the wall-light pattern in the reverse direction. Browser spans ten recorded angles from -3 to -15 degrees, Game spans -0.3 to -3 degrees, and Software spans -3 to -6 degrees. Each sweep fixes its screen content and remaining imaging conditions.

Browser Opposite-Side Camera Viewpoint Variation

Appendix Table A20 and Figure A30 report the Browser sweep.

Viewing from the opposite side yields a Browser PSNR decline from 18.318 to 15.196 dB as the angle magnitude increases, with SSIM decreasing overall and LPIPS increasing; RECALL leads all three metrics at the 10 recorded conditions.

The opposite-side viewpoint curves mirror the relocation test across the other direction, with RECALL preserving its leading rank as the offset grows. This evaluation shows that coarse webpage evidence can be reorganized from changed wall patterns on both sides of the capture geometry.

The sustained lead across the opposite-side trajectory extends the reconstruction advantage to both recorded viewing directions.

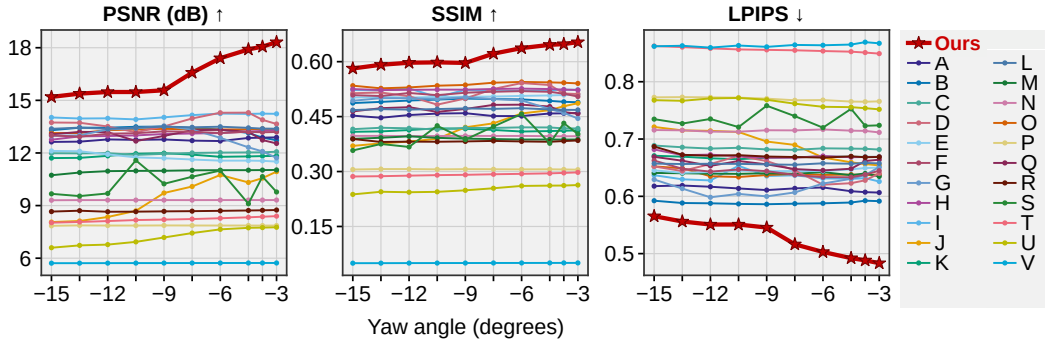


Figure A30: Browser Opposite-Side Camera Viewpoint Variation curves, generated from the same values as Appendix Table A20. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

Table A20: Full Browser Opposite-Side Camera Viewpoint Variation results, with 23 methods and 10 conditions.

Method	(-3 deg)			(-3.75 deg)			(-4.5 deg)			(-6 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	12.72	0.4892	**0.5916**	12.87	0.4904	**0.5924**	13.14	0.4929	**0.5892**	13.34	0.4969	**0.5878**
UniProcessor	11.83	0.4123	0.6688	11.82	0.4114	0.6689	11.80	0.4105	0.6689	11.78	0.4093	0.6694
AST	10.94	0.4866	0.6540	10.57	0.4783	0.6562	10.32	0.4677	0.6594	10.75	0.4585	0.6677
OneRestore	9.32	0.3966	0.7115	9.31	0.3962	0.7142	9.32	0.3966	0.7146	9.31	0.3972	0.7167
General restoration backbones												
Restormer	**14.23**	0.5233	0.6259	**14.24**	0.5235	0.6316	14.23	0.5210	0.6305	14.25	0.5206	0.6314
X-Restormer	13.37	**0.5407**	0.6381	13.37	**0.5425**	0.6371	13.35	**0.5435**	0.6380	13.34	**0.5447**	0.6374
NAFNet	12.89	0.4600	0.6065	12.87	0.4589	0.6073	12.86	0.4585	0.6089	12.68	0.4515	0.6155
Pixel2Pixel	11.03	0.3875	0.6348	11.02	0.3872	0.6399	11.02	0.3875	0.6370	11.02	0.3875	0.6422
ConvIR	12.07	0.4177	0.6817	12.04	0.4178	0.6829	12.03	0.4204	0.6833	12.02	0.4207	0.6838
Uformer	11.51	0.5104	0.6503	11.55	0.5089	0.6493	11.56	0.5078	0.6471	11.56	0.5065	0.6441
U-Net	7.86	0.3051	0.7657	7.86	0.3057	0.7651	7.86	0.3061	0.7654	7.86	0.3059	0.7680
Degradation-specific restoration												
Ada-Deblur	13.65	0.5116	0.6400	13.89	0.5131	0.6280	**14.30**	0.5362	0.6229	**14.29**	0.5416	0.6203
DehazeFormer	13.29	0.5226	0.6689	13.26	0.5237	0.6686	13.22	0.5252	0.6683	13.13	0.5264	0.6704
OKNet	12.54	0.4578	0.6639	12.74	0.4623	0.6616	13.20	0.4775	0.6481	13.32	0.4826	0.6452
DnCNN	8.75	0.3848	0.6687	8.73	0.3832	0.6682	8.72	0.3813	0.6698	8.70	0.3822	0.6676
Enhancement-oriented restoration												
Retinexformer	11.72	0.4449	0.6511	12.09	0.4601	0.6371	12.32	0.4706	0.6306	12.86	0.4941	0.6223
HVI-CIDNet	13.20	0.5048	0.6447	13.18	0.5125	0.6378	13.21	0.5177	0.6333	13.14	0.5195	0.6334
IRNeXt	13.39	0.4683	0.6575	13.39	0.4684	0.6582	13.43	0.4696	0.6569	13.50	0.4729	0.6577
DEA-Net	9.78	0.4025	0.7239	10.65	0.4319	0.7231	9.11	0.3772	0.7527	10.99	0.4572	0.7198
SFHformer	8.40	0.2977	0.8491	8.37	0.2963	0.8509	8.33	0.2950	0.8525	8.28	0.2937	0.8536
DeepSN-Net	7.76	0.2631	0.7518	7.74	0.2618	0.7538	7.73	0.2616	0.7556	7.64	0.2607	0.7563
DarkIR	5.73	0.0505	0.8670	5.73	0.0505	0.8691	5.73	0.0505	0.8649	5.73	0.0504	0.8636
Proposed method												
Recall(Ours)	**18.32**	**0.6533**	**0.4833**	**18.06**	**0.6480**	**0.4882**	**17.90**	**0.6459**	**0.4921**	**17.40**	**0.6371**	**0.5029**

Table A20 (continued).

Method	(-7.5 deg)			(-9 deg)			(-10.5 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	13.42	0.4980	**0.5872**	13.50	0.4992	**0.5862**	13.49	0.4965	**0.5868**
UniProcessor	11.90	0.4136	0.6683	11.99	0.4168	0.6674	11.96	0.4180	0.6648
AST	10.09	0.4316	0.6897	9.72	0.4207	0.6956	8.70	0.3893	0.7123
OneRestore	9.31	0.3972	0.7151	9.31	0.3974	0.7153	9.31	0.3970	0.7128
General restoration backbones									
Restormer	**14.16**	0.5192	0.6366	**14.03**	0.5230	0.6355	**13.91**	0.5032	0.6533
X-Restormer	13.34	**0.5426**	0.6390	13.38	**0.5364**	0.6371	13.34	**0.5344**	0.6338
NAFNet	12.70	0.4515	0.6139	12.77	0.4593	0.6109	12.75	0.4583	0.6138
Pixel2Pixel	11.01	0.3887	0.6394	10.98	0.3898	0.6403	10.98	0.3920	0.6392
ConvIR	12.00	0.4191	0.6811	11.95	0.4192	0.6819	11.89	0.4149	0.6847
Uformer	11.63	0.5047	0.6441	11.70	0.5043	0.6439	11.75	0.5036	0.6446
U-Net	7.86	0.3062	0.7676	7.87	0.3065	0.7705	7.86	0.3060	0.7722
Degradation-specific restoration									
Ada-Deblur	13.97	0.5255	0.6453	13.51	0.4994	0.6615	13.18	0.4827	0.6706
DehazeFormer	13.11	0.5254	0.6673	13.08	0.5235	0.6673	13.00	0.5236	0.6698
OKNet	13.30	0.4820	0.6475	12.97	0.4709	0.6558	12.68	0.4629	0.6617
DnCNN	8.68	0.3836	0.6686	8.67	0.3823	0.6694	8.65	0.3814	0.6718
Enhancement-oriented restoration									
Retinexformer	13.33	0.4980	0.6068	13.54	0.5029	0.5999	13.41	0.4981	0.6042
HVI-CIDNet	13.21	0.5179	0.6374	13.23	0.5152	0.6439	13.12	0.5085	0.6468
IRNeXt	13.46	0.4711	0.6551	13.50	0.4724	0.6557	13.44	0.4706	0.6566
DEA-Net	10.64	0.4229	0.7400	10.24	0.3872	0.7582	11.58	0.4251	0.7209
SFHformer	8.23	0.2925	0.8549	8.20	0.2911	0.8556	8.18	0.2902	0.8564
DeepSN-Net	7.43	0.2544	0.7617	7.18	0.2487	0.7685	6.93	0.2446	0.7717
DarkIR	5.73	0.0503	0.8642	5.72	0.0502	0.8609	5.72	0.0501	0.8632

Table A20 (continued).

Method	(-7.5 deg)			(-9 deg)			(-10.5 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Proposed method									
Recall(Ours)	**16.58**	**0.6219**	**0.5162**	**15.57**	**0.5966**	**0.5455**	**15.48**	**0.5981**	**0.5508**

Table A20 (continued).

Method	(-12 deg)			(-13.5 deg)			(-15 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	13.44	0.4939	**0.5878**	13.44	0.4902	**0.5884**	13.30	0.4870	**0.5923**
UniProcessor	11.83	0.4133	0.6664	11.72	0.4096	0.6692	11.71	0.4085	0.6708
AST	8.35	0.3820	0.7143	8.12	0.3769	0.7151	8.06	0.3700	0.7211
OneRestore	9.31	0.3969	0.7129	9.31	0.3974	0.7152	9.30	0.3973	0.7157
General restoration backbones									
Restormer	**13.98**	0.5272	0.6278	**13.96**	0.5217	0.6297	**14.02**	0.5226	0.6369
X-Restormer	13.30	**0.5297**	0.6351	13.14	**0.5272**	0.6489	13.14	**0.5344**	0.6522
NAFNet	12.77	0.4542	0.6167	12.65	0.4468	0.6189	12.63	0.4527	0.6178
Pixel2Pixel	10.96	0.3961	0.6396	10.88	0.3923	0.6403	10.73	0.3892	0.6408
ConvIR	11.99	0.4181	0.6834	11.98	0.4195	0.6856	11.98	0.4157	0.6887
Uformer	11.92	0.5021	0.6425	12.10	0.5035	0.6412	12.11	0.5022	0.6453
U-Net	7.86	0.3068	0.7727	7.87	0.3068	0.7731	7.85	0.3055	0.7728
Degradation-specific restoration									
Ada-Deblur	13.51	0.5056	0.6564	13.72	0.5158	0.6441	13.74	0.5138	0.6521
DehazeFormer	12.97	0.5231	0.6728	12.94	0.5225	0.6719	12.76	0.5252	0.6818
OKNet	13.19	0.4757	0.6531	13.20	0.4730	0.6622	13.06	0.4642	0.6689
DnCNN	8.65	0.3817	0.6708	8.71	0.3808	0.6725	8.66	0.3889	0.6869
Enhancement-oriented restoration									
Retinexformer	13.34	0.5002	0.5983	13.00	0.5004	0.6135	12.97	0.4932	0.6293
HVI-CIDNet	13.10	0.5145	0.6431	12.93	0.5062	0.6481	13.00	0.5086	0.6624
IRNeXt	13.38	0.4691	0.6569	13.44	0.4703	0.6564	13.38	0.4678	0.6572
DEA-Net	9.69	0.3672	0.7351	9.54	0.3752	0.7270	9.67	0.3576	0.7347
SFHformer	8.12	0.2888	0.8583	8.07	0.2873	0.8604	8.03	0.2865	0.8623
DeepSN-Net	6.78	0.2435	0.7709	6.73	0.2448	0.7667	6.60	0.2376	0.7678
DarkIR	5.72	0.0500	0.8595	5.72	0.0498	0.8628	5.72	0.0498	0.8618
Proposed method									
Recall(Ours)	**15.48**	**0.5972**	**0.5508**	**15.38**	**0.5915**	**0.5561**	**15.20**	**0.5814**	**0.5653**

Game Opposite-Side Camera Viewpoint Variation

Appendix Table A21 and Figure A31 report the Game sweep.

Game PSNR decreases from 19.163 to 17.940 dB over the opposite-side angles, with SSIM decreasing and LPIPS increasing; RECALL leads all three metrics at the 10 recorded conditions.

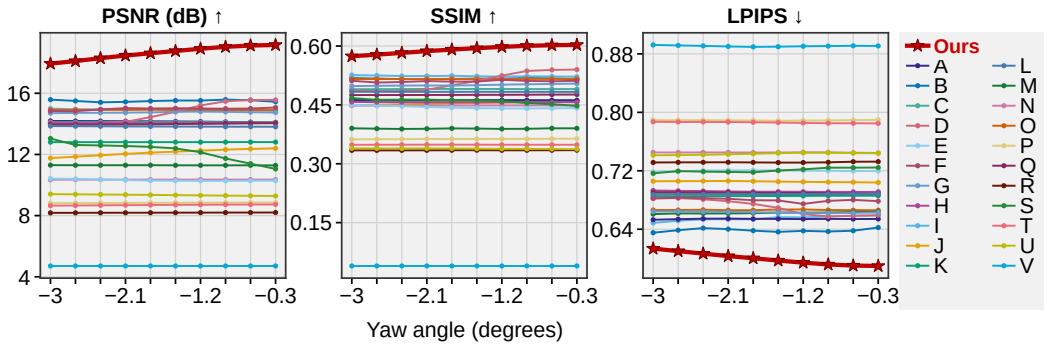


Figure A31: Game Opposite-Side Camera Viewpoint Variation curves, generated from the same values as Appendix Table A21. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

The opposite-side viewpoint curves repeat the relocation test from the reverse direction, with RECALL leading every sampled condition. Agreement across both sides shows that coarse game evidence follows content relationships in the changing wall pattern across the recorded viewing directions.

This complementary viewpoint result supports recovery of the game canvas and principal objects from wall light in both directions.

Table A21: Full Game Opposite-Side Camera Viewpoint Variation results, with 23 methods and 10 conditions.

Method	(-0.3 deg)			(-0.6 deg)			(-0.9 deg)			(-1.2 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	15.45	0.5158	**0.6423**	15.55	0.5175	**0.6379**	**15.59**	0.5185	**0.6369**	**15.53**	0.5166	**0.6378**
UniProcessor	12.81	0.4616	0.6859	12.81	0.4614	0.6859	12.81	0.4613	0.6858	12.81	0.4611	0.6856
AST	12.40	0.4583	0.7039	12.36	0.4575	0.7044	12.32	0.4568	0.7045	12.25	0.4559	0.7048
OneRestore	10.36	0.4485	0.7444	10.36	0.4486	0.7447	10.36	0.4486	0.7451	10.36	0.4486	0.7452
General restoration backbones												
Restormer	14.87	0.5219	0.6586	14.88	0.5225	0.6584	14.91	0.5229	0.6575	14.91	0.5221	0.6562
X-Restormer	14.90	0.5163	0.6660	14.91	0.5164	0.6661	14.91	0.5162	0.6663	14.91	0.5163	0.6671
NAFNet	14.10	0.4615	0.6541	14.11	0.4617	0.6539	14.13	0.4619	0.6542	14.15	0.4621	0.6539
Pixel2Pixel	11.28	0.3903	0.6639	11.29	0.3904	0.6635	11.29	0.3892	0.6629	11.29	0.3889	0.6626
ConvIR	14.10	0.4903	0.6912	14.10	0.4903	0.6908	14.10	0.4904	0.6905	14.11	0.4905	0.6902
Uformer	10.29	0.4418	0.7197	10.28	0.4414	0.7196	10.27	0.4410	0.7200	10.27	0.4412	0.7202
U-Net	8.86	0.3641	0.7898	8.85	0.3637	0.7893	8.85	0.3634	0.7889	8.85	0.3632	0.7887
Degradation-specific restoration												
Ada-Deblur	**15.57**	**0.5401**	0.6593	**15.56**	**0.5392**	0.6585	15.48	**0.5365**	0.6575	15.20	**0.5247**	0.6607
DehazeFormer	14.06	0.4567	0.6910	14.06	0.4569	0.6911	14.06	0.4570	0.6911	14.05	0.4569	0.6913
OKNet	14.04	0.4764	0.6884	14.03	0.4763	0.6887	14.02	0.4760	0.6893	14.00	0.4758	0.6896
DnCNN	8.20	0.3346	0.7325	8.20	0.3345	0.7324	8.20	0.3343	0.7316	8.19	0.3343	0.7312
Enhancement-oriented restoration												
Retinexformer	14.74	0.5042	0.6629	14.76	0.5034	0.6624	14.79	0.5026	0.6620	14.80	0.5015	0.6621
HVI-CIDNet	15.07	0.5114	0.6784	15.00	0.5103	0.6802	14.99	0.5112	0.6788	15.01	0.5141	0.6747
IRNeXt	13.81	0.4831	0.6882	13.82	0.4833	0.6882	13.82	0.4833	0.6881	13.82	0.4833	0.6882
DEA-Net	11.05	0.4476	0.7244	11.40	0.4518	0.7243	11.74	0.4547	0.7242	12.15	0.4599	0.7219
SFHformer	8.73	0.3484	0.7849	8.72	0.3485	0.7850	8.72	0.3484	0.7851	8.71	0.3485	0.7855
DeepSN-Net	9.28	0.3373	0.7440	9.30	0.3377	0.7443	9.31	0.3379	0.7447	9.32	0.3381	0.7447
DarkIR	4.71	0.0396	0.8909	4.71	0.0396	0.8911	4.71	0.0396	0.8907	4.71	0.0396	0.8904
Proposed method												
Recall(Ours)	**19.16**	**0.6028**	**0.5897**	**19.12**	**0.6021**	**0.5902**	**19.04**	**0.6005**	**0.5918**	**18.91**	**0.5979**	**0.5943**

Table A21 (continued).

Method	(-1.5 deg)			(-1.8 deg)			(-2.1 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	**15.53**	0.5168	**0.6364**	**15.49**	0.5161	**0.6380**	**15.44**	0.5158	**0.6402**
UniProcessor	12.81	0.4610	0.6855	12.81	0.4610	0.6854	12.80	0.4609	0.6853
AST	12.19	0.4549	0.7052	12.12	0.4538	0.7057	12.04	0.4526	0.7061
OneRestore	10.36	0.4485	0.7450	10.35	0.4485	0.7449	10.35	0.4484	0.7451
General restoration backbones									
Restormer	14.92	**0.5229**	0.6564	14.98	**0.5242**	0.6536	14.95	**0.5235**	0.6537
X-Restormer	14.91	0.5162	0.6670	14.93	0.5164	0.6660	14.91	0.5160	0.6661
NAFNet	14.16	0.4623	0.6541	14.17	0.4624	0.6542	14.17	0.4624	0.6545
Pixel2Pixel	11.29	0.3897	0.6628	11.30	0.3902	0.6620	11.30	0.3892	0.6616
ConvIR	14.11	0.4907	0.6899	14.11	0.4907	0.6897	14.11	0.4906	0.6895
Uformer	10.28	0.4418	0.7206	10.29	0.4430	0.7207	10.33	0.4448	0.7206
U-Net	8.84	0.3631	0.7885	8.84	0.3632	0.7888	8.83	0.3631	0.7891
Degradation-specific restoration									
Ada-Deblur	14.79	0.5113	0.6693	14.44	0.5000	0.6747	14.13	0.4886	0.6783
DehazeFormer	14.04	0.4568	0.6914	14.04	0.4566	0.6914	14.04	0.4567	0.6917
OKNet	13.99	0.4756	0.6897	13.97	0.4755	0.6899	13.97	0.4753	0.6902
DnCNN	8.19	0.3345	0.7312	8.19	0.3345	0.7314	8.19	0.3343	0.7317

Table A21 (continued).

Method	(-1.5 deg)			(-1.8 deg)			(-2.1 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Enhancement-oriented restoration									
Retinexformer	14.79	0.5003	0.6627	14.75	0.4994	0.6634	14.73	0.4995	0.6638
HVI-CIDNet	15.02	0.5096	0.6794	15.00	0.5094	0.6797	15.03	0.5108	0.6817
IRNeXt	13.83	0.4834	0.6882	13.83	0.4833	0.6881	13.83	0.4833	0.6881
DEA-Net	12.40	0.4618	0.7203	12.49	0.4620	0.7179	12.55	0.4634	0.7184
SFHformer	8.70	0.3486	0.7860	8.69	0.3487	0.7864	8.68	0.3487	0.7868
DeepSN-Net	9.34	0.3385	0.7441	9.35	0.3388	0.7433	9.37	0.3391	0.7426
DarkIR	4.71	0.0396	0.8899	4.71	0.0396	0.8896	4.71	0.0396	0.8902
Proposed method									
Recall(Ours)	**18.77**	**0.5946**	**0.5972**	**18.62**	**0.5910**	**0.6003**	**18.47**	**0.5871**	**0.6032**

Table A21 (continued).

Method	(-2.4 deg)			(-2.7 deg)			(-3 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	**15.41**	0.5157	**0.6415**	**15.50**	0.5171	**0.6387**	**15.59**	0.5184	**0.6352**
UniProcessor	12.81	0.4607	0.6853	12.81	0.4605	0.6851	12.81	0.4605	0.6849
AST	11.95	0.4515	0.7059	11.85	0.4503	0.7058	11.76	0.4493	0.7057
OneRestore	10.35	0.4483	0.7452	10.35	0.4482	0.7451	10.35	0.4482	0.7452
General restoration backbones									
Restormer	14.95	**0.5235**	0.6535	14.95	**0.5250**	0.6515	15.00	**0.5259**	0.6487
X-Restormer	14.92	0.5159	0.6666	14.92	0.5160	0.6663	14.92	0.5159	0.6663
NAFNet	14.18	0.4623	0.6545	14.19	0.4623	0.6538	14.19	0.4625	0.6530
Pixel2Pixel	11.29	0.3887	0.6615	11.30	0.3895	0.6616	11.30	0.3904	0.6607
ConvIR	14.11	0.4904	0.6891	14.11	0.4901	0.6887	14.11	0.4900	0.6885
Uformer	10.36	0.4469	0.7202	10.40	0.4486	0.7193	10.42	0.4501	0.7185
U-Net	8.83	0.3628	0.7893	8.82	0.3624	0.7893	8.82	0.3622	0.7893
Degradation-specific restoration									
Ada-Deblur	14.04	0.4854	0.6810	14.04	0.4853	0.6826	14.09	0.4872	0.6823
DehazeFormer	14.04	0.4568	0.6922	14.04	0.4570	0.6925	14.04	0.4575	0.6931
OKNet	13.96	0.4752	0.6904	13.96	0.4752	0.6906	13.96	0.4751	0.6908
DnCNN	8.19	0.3342	0.7316	8.18	0.3341	0.7315	8.18	0.3342	0.7314
Enhancement-oriented restoration									
Retinexformer	14.73	0.4993	0.6639	14.72	0.4987	0.6644	14.70	0.4980	0.6642
HVI-CIDNet	14.94	0.5083	0.6826	14.83	0.5071	0.6832	14.84	0.5115	0.6821
IRNeXt	13.84	0.4833	0.6878	13.85	0.4834	0.6876	13.86	0.4834	0.6873
DEA-Net	12.59	0.4634	0.7188	12.62	0.4630	0.7195	13.05	0.4674	0.7164
SFHformer	8.67	0.3486	0.7869	8.66	0.3484	0.7869	8.65	0.3484	0.7871
DeepSN-Net	9.38	0.3390	0.7419	9.39	0.3391	0.7415	9.40	0.3393	0.7413
DarkIR	4.71	0.0396	0.8909	4.71	0.0396	0.8916	4.71	0.0396	0.8923
Proposed method									
Recall(Ours)	**18.29**	**0.5826**	**0.6066**	**18.11**	**0.5781**	**0.6101**	**17.94**	**0.5741**	**0.6134**

Software Opposite-Side Camera Viewpoint Variation

Appendix Table A22 and Figure A32 report the Software sweep.

The opposite-side angles reduce Software PSNR from 19.669 to 17.539 dB, with SSIM decreasing and LPIPS increasing; RECALL leads all three metrics at the 10 recorded conditions.

The opposite-side curves complete the directional viewpoint pair, with RECALL leading throughout the reversed offset. The consistent ordering across both sides shows that the recovered interface hierarchy follows the content evidence carried by each changed wall pattern.

This opposite-side result extends the evidence for recovering dense software layout from wall light to both viewing directions.

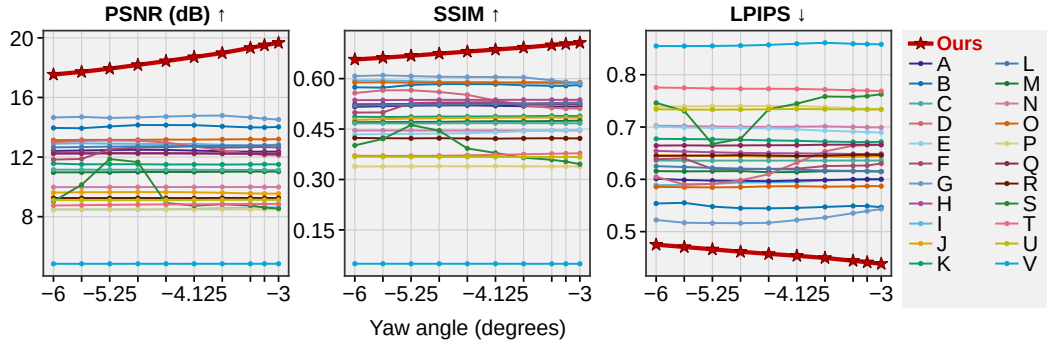


Figure A32: Software Opposite-Side Camera Viewpoint Variation curves, generated from the same values as Appendix Table A22. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

Table A22: Full Software Opposite-Side Camera Viewpoint Variation results, with 23 methods and 10 conditions.

Method	(-3 deg)			(-3.1875 deg)			(-3.375 deg)			(-3.75 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	14.02	0.5813	0.5467	13.99	0.5787	0.5489	13.99	0.5785	0.5491	14.06	0.5804	0.5473
UniProcessor	11.51	0.4886	0.6717	11.52	0.4889	0.6711	11.51	0.4893	0.6715	11.50	0.4881	0.6722
AST	9.55	0.4838	0.6436	9.55	0.4842	0.6432	9.56	0.4843	0.6426	9.60	0.4840	0.6433
OneRestore	9.99	0.4459	0.6992	9.99	0.4457	0.6995	9.99	0.4456	0.7001	9.99	0.4454	0.7012
General restoration backbones												
Restormer	12.84	0.5860	0.5998	12.78	0.5859	0.5996	12.79	0.5851	0.5998	12.82	0.5857	0.5977
X-Restormer	13.20	**0.5889**	0.5869	13.18	0.5879	0.5870	13.20	0.5891	0.5863	13.19	0.5893	0.5859
NAFNet	12.37	0.5171	0.6002	12.36	0.5168	0.6001	12.36	0.5168	0.5997	12.39	0.5179	0.5987
Pixel2Pixel	11.02	0.4750	0.6149	11.02	0.4745	0.6157	11.02	0.4739	0.6157	11.02	0.4731	0.6156
ConvIR	11.13	0.4670	0.6360	11.13	0.4672	0.6360	11.13	0.4673	0.6360	11.14	0.4676	0.6359
Uformer	8.66	0.4481	0.6895	8.65	0.4470	0.6902	8.62	0.4458	0.6912	8.58	0.4436	0.6930
U-Net	8.49	0.3387	0.7344	8.49	0.3387	0.7346	8.49	0.3388	0.7357	8.48	0.3391	0.7383
Degradation-specific restoration												
Ada-Deblur	12.12	0.5110	0.6658	12.14	0.5110	0.6652	12.22	0.5129	0.6643	12.45	0.5205	0.6534
DehazeFormer	12.25	0.5369	0.6487	12.26	0.5369	0.6484	12.26	0.5370	0.6485	12.26	0.5370	0.6492
OKNet	12.22	0.5237	0.6662	12.21	0.5237	0.6663	12.22	0.5238	0.6663	12.22	0.5239	0.6662
DnCNN	9.25	0.4222	0.6464	9.25	0.4224	0.6468	9.26	0.4226	0.6466	9.26	0.4222	0.6453
Enhancement-oriented restoration												
Retinexformer	**14.52**	0.5874	**0.5433**	**14.58**	**0.5905**	**0.5392**	**14.66**	**0.5950**	**0.5353**	**14.79**	**0.6039**	**0.5269**
HVI-CIDNet	12.63	0.5285	0.6303	12.68	0.5284	0.6264	12.66	0.5273	0.6260	12.63	0.5261	0.6253
IRNeXt	12.79	0.5268	0.6148	12.78	0.5263	0.6154	12.77	0.5258	0.6162	12.75	0.5250	0.6169
DEA-Net	8.55	0.3456	0.7627	8.61	0.3534	0.7593	8.75	0.3586	0.7577	8.83	0.3648	0.7584
SFHformer	8.85	0.3781	0.7687	8.85	0.3773	0.7696	8.85	0.3766	0.7703	8.84	0.3750	0.7718
DeepSN-Net	9.13	0.3668	0.7335	9.13	0.3668	0.7337	9.13	0.3669	0.7339	9.13	0.3669	0.7340
DarkIR	4.84	0.0491	0.8581	4.84	0.0491	0.8585	4.84	0.0492	0.8592	4.84	0.0492	0.8611
Proposed method												
Recall(Ours)	**19.67**	**0.7066**	**0.4384**	**19.50**	**0.7032**	**0.4414**	**19.33**	**0.6996**	**0.4443**	**18.98**	**0.6924**	**0.4497**

Table A22 (continued).

Method	(-4.125 deg)			(-4.5 deg)			(-4.875 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.14	0.5835	0.5453	14.15	0.5838	0.5445	14.15	0.5838	0.5448
UniProcessor	11.51	0.4877	0.6736	11.50	0.4873	0.6745	11.52	0.4872	0.6756
AST	9.64	0.4837	0.6433	9.65	0.4830	0.6433	9.65	0.4823	0.6442
OneRestore	9.99	0.4453	0.7007	9.99	0.4454	0.7003	9.99	0.4455	0.7006

Table A22 (continued).

Method	(-4.125 deg)			(-4.5 deg)			(-4.875 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones									
Restormer	12.89	0.5899	0.5951	12.87	0.5904	0.5941	12.89	0.5905	0.5939
X-Restormer	13.17	0.5876	0.5869	13.17	0.5875	0.5866	13.16	0.5882	0.5851
NAFNet	12.43	0.5192	0.5978	12.48	0.5204	0.5965	12.49	0.5203	0.5972
Pixel2Pixel	11.00	0.4734	0.6139	11.00	0.4725	0.6136	11.00	0.4714	0.6158
ConvIR	11.14	0.4676	0.6359	11.14	0.4674	0.6358	11.15	0.4670	0.6359
Uformer	8.53	0.4405	0.6955	8.49	0.4377	0.6975	8.48	0.4366	0.6981
U-Net	8.48	0.3394	0.7403	8.49	0.3392	0.7401	8.49	0.3393	0.7400
Degradation-specific restoration									
Ada-Deblur	12.72	0.5351	0.6320	12.98	0.5517	0.6098	13.10	0.5603	0.5981
DehazeFormer	12.26	0.5368	0.6496	12.27	0.5369	0.6500	12.28	0.5368	0.6506
OKNet	12.23	0.5247	0.6653	12.24	0.5250	0.6651	12.24	0.5249	0.6648
DnCNN	9.25	0.4215	0.6447	9.25	0.4221	0.6456	9.26	0.4228	0.6463
Enhancement-oriented restoration									
Retinexformer	**14.77**	**0.6049**	**0.5221**	**14.72**	**0.6049**	**0.5168**	**14.66**	**0.6057**	**0.5162**
HVI-CIDNet	12.72	0.5303	0.6204	12.66	0.5294	0.6200	12.64	0.5291	0.6194
IRNeXt	12.74	0.5241	0.6184	12.73	0.5232	0.6197	12.72	0.5228	0.6206
DEA-Net	8.74	0.3789	0.7447	8.92	0.3923	0.7339	11.66	0.4453	0.6774
SFHformer	8.83	0.3734	0.7729	8.82	0.3717	0.7732	8.81	0.3705	0.7733
DeepSN-Net	9.12	0.3669	0.7346	9.12	0.3672	0.7340	9.11	0.3671	0.7335
DarkIR	4.84	0.0492	0.8593	4.84	0.0493	0.8571	4.84	0.0493	0.8557
Proposed method									
Recall(Ours)	**18.71**	**0.6864**	**0.4538**	**18.44**	**0.6805**	**0.4575**	**18.18**	**0.6743**	**0.4616**

Table A22 (continued).

Method	(-5.25 deg)			(-5.625 deg)			(-6 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.05	0.5813	0.5479	13.93	0.5732	0.5551	13.96	0.5742	0.5538
UniProcessor	11.52	0.4865	0.6766	11.51	0.4858	0.6770	11.57	0.4864	0.6775
AST	9.64	0.4814	0.6448	9.64	0.4794	0.6457	9.62	0.4770	0.6464
OneRestore	9.98	0.4456	0.7010	9.98	0.4456	0.7019	9.98	0.4457	0.7025
General restoration backbones									
Restormer	12.90	0.5929	0.5911	12.92	0.5946	0.5894	12.90	0.5945	0.5889
X-Restormer	13.15	0.5879	0.5845	13.15	0.5889	0.5850	13.13	0.5885	0.5856
NAFNet	12.47	0.5195	0.5975	12.44	0.5179	0.5988	12.41	0.5161	0.6010
Pixel2Pixel	10.98	0.4713	0.6155	10.98	0.4709	0.6152	10.97	0.4704	0.6157
ConvIR	11.15	0.4668	0.6358	11.15	0.4669	0.6356	11.15	0.4669	0.6360
Uformer	8.48	0.4357	0.6983	8.48	0.4351	0.6991	8.48	0.4340	0.7006
U-Net	8.49	0.3389	0.7399	8.48	0.3387	0.7395	8.48	0.3388	0.7387
Degradation-specific restoration									
Ada-Deblur	13.11	0.5655	0.5912	13.08	0.5651	0.5901	13.00	0.5573	0.6049
DehazeFormer	12.29	0.5366	0.6517	12.30	0.5361	0.6531	12.30	0.5360	0.6542
OKNet	12.24	0.5246	0.6646	12.23	0.5241	0.6649	12.22	0.5238	0.6645
DnCNN	9.25	0.4223	0.6455	9.25	0.4227	0.6451	9.26	0.4235	0.6447
Enhancement-oriented restoration									
Retinexformer	**14.63**	**0.6075**	**0.5164**	**14.70**	**0.6099**	**0.5170**	**14.66**	**0.6076**	**0.5223**
HVI-CIDNet	12.53	0.5271	0.6199	11.87	0.4996	0.6400	11.83	0.4991	0.6386
IRNeXt	12.70	0.5221	0.6218	12.67	0.5210	0.6235	12.65	0.5198	0.6252
DEA-Net	11.87	0.4620	0.6677	10.14	0.4208	0.7308	9.03	0.4014	0.7462
SFHformer	8.79	0.3701	0.7737	8.77	0.3702	0.7749	8.75	0.3706	0.7755
DeepSN-Net	9.11	0.3672	0.7333	9.11	0.3675	0.7334	9.11	0.3679	0.7341
DarkIR	4.84	0.0493	0.8550	4.84	0.0493	0.8548	4.84	0.0493	0.8549
Proposed method									
Recall(Ours)	**17.93**	**0.6680**	**0.4661**	**17.72**	**0.6621**	**0.4707**	**17.54**	**0.6570**	**0.4750**

D.2.2 Vertical Camera Viewpoint Variation

Vertical viewpoint variation tests whether page sections and block boundaries remain recoverable as the wall projection changes with viewing direction. The Browser sweep spans ten recorded vertical angles from 2 to 10 degrees while screen content and the remaining imaging conditions stay fixed.



Figure A33: Real captures of the physical acquisition scene at three camera heights. The displayed screen, wall, and camera-facing arrangement remain visible while the camera elevation changes across the configurations.

Browser Vertical Viewpoint Variation

Appendix Table A23 and Figure A34 report the Browser sweep.

Increasing the vertical viewing angle lowers Browser PSNR from 16.915 to 15.018 dB, with SSIM decreasing and LPIPS increasing; RECALL leads all three metrics at the 10 recorded conditions.

The vertical-viewpoint curves show a steady decline in reconstruction quality as the observed wall projection moves, while RECALL remains the leading method across the full trajectory. This continuous ordering strengthens the table-level result: webpage sections and the boundaries of text and image blocks remain the most recoverable under RECALL even as their wall support shifts.

The complete model preserves the strongest coarse webpage reconstruction across the recorded vertical directions.

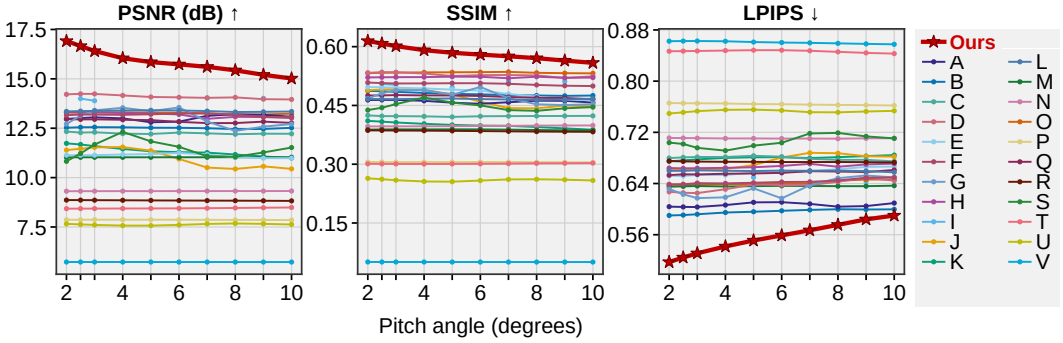


Figure A34: Browser Vertical Viewpoint Variation curves, generated from the same values as Appendix Table A23. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

Table A23: Full Browser Vertical Viewpoint Variation results, with 23 methods and 10 conditions.

Method	(2 deg)			(2.5 deg)			(3 deg)			(4 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	12.53	0.4873	**0.5901**	12.55	0.4862	**0.5907**	12.55	0.4847	**0.5920**	12.55	0.4819	**0.5947**
UniProcessor	11.73	0.4106	0.6747	11.68	0.4086	0.6761	11.59	0.4065	0.6777	11.45	0.4031	0.6800
AST	11.39	0.4887	0.6626	11.46	0.4905	0.6618	11.53	0.4916	0.6615	11.55	0.4897	0.6628
OneRestore	9.31	0.3965	0.7112	9.31	0.3966	0.7111	9.31	0.3967	0.7109	9.32	0.3968	0.7104

Table A23 (continued).

Method	(2 deg)			(2.5 deg)			(3 deg)			(4 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones												
Restormer	N/A	N/A	N/A	14.00	0.5046	0.6363	13.89	0.5026	0.6405	N/A	N/A	N/A
X-Restormer	13.29	0.5324	0.6380	13.29	0.5333	0.6383	13.30	0.5338	0.6382	13.30	**0.5343**	0.6390
NAFNet	12.97	0.4638	0.6039	13.01	0.4641	0.6034	13.05	0.4641	0.6033	13.00	0.4618	0.6063
Pixel2Pixel	11.03	0.3883	0.6350	11.03	0.3888	0.6356	11.03	0.3890	0.6361	11.03	0.3889	0.6354
ConvIR	12.33	0.4246	0.6798	12.28	0.4228	0.6808	12.30	0.4227	0.6815	12.23	0.4222	0.6815
Uformer	11.14	0.4970	0.6520	11.13	0.4961	0.6519	11.14	0.4953	0.6533	11.17	0.4934	0.6533
U-Net	7.87	0.3055	0.7658	7.87	0.3055	0.7655	7.87	0.3054	0.7654	7.87	0.3054	0.7651
Degradation-specific restoration												
Ada-Deblur	**14.21**	**0.5332**	0.6270	**14.24**	**0.5349**	0.6256	**14.24**	**0.5347**	0.6251	**14.16**	0.5315	0.6311
DehazeFormer	13.31	0.5215	0.6642	13.31	0.5219	0.6638	13.30	0.5221	0.6640	13.27	0.5223	0.6645
OKNet	12.96	0.4754	0.6531	12.95	0.4756	0.6544	12.95	0.4765	0.6542	12.93	0.4756	0.6553
DnCNN	8.86	0.3863	0.6752	8.86	0.3862	0.6745	8.86	0.3860	0.6743	8.85	0.3857	0.6740
Enhancement-oriented restoration												
Retinexformer	12.72	0.4676	0.6317	13.14	0.4812	0.6231	13.41	0.4886	0.6172	13.54	0.4893	0.6185
HVI-CIDNet	13.16	0.5084	0.6387	13.19	0.5070	0.6388	13.19	0.5061	0.6406	13.18	0.5062	0.6402
IRNeXt	13.35	0.4664	0.6598	13.37	0.4663	0.6598	13.38	0.4660	0.6606	13.40	0.4672	0.6600
DEA-Net	10.82	0.4381	0.7039	11.22	0.4442	0.7018	11.67	0.4533	0.6958	12.31	0.4701	0.6914
SFHformer	8.43	0.3011	0.8467	8.43	0.3009	0.8469	8.43	0.3008	0.8471	8.44	0.3006	0.8478
DeepSN-Net	7.66	0.2640	0.7494	7.63	0.2617	0.7512	7.60	0.2592	0.7532	7.57	0.2559	0.7552
DarkIR	5.73	0.0505	0.8624	5.73	0.0505	0.8626	5.73	0.0505	0.8627	5.73	0.0504	0.8623
Proposed method												
Recall(Ours)	**16.91**	**0.6144**	**0.5173**	**16.66**	**0.6079**	**0.5244**	**16.41**	**0.6014**	**0.5310**	**16.04**	**0.5910**	**0.5417**

Table A23 (continued).

Method	(5 deg)			(6 deg)			(7 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.52	0.4795	**0.5959**	12.52	0.4784	**0.5974**	12.50	0.4762	**0.5988**
UniProcessor	11.33	0.4004	0.6810	11.29	0.3986	0.6811	11.27	0.3980	0.6798
AST	11.36	0.4782	0.6687	10.95	0.4596	0.6807	10.51	0.4432	0.6880
OneRestore	9.32	0.3971	0.7105	9.32	0.3976	0.7102	9.32	0.3979	0.7103
General restoration backbones									
Restormer	13.34	0.4957	0.6496	N/A	N/A	N/A	14.03	0.5118	0.6384
X-Restormer	13.29	**0.5346**	0.6394	13.28	**0.5350**	0.6397	13.27	**0.5357**	0.6399
NAFNet	12.80	0.4570	0.6106	12.83	0.4543	0.6109	13.13	0.4581	0.6082
Pixel2Pixel	11.03	0.3891	0.6359	11.03	0.3890	0.6364	11.03	0.3883	0.6362
ConvIR	12.21	0.4207	0.6833	12.28	0.4224	0.6819	12.24	0.4228	0.6786
Uformer	11.19	0.4904	0.6569	11.25	0.4879	0.6573	11.17	0.4792	0.6593
U-Net	7.87	0.3054	0.7642	7.87	0.3054	0.7640	7.86	0.3054	0.7633
Degradation-specific restoration									
Ada-Deblur	**14.08**	0.5250	0.6385	**14.06**	0.5273	0.6377	**14.04**	0.5276	0.6375
DehazeFormer	13.25	0.5234	0.6655	13.20	0.5232	0.6675	12.97	0.5194	0.6708
OKNet	12.91	0.4755	0.6557	12.82	0.4742	0.6567	12.76	0.4716	0.6593
DnCNN	8.85	0.3851	0.6739	8.84	0.3846	0.6736	8.84	0.3839	0.6736
Enhancement-oriented restoration									
Retinexformer	13.36	0.4774	0.6325	13.55	0.4971	0.6168	12.84	0.4686	0.6373
HVI-CIDNet	13.21	0.5067	0.6412	13.24	0.5067	0.6424	13.24	0.5053	0.6426
IRNeXt	13.41	0.4677	0.6595	13.40	0.4663	0.6602	13.37	0.4652	0.6599
DEA-Net	11.84	0.4573	0.6992	11.56	0.4501	0.7037	11.08	0.4381	0.7183
SFHformer	8.44	0.3008	0.8484	8.44	0.3010	0.8483	8.45	0.3015	0.8474
DeepSN-Net	7.57	0.2555	0.7555	7.61	0.2583	0.7542	7.66	0.2612	0.7515
DarkIR	5.73	0.0504	0.8611	5.73	0.0504	0.8603	5.73	0.0503	0.8598
Proposed method									
Recall(Ours)	**15.85**	**0.5844**	**0.5509**	**15.73**	**0.5797**	**0.5589**	**15.61**	**0.5755**	**0.5670**

Table A23 (continued).

Method	(8 deg)			(9 deg)			(10 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.46	0.4754	**0.5998**	12.46	0.4744	**0.5994**	12.52	0.4753	**0.5997**
UniProcessor	11.17	0.3949	0.6812	11.07	0.3915	0.6829	10.99	0.3880	0.6845
AST	10.44	0.4425	0.6873	10.57	0.4497	0.6826	10.44	0.4476	0.6820
OneRestore	9.32	0.3985	0.7101	9.32	0.3988	0.7106	9.32	0.3989	0.7108
General restoration backbones									
Restormer	N/A	N/A	N/A	**14.01**	0.5110	0.6430	N/A	N/A	N/A
X-Restormer	13.18	**0.5333**	0.6444	13.20	**0.5323**	0.6462	13.24	**0.5319**	0.6464
NAFNet	13.21	0.4621	0.6039	13.18	0.4617	0.6048	13.08	0.4575	0.6095
Pixel2Pixel	11.03	0.3873	0.6359	11.03	0.3865	0.6359	11.03	0.3862	0.6366
ConvIR	12.20	0.4230	0.6769	12.22	0.4232	0.6770	12.22	0.4234	0.6746
Uformer	11.03	0.4725	0.6623	10.98	0.4651	0.6660	10.98	0.4631	0.6665
U-Net	7.86	0.3052	0.7628	7.86	0.3049	0.7626	7.85	0.3047	0.7619
Degradation-specific restoration									
Ada-Deblur	**14.06**	0.5266	0.6428	13.97	0.5201	0.6490	**13.96**	0.5243	0.6444
DehazeFormer	13.08	0.5232	0.6662	13.07	0.5206	0.6699	13.06	0.5211	0.6711
OKNet	12.76	0.4695	0.6587	12.83	0.4690	0.6579	12.77	0.4659	0.6612
DnCNN	8.83	0.3833	0.6736	8.83	0.3830	0.6734	8.82	0.3827	0.6730
Enhancement-oriented restoration									
Retinexformer	12.36	0.4529	0.6484	12.58	0.4508	0.6525	12.71	0.4532	0.6495
HVI-CIDNet	13.19	0.5023	0.6449	13.07	0.5003	0.6489	13.02	0.4995	0.6495
IRNeXt	13.32	0.4642	0.6602	13.33	0.4650	0.6594	13.35	0.4673	0.6575
DEA-Net	11.05	0.4362	0.7191	11.27	0.4426	0.7136	11.52	0.4458	0.7105
SFHformer	8.46	0.3022	0.8458	8.48	0.3024	0.8441	8.49	0.3029	0.8430
DeepSN-Net	7.68	0.2616	0.7512	7.66	0.2604	0.7526	7.63	0.2586	0.7536
DarkIR	5.73	0.0503	0.8590	5.73	0.0503	0.8582	5.73	0.0503	0.8576
Proposed method									
Recall(Ours)	**15.43**	**0.5707**	**0.5754**	**15.20**	**0.5645**	**0.5840**	**15.02**	**0.5587**	**0.5900**

Camera-Pitch Variation

Camera-pitch variation tests whether dense software structure remains recoverable as pitch changes the positions at which wall evidence mixes. The Software sweep spans ten recorded pitch angles from 0.2 to 2 degrees while screen content and the remaining imaging conditions stay fixed.

Software Camera-Pitch Variation

Appendix Table A24 and Figure A35 report the Software sweep.

Increasing camera pitch lowers Software PSNR from 21.419 to 17.265 dB, with SSIM decreasing and LPIPS increasing; RECALL leads all three metrics at the 10 recorded conditions.

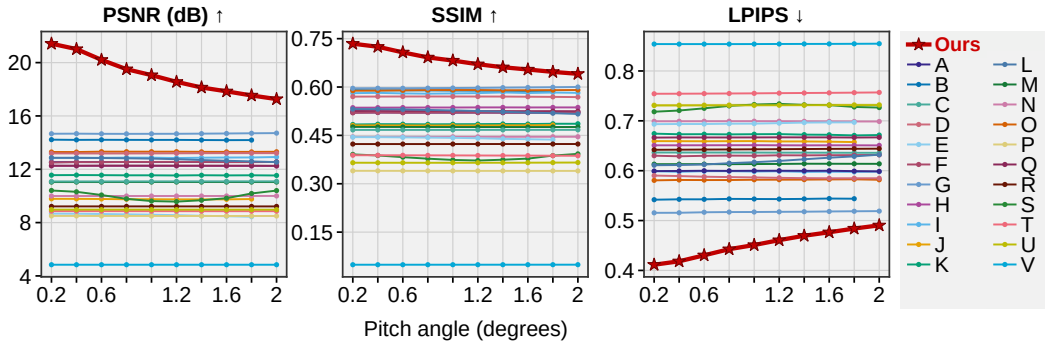


Figure A35: Software Camera-Pitch Variation curves, generated from the same values as Appendix Table A24. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

The camera-pitch variation changes the observed wall projection along another geometric axis, and RECALL preserves its lead as the offset grows. Dense panels, tool regions, and page hierarchy therefore remain the strongest recovered structures through the recorded pitch range.

This axis complements the lateral viewpoint sweep by testing recovery of the same software hierarchy in a distinct viewing direction.

Table A24: Full Software Camera-Pitch Variation results, with 23 methods and 10 conditions.

Method	(0.2 deg)			(0.4 deg)			(0.6 deg)			(0.8 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	14.22	0.5904	0.5418	14.20	0.5896	0.5426	14.21	0.5897	0.5426	14.21	0.5895	0.5435
UniProcessor	11.56	0.4838	0.6743	11.57	0.4848	0.6731	11.56	0.4848	0.6732	11.55	0.4843	0.6728
AST	9.78	0.4809	0.6593	9.78	0.4810	0.6592	9.77	0.4809	0.6590	9.75	0.4806	0.6592
OneRestore	9.99	0.4454	0.6991	9.99	0.4454	0.6991	9.99	0.4454	0.6992	9.99	0.4455	0.6992
General restoration backbones												
Restormer	12.85	0.5810	0.5989	12.86	0.5819	0.5977	12.86	0.5803	0.5990	12.87	0.5794	0.5990
X-Restormer	13.30	0.5886	0.5806	13.29	0.5890	0.5814	13.32	0.5897	0.5812	13.32	0.5906	0.5813
NAFNet	12.53	0.5211	0.5992	12.54	0.5211	0.5994	12.54	0.5210	0.5999	12.54	0.5208	0.5996
Pixel2Pixel	11.04	0.4763	0.6131	11.04	0.4762	0.6131	11.04	0.4762	0.6132	11.04	0.4761	0.6131
ConvIR	11.09	0.4670	0.6365	11.09	0.4670	0.6364	11.09	0.4670	0.6364	11.09	0.4670	0.6364
Uformer	8.67	0.4446	0.6933	8.67	0.4446	0.6937	8.65	0.4439	0.6936	8.62	0.4431	0.6942
U-Net	8.50	0.3402	0.7318	8.50	0.3401	0.7318	8.50	0.3401	0.7319	8.50	0.3400	0.7321
Degradation-specific restoration												
Ada-Deblur	13.19	0.5702	0.5902	13.19	0.5705	0.5892	13.18	0.5706	0.5880	13.19	0.5707	0.5872
DehazeFormer	12.25	0.5360	0.6509	12.25	0.5361	0.6509	12.25	0.5363	0.6510	12.25	0.5365	0.6511
OKNet	12.27	0.5255	0.6664	12.27	0.5254	0.6667	12.28	0.5252	0.6666	12.28	0.5254	0.6666
DnCNN	9.22	0.4231	0.6419	9.22	0.4231	0.6421	9.22	0.4231	0.6424	9.22	0.4231	0.6426
Enhancement-oriented restoration												
Retinexformer	**14.66**	**0.5961**	**0.5155**	**14.67**	**0.5963**	**0.5156**	**14.66**	**0.5962**	**0.5166**	**14.66**	**0.5966**	**0.5170**
HVI-CIDNet	12.51	0.5199	0.6301	12.54	0.5210	0.6289	12.53	0.5202	0.6298	12.55	0.5207	0.6302
IRNeXt	12.86	0.5317	0.6110	12.85	0.5314	0.6114	12.84	0.5307	0.6125	12.82	0.5289	0.6150
DEA-Net	10.41	0.3911	0.7183	10.31	0.3877	0.7207	10.07	0.3825	0.7251	9.78	0.3778	0.7299
SFHformer	8.86	0.3884	0.7543	8.86	0.3884	0.7544	8.86	0.3883	0.7546	8.86	0.3881	0.7548
DeepSN-Net	8.97	0.3652	0.7308	8.97	0.3651	0.7308	8.97	0.3651	0.7309	8.97	0.3651	0.7310
DarkIR	4.84	0.0489	0.8540	4.84	0.0489	0.8539	4.84	0.0489	0.8539	4.84	0.0489	0.8539
Proposed method												
Recall(Ours)	**21.42**	**0.7344**	**0.4114**	**21.02**	**0.7249**	**0.4183**	**20.21**	**0.7074**	**0.4303**	**19.51**	**0.6919**	**0.4426**

Table A24 (continued).

Method	(1 deg)			(1.2 deg)			(1.4 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.20	0.5891	0.5432	14.20	0.5888	0.5431	14.19	0.5883	0.5434
UniProcessor	11.55	0.4847	0.6732	11.54	0.4849	0.6734	11.55	0.4855	0.6723
AST	9.75	0.4807	0.6594	9.74	0.4808	0.6587	9.74	0.4811	0.6587
OneRestore	9.99	0.4455	0.6993	10.00	0.4455	0.6992	10.00	0.4456	0.6991
General restoration backbones									
Restormer	12.87	0.5803	0.5983	12.84	0.5811	0.5989	12.87	0.5832	0.5977
X-Restormer	13.32	0.5906	0.5818	13.32	0.5907	0.5820	13.31	0.5899	0.5821
NAFNet	12.54	0.5206	0.5999	12.54	0.5208	0.5999	12.54	0.5206	0.5997
Pixel2Pixel	11.04	0.4760	0.6133	11.04	0.4760	0.6136	11.04	0.4760	0.6140
ConvIR	11.09	0.4670	0.6364	11.09	0.4671	0.6362	11.09	0.4671	0.6362
Uformer	8.59	0.4424	0.6944	8.56	0.4412	0.6954	8.51	0.4393	0.6965
U-Net	8.50	0.3400	0.7322	8.49	0.3399	0.7323	8.50	0.3399	0.7323
Degradation-specific restoration									
Ada-Deblur	13.19	0.5706	0.5865	13.20	0.5705	0.5857	13.20	0.5704	0.5851
DehazeFormer	12.25	0.5365	0.6512	12.25	0.5368	0.6510	12.25	0.5368	0.6508
OKNet	12.28	0.5252	0.6667	12.27	0.5250	0.6669	12.27	0.5252	0.6668
DnCNN	9.22	0.4232	0.6429	9.22	0.4232	0.6431	9.21	0.4232	0.6434

Table A24 (continued).

Method	(1 deg)			(1.2 deg)			(1.4 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Enhancement-oriented restoration									
Retinexformer	**14.66**	**0.5970**	**0.5172**	**14.66**	**0.5974**	**0.5175**	**14.67**	**0.5982**	**0.5177**
HVI-CIDNet	12.55	0.5211	0.6300	12.56	0.5207	0.6309	12.55	0.5206	0.6308
IRNeXt	12.80	0.5275	0.6170	12.76	0.5258	0.6196	12.69	0.5232	0.6229
DEA-Net	9.61	0.3739	0.7327	9.57	0.3721	0.7340	9.68	0.3746	0.7320
SFHformer	8.86	0.3880	0.7551	8.86	0.3877	0.7555	8.86	0.3875	0.7558
DeepSN-Net	8.97	0.3651	0.7311	8.97	0.3651	0.7313	8.97	0.3652	0.7313
DarkIR	4.84	0.0489	0.8540	4.84	0.0489	0.8541	4.84	0.0489	0.8542
Proposed method									
Recall(Ours)	**19.06**	**0.6821**	**0.4509**	**18.56**	**0.6707**	**0.4607**	**18.13**	**0.6614**	**0.4696**

Table A24 (continued).

Method	(1.6 deg)			(1.8 deg)			(2 deg)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.18	0.5881	0.5441	14.19	0.5884	0.5438	N/A	N/A	N/A
UniProcessor	11.54	0.4851	0.6720	11.55	0.4861	0.6708	11.53	0.4861	0.6715
AST	9.74	0.4812	0.6582	9.77	0.4821	0.6574	N/A	N/A	N/A
OneRestore	10.00	0.4457	0.6989	10.00	0.4457	0.6987	10.00	0.4458	0.6987
General restoration backbones									
Restormer	12.88	0.5814	0.5979	12.89	0.5830	0.5976	12.92	0.5820	0.5981
X-Restormer	13.30	0.5901	0.5825	13.30	0.5904	0.5827	13.31	0.5907	0.5818
NAFNet	12.54	0.5208	0.5999	12.54	0.5211	0.5991	12.55	0.5212	0.5986
Pixel2Pixel	11.04	0.4759	0.6139	11.04	0.4760	0.6138	11.04	0.4760	0.6138
ConvIR	11.09	0.4672	0.6361	11.09	0.4672	0.6359	11.09	0.4672	0.6358
Uformer	8.48	0.4382	0.6968	8.44	0.4369	0.6970	N/A	N/A	N/A
U-Net	8.50	0.3399	0.7323	8.50	0.3399	0.7323	8.50	0.3399	0.7323
Degradation-specific restoration									
Ada-Deblur	13.21	0.5699	0.5848	13.21	0.5695	0.5848	13.21	0.5687	0.5848
DehazeFormer	12.24	0.5367	0.6509	12.24	0.5368	0.6509	12.24	0.5368	0.6507
OKNet	12.27	0.5250	0.6668	12.27	0.5251	0.6665	12.26	0.5249	0.6668
DnCNN	9.21	0.4233	0.6438	9.21	0.4233	0.6439	9.21	0.4232	0.6441
Enhancement-oriented restoration									
Retinexformer	**14.68**	**0.5987**	**0.5182**	**14.70**	**0.5993**	**0.5186**	**14.71**	**0.6001**	**0.5189**
HVI-CIDNet	12.54	0.5205	0.6311	12.54	0.5201	0.6312	12.55	0.5205	0.6316
IRNeXt	12.64	0.5208	0.6261	12.59	0.5189	0.6287	12.53	0.5164	0.6321
DEA-Net	9.83	0.3780	0.7315	10.18	0.3873	0.7279	10.40	0.3927	0.7266
SFHformer	8.86	0.3873	0.7561	8.86	0.3870	0.7565	8.86	0.3868	0.7570
DeepSN-Net	8.97	0.3653	0.7315	8.97	0.3656	0.7315	8.97	0.3658	0.7316
DarkIR	4.84	0.0490	0.8543	4.84	0.0490	0.8545	4.84	0.0490	0.8547
Proposed method									
Recall(Ours)	**17.85**	**0.6544**	**0.4765**	**17.54**	**0.6470**	**0.4840**	**17.26**	**0.6409**	**0.4904**

D.2.3 Camera Lateral-Shift Variation

Camera lateral-shift variation tests coarse screen recovery as camera movement changes the wall observation. Browser spans ten recorded displacements from 2.56 to 19.2 px, Game spans 0.256 to 2.56 px, and Software spans 2.56 to 5.12 px. Content and the remaining imaging conditions stay fixed within every sweep.

Browser Camera Lateral-Shift Variation

Appendix Table A25 and Figure A36 report the Browser sweep.

Browser PSNR fluctuates between 14.286 and 16.411 dB across lateral camera positions, with RECALL leading all three metrics at the 10 recorded conditions.

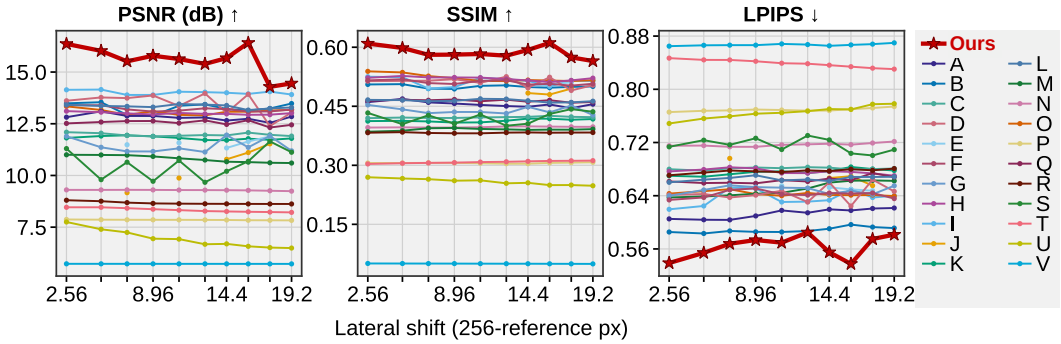


Figure A36: Browser Camera Lateral-Shift Variation curves, generated from the same values as Appendix Table A25. Higher PSNR and SSIM and lower LPIPS indicate better restoration. The axis shows the displacement fraction multiplied by 256, in 256-reference pixels. Method letters follow Section D.

Table A25: Full Browser Camera Lateral-Shift Variation results, with 23 methods and 10 conditions.

Method	(2.56 px)			(5.12 px)			(7.04 px)			(8.96 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	13.49	0.5054	**0.5855**	13.54	0.5062	**0.5832**	12.93	0.4949	**0.5870**	12.89	0.4939	**0.5857**
UniProcessor	11.81	0.4123	0.6699	11.91	0.4129	0.6685	11.94	0.4115	0.6723	11.89	0.4086	0.6760
AST	N/A	N/A	N/A	N/A	N/A	N/A	9.17	0.4248	0.6961	N/A	N/A	N/A
OneRestore	9.30	0.3959	0.7151	9.30	0.3964	0.7154	9.30	0.3959	0.7135	9.30	0.3959	0.7135
General restoration backbones												
Restormer	**14.14**	0.5251	0.6196	**14.15**	0.5240	0.6246	**13.89**	0.4951	0.6522	**13.89**	0.4987	0.6510
X-Restormer	13.34	**0.5388**	0.6432	13.17	**0.5360**	0.6469	12.93	**0.5267**	0.6498	13.10	0.5214	0.6425
NAFNet	12.82	0.4605	0.6052	13.10	0.4688	0.6039	12.88	0.4598	0.6037	12.88	0.4569	0.6096
Pixel2Pixel	11.00	0.3853	0.6373	10.99	0.3878	0.6389	10.98	0.3942	0.6406	10.92	0.3949	0.6430
ConvIR	12.09	0.4198	0.6799	12.04	0.4213	0.6776	11.93	0.4203	0.6812	11.89	0.4202	0.6824
Uformer	N/A	N/A	N/A	N/A	N/A	N/A	11.49	0.5002	0.6595	N/A	N/A	N/A
U-Net	7.87	0.3058	0.7657	7.86	0.3058	0.7677	7.86	0.3062	0.7683	7.86	0.3062	0.7696
Degradation-specific restoration												
Ada-Deblur	13.61	0.5138	0.6413	13.77	0.5145	0.6425	13.74	0.5150	0.6374	13.87	0.5188	0.6409
DehazeFormer	13.11	0.5223	0.6766	13.06	0.5271	0.6793	13.00	0.5233	0.6827	12.95	**0.5232**	0.6811
OKNet	12.52	0.4640	0.6615	12.58	0.4665	0.6591	12.63	0.4653	0.6595	12.63	0.4672	0.6586
DnCNN	8.80	0.3828	0.6707	8.76	0.3842	0.6747	8.69	0.3822	0.6779	8.65	0.3813	0.6767
Enhancement-oriented restoration												
Retinexformer	11.89	0.4534	0.6399	11.36	0.4421	0.6486	11.16	0.4325	0.6556	11.16	0.4355	0.6529
HVI-CIDNet	13.40	0.5158	0.6337	13.39	0.5187	0.6374	13.19	0.5089	0.6488	13.09	0.5066	0.6509
IRNeXt	13.41	0.4663	0.6601	13.36	0.4656	0.6641	13.34	0.4627	0.6668	13.30	0.4637	0.6708
DEA-Net	11.30	0.4331	0.7135	9.80	0.4044	0.7235	10.64	0.4271	0.7165	9.72	0.4055	0.7264
SFHformer	8.46	0.3034	0.8468	8.46	0.3053	0.8442	8.42	0.3061	0.8441	8.37	0.3068	0.8421
DeepSN-Net	7.75	0.2696	0.7486	7.40	0.2665	0.7560	7.25	0.2647	0.7593	6.94	0.2609	0.7633
DarkIR	5.73	0.0505	0.8648	5.73	0.0504	0.8661	5.73	0.0503	0.8664	5.73	0.0502	0.8664
Proposed method												
Recall(Ours)	**16.36**	**0.6093**	**0.5388**	**16.02**	**0.5982**	**0.5542**	**15.52**	**0.5808**	**0.5678**	**15.79**	**0.5812**	**0.5734**

Table A25 (continued).

Method	(10.88 px)			(12.8 px)			(14.4 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	13.37	0.5019	**0.5855**	13.43	0.5032	**0.5869**	13.22	0.4988	**0.5904**
UniProcessor	11.81	0.4091	0.6767	11.71	0.4132	0.6743	11.71	0.4187	0.6768
AST	9.88	0.4592	0.6762	N/A	N/A	N/A	10.78	0.4836	0.6666
OneRestore	9.29	0.3967	0.7165	9.29	0.3988	0.7172	9.29	0.3990	0.7181
General restoration backbones									
Restormer	**14.05**	0.5220	0.6306	**14.03**	0.5187	0.6311	**14.00**	0.5143	0.6333
X-Restormer	12.93	0.5143	0.6400	12.90	0.5140	0.6442	13.08	**0.5166**	0.6412
NAFNet	12.78	0.4534	0.6179	12.80	0.4505	0.6143	12.66	0.4488	0.6195
Pixel2Pixel	10.83	0.3924	0.6443	10.75	0.3912	0.6509	10.66	0.3899	0.6597
ConvIR	11.92	0.4217	0.6814	11.95	0.4224	0.6829	11.94	0.4231	0.6822
Uformer	11.58	0.5079	0.6549	N/A	N/A	N/A	11.33	0.5013	0.6525
U-Net	7.85	0.3053	0.7688	7.85	0.3040	0.7679	7.85	0.3041	0.7680
Degradation-specific restoration									
Ada-Deblur	13.36	0.5095	0.6474	13.97	**0.5252**	0.6305	13.03	0.4968	0.6601
DehazeFormer	13.02	**0.5229**	0.6741	12.98	0.5192	0.6739	12.98	0.5156	0.6768
OKNet	12.53	0.4627	0.6634	12.66	0.4667	0.6614	12.47	0.4616	0.6658
DnCNN	8.64	0.3812	0.6756	8.63	0.3830	0.6781	8.63	0.3835	0.6770
Enhancement-oriented restoration									
Retinexformer	11.31	0.4355	0.6521	11.13	0.4317	0.6515	11.95	0.4486	0.6426
HVI-CIDNet	13.14	0.5146	0.6421	13.25	0.5161	0.6410	13.20	0.5050	0.6441
IRNeXt	13.45	0.4690	0.6630	13.43	0.4683	0.6644	13.39	0.4641	0.6620
DEA-Net	10.72	0.4291	0.7094	9.67	0.4005	0.7305	10.20	0.4057	0.7239
SFHformer	8.32	0.3082	0.8392	8.28	0.3089	0.8384	8.26	0.3101	0.8363
DeepSN-Net	6.92	0.2618	0.7647	6.67	0.2542	0.7671	6.69	0.2555	0.7703
DarkIR	5.73	0.0500	0.8682	5.73	0.0499	0.8672	5.73	0.0499	0.8654
Proposed method									
Recall(Ours)	**15.63**	**0.5828**	**0.5694**	**15.39**	**0.5785**	**0.5849**	**15.68**	**0.5931**	**0.5551**

Table A25 (continued).

Method	(16 px)			(17.6 px)			(19.2 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	13.14	0.4972	**0.5966**	13.24	0.4992	**0.5929**	13.48	0.5004	**0.5914**
UniProcessor	11.78	0.4184	0.6832	11.72	0.4158	0.6801	11.79	0.4175	0.6779
AST	11.11	0.4798	0.6694	11.53	0.4948	0.6552	N/A	N/A	N/A
OneRestore	9.28	0.3983	0.7168	9.26	0.3978	0.7192	9.24	0.3977	0.7215
General restoration backbones									
Restormer	**13.94**	0.5005	0.6495	**14.05**	0.5152	0.6373	**13.91**	0.5141	0.6399
X-Restormer	13.08	0.5154	0.6409	13.14	0.5141	0.6410	13.17	0.5161	0.6395
NAFNet	12.74	0.4546	0.6179	12.54	0.4450	0.6208	12.85	0.4553	0.6215
Pixel2Pixel	10.65	0.3907	0.6625	10.61	0.3905	0.6630	10.60	0.3918	0.6624
ConvIR	12.07	0.4258	0.6795	11.97	0.4232	0.6801	11.90	0.4223	0.6809
Uformer	11.64	0.5055	0.6496	11.89	0.5108	0.6475	N/A	N/A	N/A
U-Net	7.84	0.3061	0.7701	7.83	0.3068	0.7719	7.83	0.3076	0.7741
Degradation-specific restoration									
Ada-Deblur	13.93	**0.5238**	0.6245	12.39	0.4902	0.6642	13.05	0.5036	0.6465
DehazeFormer	12.93	0.5114	0.6758	12.94	**0.5158**	0.6736	13.01	**0.5215**	0.6701
OKNet	12.67	0.4654	0.6633	12.32	0.4590	0.6740	12.45	0.4609	0.6680
DnCNN	8.62	0.3828	0.6799	8.62	0.3832	0.6782	8.62	0.3833	0.6808
Enhancement-oriented restoration									
Retinexformer	11.36	0.4345	0.6474	11.91	0.4518	0.6421	11.19	0.4278	0.6550
HVI-CIDNet	13.09	0.5070	0.6433	13.10	0.5025	0.6441	13.19	0.5072	0.6357
IRNeXt	13.16	0.4593	0.6683	13.24	0.4599	0.6682	13.29	0.4629	0.6685
DEA-Net	10.69	0.4305	0.7037	11.65	0.4427	0.7005	11.12	0.4361	0.7093
SFHformer	8.24	0.3111	0.8340	8.23	0.3114	0.8318	8.21	0.3119	0.8303
DeepSN-Net	6.57	0.2496	0.7697	6.51	0.2498	0.7776	6.49	0.2480	0.7783
DarkIR	5.73	0.0497	0.8667	5.72	0.0496	0.8679	5.72	0.0494	0.8698

Table A25 (continued).

Method	(16 px)			(17.6 px)			(19.2 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Proposed method									
Recall(Ours)	**16.41**	**0.6111**	**0.5375**	**14.29**	**0.5743**	**0.5749**	**14.45**	**0.5649**	**0.5815**

The Browser lateral-shift curves contain local peaks and troughs, and RECALL remains first at every sampled position. The varying metrics show that reconstruction quality depends on the recorded position.

The resulting trajectory supports coarse webpage recovery across the recorded camera positions.

Game Camera Lateral-Shift Variation

Appendix Table A26 and Figure A37 report the Game sweep.

Game PSNR decreases steadily from 19.141 to 17.183 dB across the 10 recorded lateral positions, with RECALL leading all three metrics throughout.

The game lateral-shift PSNR curve decreases across positions, with RECALL first throughout; the broad canvas and principal objects remain the strongest recovered structures.

The end-to-end result keeps the moving low-signal game field recoverable across the recorded positions.

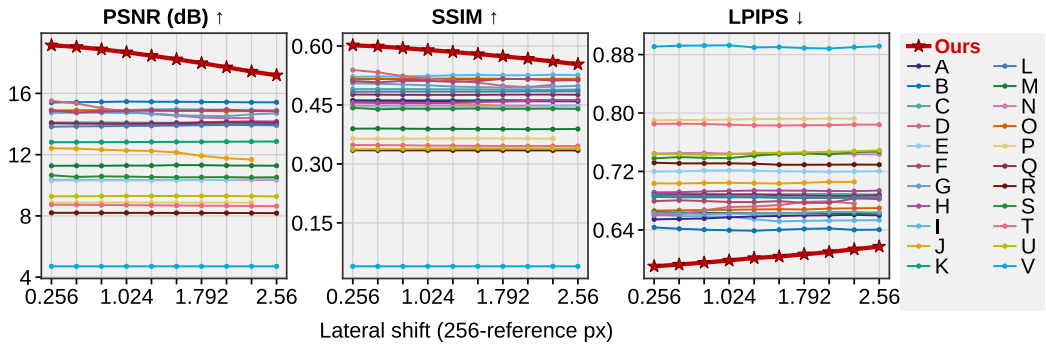


Figure A37: Game Camera Lateral-Shift Variation curves, generated from the same values as Appendix Table A26. Higher PSNR and SSIM and lower LPIPS indicate better restoration. The axis shows the displacement fraction multiplied by 256, in 256-reference pixels. Method letters follow Section D.

Table A26: Full Game Camera Lateral-Shift Variation results, with 23 methods and 10 conditions.

Method	(0.256 px)			(0.512 px)			(0.768 px)			(1.024 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	15.40	0.5145	**0.6434**	**15.43**	0.5160	**0.6416**	**15.44**	0.5154	**0.6403**	**15.47**	0.5158	**0.6395**
UniProcessor	12.81	0.4618	0.6852	12.81	0.4619	0.6846	12.82	0.4619	0.6845	12.82	0.4621	0.6846
AST	12.42	0.4585	0.7037	12.39	0.4579	0.7036	12.33	0.4570	0.7042	12.27	0.4559	0.7045
OneRestore	10.36	0.4483	0.7445	10.36	0.4483	0.7452	10.35	0.4484	0.7455	10.35	0.4484	0.7445
General restoration backbones												
Restormer	14.84	0.5218	0.6606	14.88	0.5224	0.6589	14.91	0.5230	0.6587	14.91	**0.5236**	0.6581
X-Restormer	14.89	0.5164	0.6663	14.89	0.5167	0.6668	14.90	0.5170	0.6672	14.89	0.5168	0.6675
NAFNet	14.07	0.4610	0.6545	14.07	0.4608	0.6551	14.07	0.4604	0.6557	14.06	0.4601	0.6572
Pixel2Pixel	11.27	0.3895	0.6642	11.28	0.3901	0.6637	11.28	0.3898	0.6635	11.29	0.3891	0.6631
ConvIR	14.10	0.4903	0.6908	14.10	0.4903	0.6897	14.10	0.4903	0.6885	14.10	0.4902	0.6880
Uformer	10.31	0.4424	0.7199	10.32	0.4431	0.7200	10.32	0.4436	0.7213	10.32	0.4437	0.7217
U-Net	8.86	0.3643	0.7900	8.87	0.3642	0.7904	8.87	0.3642	0.7905	8.87	0.3645	0.7911

Table A26 (continued).

Method	(0.256 px)			(0.512 px)			(0.768 px)			(1.024 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Degradation-specific restoration												
Ada-Deblur	**15.51**	**0.5389**	0.6598	15.34	**0.5331**	0.6608	15.04	**0.5232**	0.6669	14.81	0.5173	0.6713
DehazeFormer	14.06	0.4559	0.6914	14.05	0.4550	0.6917	14.04	0.4551	0.6926	14.03	0.4546	0.6934
OKNet	14.04	0.4765	0.6883	14.03	0.4763	0.6883	14.02	0.4758	0.6886	14.01	0.4757	0.6887
DnCNN	8.20	0.3346	0.7319	8.20	0.3345	0.7311	8.20	0.3345	0.7310	8.20	0.3345	0.7311
Enhancement-oriented restoration												
Retinexformer	14.73	0.5052	0.6630	14.74	0.5040	0.6626	14.74	0.5021	0.6617	14.73	0.4999	0.6623
HVI-CIDNet	14.89	0.5105	0.6794	14.75	0.5075	0.6806	14.81	0.5111	0.6796	14.86	0.5113	0.6782
IRNeXt	13.82	0.4835	0.6876	13.85	0.4838	0.6868	13.86	0.4840	0.6862	13.87	0.4840	0.6861
DEA-Net	10.65	0.4427	0.7380	10.55	0.4390	0.7397	10.58	0.4404	0.7387	10.57	0.4400	0.7383
SFHformer	8.73	0.3482	0.7851	8.72	0.3478	0.7853	8.71	0.3473	0.7850	8.70	0.3467	0.7840
DeepSN-Net	9.28	0.3372	0.7437	9.28	0.3376	0.7435	9.29	0.3380	0.7429	9.30	0.3387	0.7433
DarkIR	4.71	0.0396	0.8910	4.71	0.0396	0.8922	4.71	0.0396	0.8924	4.71	0.0396	0.8927
Proposed method												
Recall(Ours)	**19.14**	**0.6018**	**0.5902**	**19.04**	**0.5989**	**0.5926**	**18.88**	**0.5948**	**0.5952**	**18.68**	**0.5899**	**0.5982**

Table A26 (continued).

Method	(1.28 px)			(1.536 px)			(1.792 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	**15.45**	0.5158	**0.6389**	**15.46**	0.5163	**0.6402**	**15.44**	0.5162	**0.6413**
UniProcessor	12.83	0.4621	0.6845	12.83	0.4621	0.6840	12.84	0.4625	0.6838
AST	12.24	0.4545	0.7040	12.15	0.4512	0.7035	11.92	0.4475	0.7044
OneRestore	10.35	0.4483	0.7438	10.35	0.4482	0.7435	10.35	0.4483	0.7448
General restoration backbones									
Restormer	14.97	**0.5254**	0.6546	14.98	**0.5262**	0.6517	14.96	**0.5255**	0.6524
X-Restormer	14.88	0.5172	0.6680	14.87	0.5170	0.6684	14.86	0.5163	0.6680
NAFNet	14.04	0.4598	0.6585	14.01	0.4595	0.6591	14.00	0.4595	0.6597
Pixel2Pixel	11.28	0.3892	0.6627	11.32	0.3889	0.6626	11.31	0.3887	0.6630
ConvIR	14.09	0.4898	0.6886	14.07	0.4895	0.6889	14.05	0.4890	0.6891
Uformer	10.31	0.4435	0.7211	10.32	0.4430	0.7203	10.34	0.4431	0.7199
U-Net	8.87	0.3646	0.7917	8.87	0.3648	0.7920	8.87	0.3647	0.7920
Degradation-specific restoration									
Ada-Deblur	14.66	0.5116	0.6720	14.55	0.5068	0.6740	14.43	0.4986	0.6782
DehazeFormer	14.05	0.4555	0.6939	14.09	0.4573	0.6939	14.12	0.4589	0.6937
OKNet	14.02	0.4757	0.6885	14.05	0.4758	0.6876	14.08	0.4762	0.6870
DnCNN	8.20	0.3344	0.7306	8.19	0.3345	0.7292	8.19	0.3345	0.7292
Enhancement-oriented restoration									
Retinexformer	14.69	0.4970	0.6623	14.59	0.4953	0.6625	14.53	0.4943	0.6637
HVI-CIDNet	14.89	0.5088	0.6782	14.86	0.5108	0.6794	14.89	0.5163	0.6771
IRNeXt	13.88	0.4839	0.6856	13.90	0.4838	0.6847	13.92	0.4841	0.6844
DEA-Net	10.54	0.4402	0.7416	10.52	0.4411	0.7440	10.53	0.4401	0.7449
SFHformer	8.69	0.3462	0.7831	8.68	0.3459	0.7829	8.67	0.3456	0.7832
DeepSN-Net	9.30	0.3396	0.7455	9.30	0.3397	0.7454	9.30	0.3394	0.7462
DarkIR	4.71	0.0396	0.8898	4.71	0.0396	0.8903	4.71	0.0396	0.8889
Proposed method									
Recall(Ours)	**18.46**	**0.5848**	**0.6016**	**18.23**	**0.5794**	**0.6036**	**17.98**	**0.5737**	**0.6066**

Table A26 (continued).

Method	(2.048 px)			(2.304 px)			(2.56 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	**15.43**	0.5159	**0.6421**	**15.42**	0.5151	**0.6401**	**15.42**	0.5150	**0.6404**
UniProcessor	12.85	0.4626	0.6839	12.85	0.4625	0.6842	12.86	0.4626	0.6839
AST	11.76	0.4454	0.7058	11.68	0.4445	0.7057	N/A	N/A	N/A
OneRestore	10.35	0.4482	0.7449	10.35	0.4482	0.7436	10.35	0.4482	0.7434

Table A26 (continued).

Method	(2.048 px)			(2.304 px)			(2.56 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones									
Restormer	14.92	**0.5255**	0.6529	14.93	**0.5268**	0.6531	14.89	**0.5259**	0.6534
X-Restormer	14.83	0.5158	0.6692	14.84	0.5165	0.6696	14.83	0.5166	0.6699
NAFNet	13.99	0.4594	0.6600	13.98	0.4594	0.6606	13.98	0.4593	0.6598
Pixel2Pixel	11.29	0.3884	0.6628	11.29	0.3884	0.6624	11.28	0.3890	0.6622
ConvIR	14.03	0.4885	0.6892	14.04	0.4887	0.6890	14.07	0.4892	0.6884
Uformer	10.37	0.4443	0.7196	10.40	0.4455	0.7199	10.43	0.4465	0.7205
U-Net	8.87	0.3645	0.7924	8.86	0.3644	0.7922	N/A	N/A	N/A
Degradation-specific restoration									
Ada-Deblur	14.39	0.4955	0.6792	14.40	0.5015	0.6760	N/A	N/A	N/A
DehazeFormer	14.15	0.4603	0.6933	14.18	0.4612	0.6931	14.17	0.4623	0.6938
OKNet	14.11	0.4764	0.6865	14.10	0.4764	0.6866	14.08	0.4761	0.6875
DnCNN	8.19	0.3344	0.7293	8.19	0.3344	0.7295	8.18	0.3343	0.7293
Enhancement-oriented restoration									
Retinexformer	14.52	0.4941	0.6647	14.63	0.4966	0.6646	14.69	0.4987	0.6638
HVI-CIDNet	14.94	0.5157	0.6771	14.86	0.5121	0.6830	14.86	0.5129	0.6823
IRNeXt	13.94	0.4845	0.6841	13.93	0.4846	0.6843	13.91	0.4849	0.6849
DEA-Net	10.53	0.4402	0.7432	10.51	0.4405	0.7466	10.53	0.4400	0.7471
SFHformer	8.66	0.3455	0.7834	8.65	0.3454	0.7842	8.64	0.3454	0.7841
DeepSN-Net	9.30	0.3393	0.7469	9.29	0.3394	0.7477	9.28	0.3395	0.7490
DarkIR	4.71	0.0396	0.8883	4.71	0.0395	0.8902	4.71	0.0395	0.8915
Proposed method									
Recall(Ours)	**17.71**	**0.5676**	**0.6097**	**17.43**	**0.5606**	**0.6135**	**17.18**	**0.5536**	**0.6172**

Software Camera Lateral-Shift Variation

Appendix Table A27 and Figure A38 report the Software sweep.

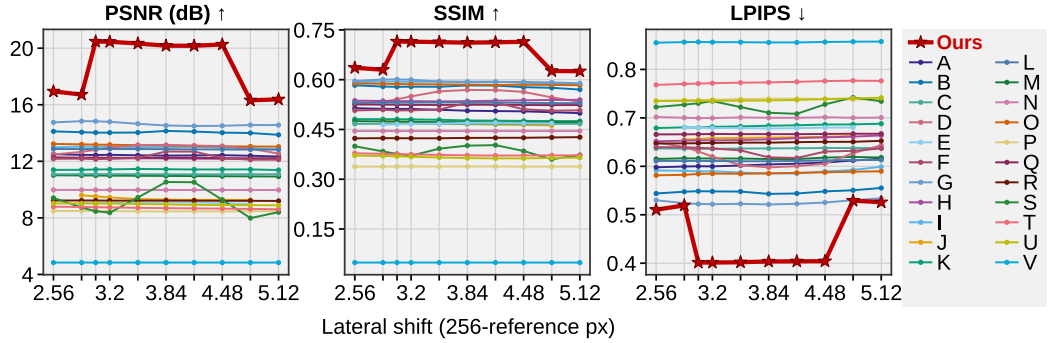


Figure A38: Software Camera Lateral-Shift Variation curves, generated from the same values as Appendix Table A27. Higher PSNR and SSIM and lower LPIPS indicate better restoration. The axis shows the displacement fraction multiplied by 256, in 256-reference pixels. Method letters follow Section D.

Table A27: Full Software Camera Lateral-Shift Variation results, with 23 methods and 10 conditions.

Method	(2.56 px)			(2.88 px)			(3.04 px)			(3.2 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	14.12	0.5831	0.5440	14.06	0.5793	0.5475	14.03	0.5785	0.5487	14.03	0.5789	0.5482
UniProcessor	11.39	0.4811	0.6790	11.40	0.4811	0.6804	11.42	0.4811	0.6798	11.43	0.4803	0.6815
AST	N/A	N/A	N/A	9.60	0.4753	0.6550	9.52	0.4729	0.6565	9.45	0.4707	0.6580
OneRestore	9.98	0.4453	0.7018	9.98	0.4452	0.7003	9.98	0.4452	0.6996	9.98	0.4452	0.6996

Table A27 (continued).

Method	(2.56 px)			(2.88 px)			(3.04 px)			(3.2 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones												
Restormer	12.99	0.5919	0.5914	13.04	0.5945	0.5909	13.02	0.5940	0.5895	13.04	0.5931	0.5899
X-Restormer	13.23	0.5886	0.5814	13.20	0.5876	0.5824	13.18	0.5868	0.5843	13.17	0.5864	0.5850
NAFNet	12.50	0.5142	0.5980	12.46	0.5122	0.5995	12.44	0.5118	0.6001	12.46	0.5118	0.5999
Pixel2Pixel	11.01	0.4750	0.6152	11.00	0.4743	0.6165	10.99	0.4741	0.6162	10.99	0.4733	0.6163
ConvIR	11.08	0.4669	0.6369	11.09	0.4670	0.6363	11.09	0.4671	0.6361	11.09	0.4670	0.6362
Uformer	N/A	N/A	N/A	9.02	0.4640	0.6801	9.04	0.4654	0.6796	9.07	0.4666	0.6789
U-Net	8.48	0.3380	0.7356	8.49	0.3381	0.7362	8.49	0.3384	0.7368	8.48	0.3385	0.7376
Degradation-specific restoration												
Ada-Deblur	12.48	0.5271	0.6494	12.67	0.5337	0.6400	12.81	0.5408	0.6308	12.98	0.5497	0.6201
DehazeFormer	12.22	0.5368	0.6516	12.22	0.5359	0.6529	12.22	0.5354	0.6535	12.21	0.5354	0.6536
OKNet	12.28	0.5253	0.6659	12.25	0.5248	0.6660	12.26	0.5247	0.6662	12.25	0.5241	0.6668
DnCNN	9.23	0.4232	0.6471	9.23	0.4238	0.6474	9.23	0.4237	0.6477	9.22	0.4234	0.6483
Enhancement-oriented restoration												
Retinexformer	**14.75**	**0.5960**	**0.5300**	**14.84**	**0.6007**	**0.5239**	**14.83**	**0.6009**	**0.5224**	**14.79**	**0.5999**	**0.5218**
HVI-CIDNet	12.18	0.5072	0.6395	12.19	0.5093	0.6394	12.15	0.5073	0.6382	12.18	0.5076	0.6369
IRNeXt	12.87	0.5311	0.6109	12.87	0.5305	0.6112	12.87	0.5306	0.6111	12.87	0.5310	0.6111
DEA-Net	9.41	0.3994	0.7223	8.73	0.3839	0.7272	8.47	0.3763	0.7301	8.37	0.3709	0.7346
SFHformer	8.79	0.3782	0.7681	8.77	0.3765	0.7700	8.75	0.3756	0.7708	8.74	0.3748	0.7716
DeepSN-Net	9.03	0.3713	0.7347	9.02	0.3701	0.7353	9.02	0.3691	0.7351	9.01	0.3678	0.7351
DarkIR	4.84	0.0489	0.8552	4.84	0.0489	0.8563	4.84	0.0489	0.8567	4.84	0.0489	0.8563
Proposed method												
Recall(Ours)	**16.94**	**0.6359**	**0.5104**	**16.72**	**0.6299**	**0.5194**	**20.47**	**0.7149**	**0.4014**	**20.46**	**0.7145**	**0.4013**

Table A27 (continued).

Method	(3.52 px)			(3.84 px)			(4.16 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.03	0.5786	0.5479	14.15	0.5827	0.5431	14.10	0.5823	0.5439
UniProcessor	11.46	0.4792	0.6823	11.44	0.4772	0.6838	11.42	0.4765	0.6847
AST	9.34	0.4671	0.6586	9.29	0.4658	0.6594	9.27	0.4647	0.6600
OneRestore	9.98	0.4452	0.7010	9.97	0.4451	0.7003	9.97	0.4450	0.7002
General restoration backbones									
Restormer	12.99	0.5940	0.5871	13.01	**0.5941**	0.5855	13.02	**0.5941**	0.5852
X-Restormer	13.14	0.5861	0.5847	13.12	0.5853	0.5853	13.07	0.5841	0.5867
NAFNet	12.43	0.5093	0.6017	12.41	0.5064	0.6039	12.42	0.5054	0.6054
Pixel2Pixel	10.98	0.4722	0.6161	10.97	0.4721	0.6151	10.96	0.4717	0.6150
ConvIR	11.09	0.4669	0.6367	11.08	0.4671	0.6370	11.08	0.4671	0.6373
Uformer	9.09	0.4676	0.6789	9.10	0.4697	0.6781	9.09	0.4703	0.6788
U-Net	8.45	0.3382	0.7388	8.46	0.3385	0.7396	8.46	0.3385	0.7398
Degradation-specific restoration									
Ada-Deblur	13.14	0.5647	0.6023	13.16	0.5691	0.5978	13.12	0.5686	0.6004
DehazeFormer	12.21	0.5346	0.6542	12.20	0.5352	0.6558	12.18	0.5367	0.6582
OKNet	12.24	0.5240	0.6665	12.26	0.5244	0.6664	12.25	0.5246	0.6663
DnCNN	9.22	0.4234	0.6489	9.22	0.4245	0.6489	9.22	0.4248	0.6499
Enhancement-oriented restoration									
Retinexformer	**14.65**	**0.5946**	**0.5226**	**14.53**	0.5924	**0.5213**	**14.50**	0.5927	**0.5227**
HVI-CIDNet	12.24	0.5100	0.6329	12.69	0.5306	0.6185	12.69	0.5315	0.6172
IRNeXt	12.87	0.5315	0.6104	12.86	0.5316	0.6105	12.85	0.5311	0.6112
DEA-Net	9.44	0.3922	0.7223	10.53	0.4013	0.7106	10.52	0.4027	0.7084
SFHformer	8.71	0.3732	0.7727	8.69	0.3720	0.7732	8.67	0.3714	0.7744
DeepSN-Net	8.98	0.3655	0.7357	8.95	0.3637	0.7359	8.92	0.3628	0.7370
DarkIR	4.84	0.0489	0.8562	4.84	0.0489	0.8557	4.84	0.0489	0.8557
Proposed method									
Recall(Ours)	**20.33**	**0.7132**	**0.4020**	**20.18**	**0.7116**	**0.4036**	**20.17**	**0.7127**	**0.4039**

Table A27 (continued).

Method	(4.48 px)			(4.8 px)			(5.12 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.03	0.5775	0.5482	14.00	0.5756	0.5505	13.87	0.5702	0.5553
UniProcessor	11.42	0.4758	0.6862	11.42	0.4754	0.6866	11.38	0.4751	0.6880
AST	9.28	0.4636	0.6609	9.26	0.4623	0.6626	N/A	N/A	N/A
OneRestore	9.97	0.4452	0.7014	9.97	0.4452	0.7002	9.97	0.4451	0.7006
General restoration backbones									
Restormer	12.96	0.5906	0.5893	12.93	0.5890	0.5926	12.84	0.5863	0.5990
X-Restormer	13.06	0.5849	0.5876	13.05	0.5842	0.5889	13.04	0.5831	0.5897
NAFNet	12.43	0.5046	0.6078	12.39	0.5020	0.6120	12.34	0.4992	0.6157
Pixel2Pixel	10.95	0.4711	0.6179	10.93	0.4712	0.6193	10.92	0.4714	0.6181
ConvIR	11.08	0.4668	0.6378	11.09	0.4669	0.6378	11.09	0.4670	0.6378
Uformer	9.04	0.4688	0.6800	8.99	0.4684	0.6801	N/A	N/A	N/A
U-Net	8.45	0.3379	0.7390	8.47	0.3381	0.7382	8.47	0.3383	0.7377
Degradation-specific restoration									
Ada-Deblur	13.08	0.5632	0.6055	12.90	0.5466	0.6270	12.54	0.5332	0.6436
DehazeFormer	12.17	0.5378	0.6598	12.16	0.5388	0.6613	12.13	0.5394	0.6638
OKNet	12.23	0.5237	0.6668	12.21	0.5234	0.6672	12.22	0.5236	0.6672
DnCNN	9.21	0.4250	0.6506	9.21	0.4260	0.6505	9.20	0.4268	0.6526
Enhancement-oriented restoration									
Retinexformer	**14.51**	**0.5932**	**0.5252**	**14.57**	**0.5917**	**0.5301**	**14.56**	**0.5893**	**0.5340**
HVI-CIDNet	12.24	0.5107	0.6304	12.11	0.5066	0.6320	12.13	0.5075	0.6369
IRNeXt	12.84	0.5302	0.6121	12.83	0.5294	0.6132	12.82	0.5294	0.6131
DEA-Net	9.28	0.3851	0.7278	7.99	0.3601	0.7420	8.40	0.3731	0.7342
SFHformer	8.65	0.3716	0.7760	8.63	0.3719	0.7768	8.61	0.3718	0.7764
DeepSN-Net	8.91	0.3629	0.7388	8.90	0.3641	0.7401	8.89	0.3651	0.7416
DarkIR	4.84	0.0489	0.8566	4.84	0.0489	0.8573	4.84	0.0489	0.8575
Proposed method									
Recall(Ours)	**20.26**	**0.7142**	**0.4041**	**16.31**	**0.6263**	**0.5292**	**16.38**	**0.6254**	**0.5259**

Across the ten lateral positions, RECALL achieves the highest PSNR and SSIM and the lowest LPIPS, with PSNR ranging from 16.313 to 20.470 dB. The comparison extends hidden-screen recovery to changes in the position of the observed wall evidence, with the dense software-panel organization remaining the reconstruction target.

D.2.4 Camera-Distance Variation

Camera-distance variation in the physical acquisition scene tests whether coarse structure remains recoverable as evidence scale and spatial mixing relationships change. Browser and Software each span ten recorded camera-distance factors from 1.01x to 1.1x while screen content and the remaining imaging conditions stay fixed. Their paired sweeps cover webpage-region relationships and the denser software hierarchy.

Distance



Figure A39: Real captures of the physical acquisition scene under three camera-distance configurations. The display faces the wall and the camera remains behind the display; the views show the resulting changes in scene scale and wall-light observation geometry.

Browser Camera-Distance Variation

Appendix Table A28 and Figure A40 report the Browser sweep.

The distance sweep changes the scale and spatial arrangement of the observed wall evidence, producing local troughs and rebounds across the reported factors. RECALL retains the strongest metrics throughout this nonmonotonic trajectory. Read with the module ablations, the full-system result extends the evidence-organization and capability-allocation gains from changing evidence strength to changing evidence scale and location.

Figure A40 shows a camera-distance sweep whose curves contain visible troughs and rebounds. RECALL's lead persists through these changes in the scale and spatial arrangement of the observed evidence, connecting robustness to the recovery of relationships among page regions beyond fixed wall coordinates. The distance, luminance, and shot-noise sweeps test spatial rearrangement, signal strength, and noise under the same coarse-recovery objective.

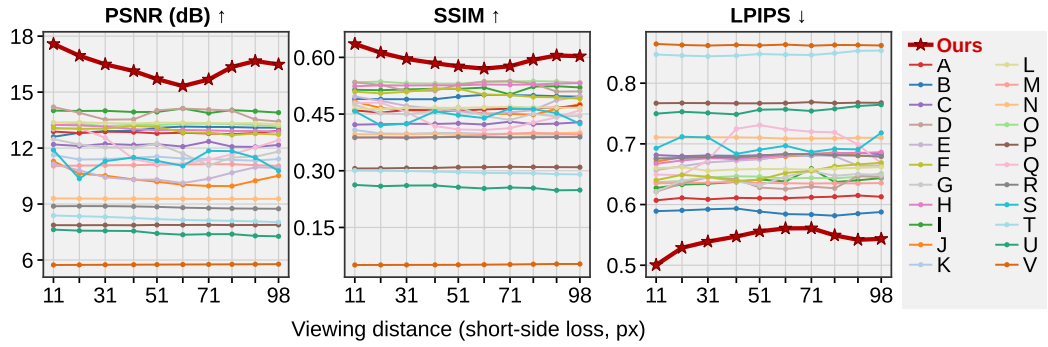


Figure A40: Browser Camera-Distance Variation curves paired with Table A28, showing scale-dependent troughs, rebounds, and method ordering over the factors. For table factor f, the axis shows the corresponding short-side loss $1080-\mathrm{round}(1080/f)$ px. Method letters follow Section D.

Table A28: Complete Browser camera-distance sweep for every method. Each camera-distance condition spans PSNR, SSIM, and LPIPS subcolumns.

Method	(1.01x)			(1.02x)			(1.03x)			(1.04x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	12.60	0.4898	**0.5891**	12.82	0.4895	**0.5904**	12.91	0.4892	**0.5922**	12.92	0.4892	**0.5935**
UniProcessor	11.63	0.4079	0.6762	11.39	0.3988	0.6792	11.40	0.3980	0.6811	11.48	0.3996	0.6811
AST	11.30	0.4827	0.6707	10.63	0.4662	0.6781	10.52	0.4595	0.6791	10.32	0.4594	0.6743
OneRestore	9.30	0.3964	0.7107	9.29	0.3968	0.7105	9.29	0.3972	0.7109	9.29	0.3978	0.7107
General restoration backbones												
Restormer	14.01	0.5144	0.6274	**13.99**	0.5131	0.6328	**14.00**	0.5153	0.6343	**13.93**	0.5170	0.6373
X-Restormer	13.23	**0.5342**	0.6368	13.30	**0.5358**	0.6388	13.18	**0.5315**	0.6447	13.25	**0.5307**	0.6466
NAFNet	12.89	0.4598	0.6070	12.81	0.4537	0.6110	12.88	0.4611	0.6086	12.86	0.4599	0.6111
Pixel2Pixel	11.04	0.3877	0.6348	11.06	0.3883	0.6355	11.08	0.3897	0.6360	11.09	0.3893	0.6376
ConvIR	12.20	0.4220	0.6816	12.11	0.4232	0.6798	12.23	0.4244	0.6807	12.17	0.4238	0.6797
Uformer	11.14	0.4964	0.6567	10.80	0.4849	0.6632	10.43	0.4716	0.6695	10.30	0.4642	0.6723
U-Net	7.87	0.3060	0.7670	7.87	0.3063	0.7673	7.87	0.3073	0.7671	7.86	0.3076	0.7668
Degradation-specific restoration												
Ada-Deblur	**14.20**	0.5338	0.6211	13.89	0.5273	0.6348	13.52	0.5113	0.6448	13.54	0.5118	0.6416
DehazeFormer	13.25	0.5235	0.6671	13.22	0.5260	0.6727	13.15	0.5257	0.6763	13.01	0.5261	0.6758
OKNet	13.02	0.4793	0.6494	13.07	0.4803	0.6484	12.55	0.4552	0.6732	11.41	0.4182	0.7248
DnCNN	8.88	0.3880	0.6757	8.89	0.3883	0.6766	8.89	0.3872	0.6782	8.87	0.3887	0.6777

Table A28 (continued).

Method	(1.01x)			(1.02x)			(1.03x)			(1.04x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Enhancement-oriented restoration												
Retinexformer	12.48	0.4747	0.6213	12.19	0.4526	0.6396	12.05	0.4495	0.6446	12.03	0.4584	0.6383
HVI-CIDNet	13.08	0.5091	0.6402	13.03	0.5048	0.6489	13.04	0.5089	0.6459	13.18	0.5171	0.6388
IRNeXt	13.37	0.4646	0.6600	13.38	0.4629	0.6616	13.34	0.4662	0.6556	13.32	0.4668	0.6579
DEA-Net	11.90	0.4575	0.6927	10.36	0.4203	0.7118	11.30	0.4244	0.7105	11.50	0.4570	0.6835
SFHformer	8.38	0.3007	0.8472	8.35	0.3000	0.8454	8.31	0.2993	0.8443	8.25	0.2979	0.8454
DeepSN-Net	7.63	0.2625	0.7497	7.57	0.2591	0.7529	7.57	0.2609	0.7510	7.55	0.2612	0.7486
DarkIR	5.73	0.0507	0.8646	5.74	0.0508	0.8629	5.74	0.0509	0.8620	5.75	0.0510	0.8630
Proposed method												
Recall(Ours)	**17.58**	**0.6355**	**0.5004**	**16.95**	**0.6124**	**0.5287**	**16.49**	**0.5960**	**0.5390**	**16.13**	**0.5845**	**0.5473**

Table A28 (continued).

Method	(1.05x)			(1.06x)			(1.07x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	13.08	0.4962	**0.5885**	13.15	0.5009	**0.5843**	13.13	0.5001	**0.5836**
UniProcessor	11.54	0.4001	0.6803	11.44	0.3979	0.6810	11.42	0.3975	0.6821
AST	10.20	0.4595	0.6751	10.03	0.4513	0.6792	9.97	0.4504	0.6822
OneRestore	9.28	0.3977	0.7102	9.28	0.3973	0.7087	9.27	0.3970	0.7089
General restoration backbones									
Restormer	13.94	0.5167	0.6413	**14.12**	0.5201	0.6381	13.88	0.5019	0.6592
X-Restormer	13.23	**0.5306**	0.6460	13.30	0.5349	0.6429	13.31	0.5365	0.6439
NAFNet	12.79	0.4589	0.6105	12.82	0.4624	0.6105	12.78	0.4642	0.6119
Pixel2Pixel	11.11	0.3916	0.6356	11.13	0.3949	0.6351	11.14	0.3983	0.6346
ConvIR	12.21	0.4254	0.6813	12.08	0.4223	0.6818	12.36	0.4300	0.6806
Uformer	10.31	0.4577	0.6746	10.13	0.4501	0.6805	10.36	0.4545	0.6816
U-Net	7.88	0.3092	0.7668	7.88	0.3096	0.7671	7.88	0.3103	0.7688
Degradation-specific restoration									
Ada-Deblur	**14.02**	0.5278	0.6281	**14.12**	**0.5361**	0.6255	**14.06**	**0.5369**	0.6296
DehazeFormer	12.96	0.5259	0.6779	12.97	0.5283	0.6811	12.95	0.5276	0.6841
OKNet	11.17	0.4093	0.7310	11.17	0.4079	0.7238	11.37	0.4128	0.7200
DnCNN	8.85	0.3895	0.6807	8.81	0.3890	0.6834	8.78	0.3885	0.6830
Enhancement-oriented restoration									
Retinexformer	12.23	0.4682	0.6312	11.70	0.4448	0.6461	11.07	0.4346	0.6550
HVI-CIDNet	13.13	0.5168	0.6411	12.84	0.5016	0.6521	12.81	0.5002	0.6555
IRNeXt	13.36	0.4664	0.6586	13.36	0.4677	0.6584	13.34	0.4692	0.6576
DEA-Net	11.32	0.4470	0.6903	11.05	0.4393	0.6969	11.85	0.4645	0.6865
SFHformer	8.19	0.2961	0.8480	8.15	0.2942	0.8470	8.12	0.2938	0.8465
DeepSN-Net	7.43	0.2565	0.7563	7.36	0.2531	0.7570	7.38	0.2557	0.7541
DarkIR	5.75	0.0511	0.8623	5.76	0.0515	0.8636	5.76	0.0521	0.8618
Proposed method									
Recall(Ours)	**15.70**	**0.5764**	**0.5558**	**15.32**	**0.5702**	**0.5607**	**15.68**	**0.5766**	**0.5610**

Table A28 (continued).

Method	(1.08x)			(1.09x)			(1.1x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	13.13	0.4992	**0.5816**	13.10	0.4974	**0.5850**	13.09	0.4960	**0.5877**
UniProcessor	11.37	0.3958	0.6847	11.32	0.3960	0.6852	11.42	0.3969	0.6842
AST	9.96	0.4480	0.6861	10.25	0.4638	0.6806	10.52	0.4763	0.6791
OneRestore	9.27	0.3978	0.7091	9.27	0.3994	0.7101	9.28	0.4010	0.7100
General restoration backbones									
Restormer	**14.03**	0.5227	0.6370	**13.98**	0.5237	0.6400	**13.90**	0.5204	0.6436
X-Restormer	13.29	**0.5371**	0.6434	13.24	**0.5361**	0.6456	13.15	**0.5330**	0.6511
NAFNet	12.75	0.4657	0.6130	12.80	0.4671	0.6150	12.93	0.4727	0.6128
Pixel2Pixel	11.13	0.4003	0.6350	11.08	0.3983	0.6349	11.04	0.3957	0.6354
ConvIR	12.08	0.4233	0.6830	12.06	0.4247	0.6855	12.17	0.4282	0.6829
Uformer	10.68	0.4605	0.6796	10.97	0.4868	0.6641	10.94	0.4961	0.6642
U-Net	7.87	0.3099	0.7671	7.88	0.3096	0.7679	7.88	0.3093	0.7677

Table A28 (continued).

Method	(1.08x)			(1.09x)			(1.1x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Degradation-specific restoration									
Ada-Deblur	14.01	0.5306	0.6268	13.53	0.5094	0.6470	13.42	0.5100	0.6450
DehazeFormer	12.92	0.5282	0.6844	12.92	0.5305	0.6849	12.88	0.5320	0.6862
OKNet	11.66	0.4274	0.7190	12.03	0.4415	0.6990	12.42	0.4601	0.6679
DnCNN	8.76	0.3888	0.6812	8.75	0.3891	0.6806	8.75	0.3893	0.6792
Enhancement-oriented restoration									
Retinexformer	11.50	0.4505	0.6474	11.53	0.4437	0.6503	11.81	0.4450	0.6485
HVI-CIDNet	12.70	0.4954	0.6631	12.77	0.4941	0.6661	12.73	0.4907	0.6688
IRNeXt	13.33	0.4677	0.6592	13.34	0.4670	0.6605	13.27	0.4667	0.6617
DEA-Net	11.84	0.4633	0.6917	11.49	0.4524	0.6909	10.78	0.4245	0.7181
SFHformer	8.10	0.2932	0.8493	8.07	0.2911	0.8533	8.03	0.2905	0.8537
DeepSN-Net	7.39	0.2542	0.7578	7.29	0.2483	0.7624	7.27	0.2489	0.7645
DarkIR	5.77	0.0528	0.8629	5.77	0.0533	0.8628	5.78	0.0533	0.8621
Proposed method									
Recall(Ours)	**16.35**	**0.5936**	**0.5492**	**16.67**	**0.6051**	**0.5419**	**16.48**	**0.6031**	**0.5435**

Software Camera-Distance Variation

Appendix Table A29 and Figure A41 report the Software sweep.

PSNR falls to 15.795 dB at a camera-distance factor of 1.06 (61 px short-side loss) and then recovers, with SSIM following the same broad trend. RECALL leads all three metrics at the 10 recorded conditions.

The distance sweep changes the scale and spatial arrangement of the observed wall evidence. RECALL leads PSNR, SSIM, and LPIPS across all ten conditions, extending the reconstruction advantage to software-panel recovery as the observation scale changes.

The complete model supports recovery of the dense software layout across the full camera-distance trajectory.

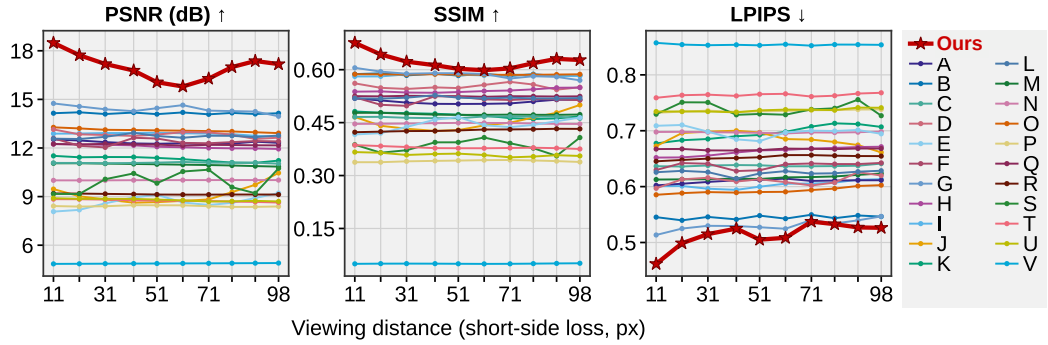


Figure A41: Software Camera-Distance Variation curves, summarizing the same values as Appendix Table A29. Higher PSNR and SSIM and lower LPIPS indicate better restoration. For table factor f, the axis shows the corresponding short-side loss $1080 - \mathrm{round}(1080/f)$ px. Method letters follow Section D.

Table A29: Full Software Camera-Distance Variation results, with 23 methods and 10 conditions.

Method	(1.01x)			(1.02x)			(1.03x)			(1.04x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	14.15	0.5875	0.5454	14.20	0.5896	0.5397	14.10	0.5837	0.5458	14.19	0.5886	0.5414
UniProcessor	11.51	0.4816	0.6774	11.43	0.4780	0.6830	11.44	0.4769	0.6852	11.44	0.4751	0.6902
AST	9.46	0.4661	0.6724	9.02	0.4410	0.6959	8.82	0.4327	0.6984	8.62	0.4266	0.7000
OneRestore	10.00	0.4463	0.6978	10.00	0.4467	0.6980	10.00	0.4473	0.6973	10.01	0.4485	0.6969

Table A29 (continued).

Method	(1.01x)			(1.02x)			(1.03x)			(1.04x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones												
Restormer	12.88	0.5808	0.6007	12.89	0.5809	0.6010	12.92	0.5866	0.5962	12.92	0.5882	0.5942
X-Restormer	13.28	0.5872	0.5854	13.21	0.5869	0.5883	13.12	0.5861	0.5902	13.11	0.5871	0.5893
NAFNet	12.53	0.5187	0.6022	12.46	0.5128	0.6052	12.36	0.5068	0.6084	12.28	0.5032	0.6114
Pixel2Pixel	11.05	0.4776	0.6126	11.06	0.4779	0.6130	11.04	0.4749	0.6132	11.01	0.4726	0.6144
ConvIR	11.08	0.4660	0.6365	11.08	0.4663	0.6360	11.06	0.4637	0.6378	11.08	0.4625	0.6386
Uformer	8.07	0.4164	0.7089	8.18	0.4201	0.7103	8.58	0.4377	0.6983	8.95	0.4584	0.6846
U-Net	8.42	0.3377	0.7321	8.38	0.3378	0.7342	8.40	0.3403	0.7360	8.47	0.3416	0.7339
Degradation-specific restoration												
Ada-Deblur	13.15	0.5613	0.5970	12.84	0.5486	0.6130	12.80	0.5454	0.6159	12.74	0.5498	0.6091
DehazeFormer	12.24	0.5377	0.6520	12.23	0.5385	0.6523	12.19	0.5353	0.6555	12.16	0.5345	0.6611
OKNet	12.25	0.5250	0.6672	12.21	0.5244	0.6674	12.26	0.5260	0.6648	12.23	0.5254	0.6646
DnCNN	9.19	0.4228	0.6453	9.19	0.4244	0.6477	9.17	0.4260	0.6502	9.15	0.4263	0.6512
Enhancement-oriented restoration												
Retinexformer	**14.75**	**0.6054**	**0.5134**	**14.57**	**0.5946**	**0.5249**	**14.39**	**0.5886**	**0.5299**	**14.27**	**0.5901**	**0.5295**
HVI-CIDNet	12.60	0.5217	0.6297	12.14	0.5005	0.6422	12.04	0.4975	0.6409	12.63	0.5248	0.6278
IRNeXt	12.58	0.5189	0.6258	12.55	0.5178	0.6282	12.69	0.5207	0.6260	12.93	0.5275	0.6141
DEA-Net	9.17	0.3874	0.7296	9.16	0.3647	0.7509	10.07	0.3718	0.7507	10.43	0.3941	0.7285
SFHformer	8.84	0.3862	0.7590	8.84	0.3836	0.7636	8.82	0.3809	0.7646	8.77	0.3777	0.7623
DeepSN-Net	8.90	0.3665	0.7344	8.87	0.3646	0.7345	8.86	0.3583	0.7344	8.86	0.3611	0.7329
DarkIR	4.85	0.0498	0.8573	4.85	0.0503	0.8542	4.86	0.0504	0.8530	4.87	0.0503	0.8538
Proposed method												
Recall(Ours)	**18.49**	**0.6760**	**0.4617**	**17.73**	**0.6432**	**0.4987**	**17.18**	**0.6228**	**0.5150**	**16.78**	**0.6126**	**0.5249**

Table A29 (continued).

Method	(1.05x)			(1.06x)			(1.07x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.09	0.5832	0.5481	14.20	**0.5881**	0.5427	14.08	0.5822	0.5497
UniProcessor	11.39	0.4726	0.6924	11.31	0.4697	0.6980	11.20	0.4628	0.7074
AST	8.66	0.4288	0.6969	8.74	0.4420	0.6851	8.83	0.4497	0.6841
OneRestore	10.02	0.4492	0.6963	10.02	0.4491	0.6952	10.02	0.4488	0.6970
General restoration backbones									
Restormer	12.94	0.5859	0.5999	12.91	0.5837	0.6052	12.89	**0.5853**	0.6054
X-Restormer	13.09	0.5861	0.5904	13.07	0.5859	0.5907	13.04	**0.5853**	0.5939
NAFNet	12.26	0.5029	0.6120	12.29	0.5032	0.6144	12.23	0.5044	0.6102
Pixel2Pixel	10.99	0.4719	0.6137	10.97	0.4720	0.6165	10.95	0.4726	0.6171
ConvIR	11.10	0.4624	0.6382	11.14	0.4674	0.6363	11.10	0.4675	0.6364
Uformer	9.11	0.4656	0.6813	8.64	0.4424	0.6970	8.48	0.4373	0.7002
U-Net	8.46	0.3424	0.7346	8.46	0.3436	0.7355	8.41	0.3441	0.7368
Degradation-specific restoration									
Ada-Deblur	12.83	0.5479	0.6132	12.98	0.5569	0.6080	12.96	0.5655	0.6021
DehazeFormer	12.08	0.5366	0.6648	12.04	0.5395	0.6657	12.00	0.5410	0.6681
OKNet	12.21	0.5250	0.6653	12.15	0.5232	0.6681	12.19	0.5248	0.6676
DnCNN	9.13	0.4278	0.6525	9.12	0.4304	0.6564	9.12	0.4307	0.6564
Enhancement-oriented restoration									
Retinexformer	**14.46**	**0.5901**	**0.5273**	**14.65**	0.5879	**0.5246**	**14.31**	0.5750	**0.5403**
HVI-CIDNet	12.59	0.5236	0.6293	12.32	0.5158	0.6401	12.29	0.5142	0.6414
IRNeXt	12.74	0.5206	0.6235	12.63	0.5185	0.6278	12.76	0.5207	0.6233
DEA-Net	9.83	0.3942	0.7300	10.55	0.4077	0.7287	10.66	0.3915	0.7382
SFHformer	8.75	0.3774	0.7654	8.74	0.3774	0.7661	8.73	0.3781	0.7612
DeepSN-Net	8.82	0.3621	0.7365	8.76	0.3582	0.7378	8.70	0.3516	0.7375
DarkIR	4.87	0.0499	0.8528	4.88	0.0496	0.8547	4.88	0.0498	0.8522
Proposed method									
Recall(Ours)	**16.06**	**0.6024**	**0.5051**	**15.79**	**0.5986**	**0.5084**	**16.28**	**0.6036**	**0.5374**

Table A29 (continued).

Method	(1.08x)			(1.09x)			(1.1x)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.17	**0.5872**	0.5435	14.10	0.5821	0.5484	**14.14**	0.5843	**0.5464**
UniProcessor	11.10	0.4601	0.7133	11.08	0.4620	0.7120	11.22	0.4678	0.7068
AST	9.28	0.4646	0.6799	9.73	0.4779	0.6744	10.46	0.5001	0.6612
OneRestore	10.02	0.4475	0.6967	10.02	0.4464	0.6973	10.02	0.4462	0.6985
General restoration backbones									
Restormer	12.86	0.5854	0.6071	12.75	0.5818	0.6123	12.71	0.5823	0.6133
X-Restormer	13.02	0.5855	0.5965	12.97	**0.5862**	0.6012	12.92	**0.5869**	0.6026
NAFNet	12.27	0.5097	0.6108	12.39	0.5150	0.6113	12.32	0.5149	0.6114
Pixel2Pixel	10.92	0.4721	0.6182	10.88	0.4721	0.6210	10.85	0.4729	0.6235
ConvIR	11.09	0.4670	0.6367	11.09	0.4672	0.6374	11.03	0.4619	0.6412
Uformer	8.61	0.4434	0.6996	8.92	0.4539	0.7013	9.22	0.4643	0.6945
U-Net	8.36	0.3428	0.7369	8.37	0.3409	0.7379	8.39	0.3385	0.7381
Degradation-specific restoration									
Ada-Deblur	12.82	0.5579	0.6073	12.56	0.5435	0.6258	12.64	0.5501	0.6198
DehazeFormer	11.98	0.5442	0.6693	11.97	0.5488	0.6708	11.94	0.5492	0.6714
OKNet	12.18	0.5246	0.6670	12.17	0.5240	0.6682	12.16	0.5245	0.6682
DnCNN	9.13	0.4313	0.6554	9.13	0.4325	0.6547	9.13	0.4322	0.6546
Enhancement-oriented restoration									
Retinexformer	**14.28**	0.5815	**0.5340**	**14.25**	0.5796	**0.5396**	13.96	0.5699	0.5467
HVI-CIDNet	12.36	0.5169	0.6404	12.43	0.5159	0.6404	12.41	0.5137	0.6424
IRNeXt	12.75	0.5187	0.6239	12.67	0.5185	0.6267	12.77	0.5195	0.6284
DEA-Net	9.58	0.3776	0.7402	9.21	0.3557	0.7556	10.74	0.4076	0.7269
SFHformer	8.69	0.3789	0.7627	8.67	0.3776	0.7666	8.63	0.3753	0.7679
DeepSN-Net	8.71	0.3538	0.7369	8.74	0.3576	0.7414	8.70	0.3555	0.7412
DarkIR	4.89	0.0504	0.8542	4.89	0.0510	0.8541	4.90	0.0514	0.8537
Proposed method									
Recall(Ours)	**16.99**	**0.6184**	**0.5328**	**17.37**	**0.6307**	**0.5270**	**17.18**	**0.6275**	**0.5263**

D.3 Equivalent-Luminance Variation

Display-luminance variation tests whether coarse screen structure remains recoverable as the recorded wall-image exposure changes with display luminance. The recorded sweep uses a nominal 600 nits reference, with 1 nit equal to 1 cd/m^2; Browser, Game, and Software each span the recorded 18-condition interval from 513.4 to 701.3 nits equivalent luminance, while screen identity and the remaining imaging conditions stay fixed. The tables and paired curves trace the same sweep across webpage regions, a low-light game canvas, and a dense software interface.

D.3.1 Browser Display-Luminance Variation

Appendix Table A30 and Figure A43 report the Browser sweep.

The recorded luminance condition changes the wall-image intensity while preserving the webpage identity that the model must recover. RECALL leads all three metrics at every recorded point, supporting recovery of page-level color and brightness regions across the observed intensity range.

Figure A43 turns the table's discrete comparisons into an evidence-strength trajectory. RECALL remains the leading curve while the methods respond to changing equivalent luminance, making clear that its advantage accompanies the same webpage layout across the recorded illumination range. This trajectory shows that coarse layout and color evidence remain recoverable as the wall signal changes in magnitude.

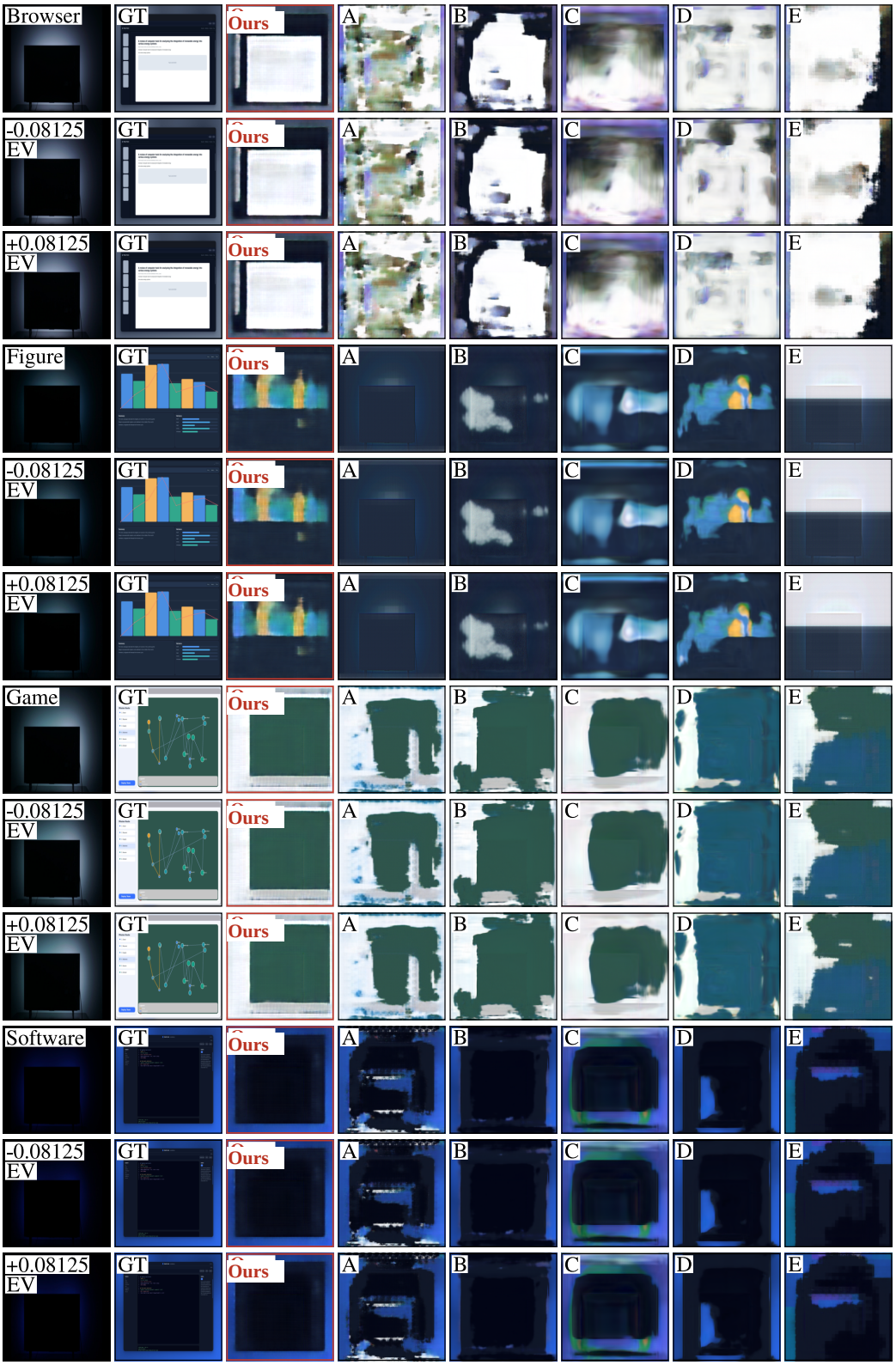


Figure A42: Brightness robustness on Browser, Figure, Game, and Software. Each three-row block shows the reference acquisition, -0.08125 EV, and $+0.08125$ EV.

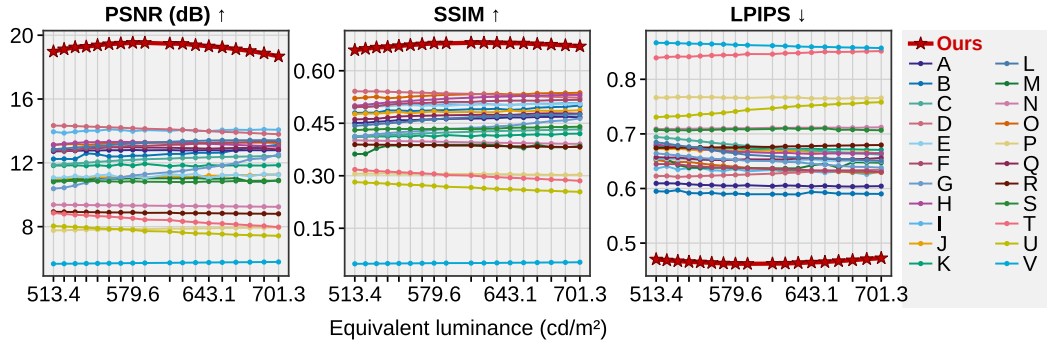


Figure A43: Browser equivalent-luminance curves paired with Table A30, showing relative ordering and within-method variation over the points. Equivalent luminance uses a nominal 600 cd/m^2 reference; 1 nit equals 1 cd/m^2. Method letters follow Section D.

Table A30: Complete Browser display-luminance sweep for the 18 conditions. Each luminance condition spans PSNR, SSIM, and LPIPS subcolumns; higher PSNR and SSIM and lower LPIPS indicate better restoration. Blue marks the best external value for each condition and metric, including ties at the displayed precision; external rows with at least three blue entries in a panel receive a pale-blue background, while RECALL receives a pale-red background with red text. Headers give luminance in nits (1 nit = 1 cd/m^2).

Method	513.4 nits			522.3 nits			531.5 nits			540.8 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	12.24	0.4795	**0.5949**	12.25	0.4801	**0.5944**	12.23	0.4804	**0.5971**	12.60	0.4866	**0.5917**
UniProcessor	11.83	0.4110	0.6780	11.83	0.4116	0.6771	11.85	0.4126	0.6764	11.81	0.4119	0.6751
AST	10.94	0.4762	0.6732	10.99	0.4776	0.6721	11.02	0.4775	0.6727	11.05	0.4798	0.6711
OneRestore	9.37	0.4012	0.7090	9.37	0.4007	0.7090	9.36	0.4001	0.7093	9.35	0.3996	0.7094
General restoration backbones												
Restormer	13.95	0.4985	0.6365	13.87	0.4966	0.6406	13.95	0.5004	0.6348	14.01	0.5026	0.6372
X-Restormer	13.12	0.5211	0.6522	13.16	0.5235	0.6494	13.17	0.5255	0.6484	13.13	0.5215	0.6486
NAFNet	12.71	0.4509	0.6094	12.73	0.4514	0.6095	12.76	0.4542	0.6092	12.77	0.4560	0.6078
Pixel2Pixel	10.87	0.3619	0.6539	10.88	0.3625	0.6540	10.96	0.3782	0.6428	10.96	0.3861	0.6384
ConvIR	11.86	0.4108	0.6944	11.91	0.4125	0.6926	11.96	0.4145	0.6908	12.01	0.4162	0.6886
Uformer	11.07	0.4956	0.6546	11.07	0.4969	0.6542	11.17	0.4990	0.6532	11.10	0.4984	0.6535
U-Net	7.76	0.3056	0.7665	7.78	0.3061	0.7665	7.79	0.3060	0.7675	7.81	0.3067	0.7674
Degradation-specific restoration												
Ada-Deblur	**14.34**	**0.5414**	0.6227	**14.32**	**0.5409**	0.6230	**14.31**	**0.5412**	0.6212	**14.28**	**0.5399**	0.6221
DehazeFormer	13.13	0.5000	0.6805	13.19	0.5029	0.6785	13.25	0.5062	0.6758	13.29	0.5093	0.6734
OKNet	12.79	0.4609	0.6572	12.79	0.4619	0.6567	12.82	0.4627	0.6567	12.88	0.4661	0.6547
DnCNN	8.93	0.3891	0.6742	8.92	0.3887	0.6746	8.92	0.3886	0.6750	8.91	0.3884	0.6747
Enhancement-oriented restoration												
Retinexformer	10.38	0.4131	0.6643	10.44	0.4148	0.6625	10.59	0.4186	0.6605	10.76	0.4215	0.6590
HVI-CIDNet	12.80	0.4966	0.6447	12.75	0.4966	0.6447	12.78	0.4984	0.6444	12.91	0.5033	0.6416
IRNeXt	12.85	0.4428	0.6845	12.90	0.4447	0.6823	12.96	0.4474	0.6788	13.00	0.4498	0.6764
DEA-Net	10.81	0.4304	0.7072	10.86	0.4318	0.7067	10.87	0.4326	0.7068	10.87	0.4337	0.7065
SFHformer	8.86	0.3178	0.8393	8.80	0.3153	0.8409	8.74	0.3132	0.8417	8.71	0.3118	0.8414
DeepSN-Net	8.04	0.2819	0.7306	8.01	0.2802	0.7317	7.98	0.2791	0.7325	7.94	0.2774	0.7335
DarkIR	5.67	0.0484	0.8669	5.68	0.0486	0.8665	5.68	0.0489	0.8660	5.69	0.0493	0.8654
Proposed method												
Recall(Ours)	**18.98**	**0.6589**	**0.4702**	**19.12**	**0.6628**	**0.4684**	**19.24**	**0.6664**	**0.4670**	**19.28**	**0.6679**	**0.4656**

Table A30 (continued).

Method	550.2 nits			559.8 nits			569.6 nits			579.6 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	12.54	0.4865	**0.5911**	12.40	0.4850	**0.5919**	12.40	0.4858	**0.5899**	12.45	0.4871	**0.5907**
UniProcessor	11.85	0.4136	0.6751	11.80	0.4124	0.6739	11.91	0.4153	0.6735	11.83	0.4123	0.6739
AST	11.10	0.4824	0.6696	11.08	0.4784	0.6722	11.10	0.4810	0.6706	11.18	0.4838	0.6696
OneRestore	9.35	0.3990	0.7097	9.34	0.3985	0.7098	9.33	0.3979	0.7101	9.32	0.3973	0.7104
General restoration backbones												
Restormer	14.01	0.5030	0.6372	14.10	0.5046	0.6335	14.06	0.5048	0.6323	13.98	0.5011	0.6358
X-Restormer	13.17	0.5231	0.6460	13.23	0.5261	0.6433	13.26	0.5278	0.6417	13.27	0.5296	0.6399
NAFNet	12.77	0.4588	0.6065	12.79	0.4587	0.6061	12.79	0.4602	0.6052	12.81	0.4616	0.6051
Pixel2Pixel	10.98	0.3865	0.6379	11.00	0.3871	0.6380	11.01	0.3875	0.6383	11.03	0.3879	0.6373
ConvIR	12.06	0.4178	0.6864	12.11	0.4194	0.6840	12.15	0.4210	0.6817	12.18	0.4222	0.6800
Uformer	11.21	0.5012	0.6524	11.27	0.5022	0.6518	11.07	0.4997	0.6534	11.15	0.5009	0.6526
U-Net	7.81	0.3054	0.7673	7.82	0.3050	0.7672	7.83	0.3051	0.7665	7.86	0.3052	0.7663
Degradation-specific restoration												
Ada-Deblur	**14.25**	**0.5389**	0.6228	**14.23**	**0.5380**	0.6235	**14.20**	**0.5372**	0.6243	**14.17**	**0.5363**	0.6249
DehazeFormer	13.30	0.5114	0.6719	13.31	0.5138	0.6705	13.32	0.5163	0.6691	13.30	0.5177	0.6670
OKNet	12.96	0.4694	0.6530	12.97	0.4706	0.6524	12.97	0.4714	0.6520	12.98	0.4720	0.6528
DnCNN	8.90	0.3881	0.6750	8.89	0.3877	0.6751	8.89	0.3875	0.6756	8.89	0.3873	0.6754
Enhancement-oriented restoration												
Retinexformer	10.92	0.4241	0.6559	11.01	0.4264	0.6544	11.09	0.4277	0.6538	11.21	0.4312	0.6528
HVI-CIDNet	12.90	0.5054	0.6405	12.99	0.5073	0.6387	13.02	0.5077	0.6381	13.07	0.5090	0.6383
IRNeXt	13.05	0.4522	0.6739	13.11	0.4552	0.6704	13.17	0.4587	0.6668	13.21	0.4609	0.6645
DEA-Net	10.84	0.4338	0.7072	10.84	0.4336	0.7074	10.82	0.4331	0.7083	10.84	0.4337	0.7087
SFHformer	8.66	0.3101	0.8426	8.63	0.3086	0.8437	8.57	0.3069	0.8443	8.53	0.3051	0.8443
DeepSN-Net	7.89	0.2754	0.7358	7.86	0.2741	0.7369	7.84	0.2730	0.7387	7.79	0.2709	0.7411
DarkIR	5.70	0.0495	0.8650	5.70	0.0497	0.8646	5.71	0.0500	0.8642	5.72	0.0503	0.8631
Proposed method												
Recall(Ours)	**19.37**	**0.6707**	**0.4648**	**19.44**	**0.6734**	**0.4638**	**19.48**	**0.6757**	**0.4629**	**19.53**	**0.6782**	**0.4622**

Table A30 (continued).

Method	589.7 nits			610.5 nits			621.2 nits			632.0 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	12.45	0.4874	**0.5895**	12.56	0.4900	**0.5895**	12.56	0.4899	**0.5894**	12.63	0.4912	**0.5892**
UniProcessor	11.94	0.4164	0.6718	11.79	0.4126	0.6728	11.85	0.4161	0.6720	11.77	0.4142	0.6724
AST	11.08	0.4815	0.6691	11.16	0.4822	0.6696	11.11	0.4812	0.6687	11.13	0.4821	0.6685
OneRestore	9.32	0.3968	0.7103	9.30	0.3955	0.7112	9.30	0.3950	0.7111	9.29	0.3943	0.7113
General restoration backbones												
Restormer	14.05	0.5049	0.6315	14.01	0.5026	0.6340	14.06	0.5058	0.6302	14.01	0.5031	0.6321
X-Restormer	13.27	0.5307	0.6379	13.26	0.5326	0.6356	13.26	**0.5337**	0.6336	13.25	**0.5341**	0.6340
NAFNet	12.79	0.4625	0.6059	12.80	0.4633	0.6044	12.78	0.4637	0.6056	12.78	0.4647	0.6050
Pixel2Pixel	11.03	0.3886	0.6371	11.03	0.3885	0.6368	11.03	0.3890	0.6369	11.04	0.3881	0.6369
ConvIR	12.23	0.4236	0.6780	12.27	0.4256	0.6748	12.30	0.4268	0.6727	12.32	0.4276	0.6716
Uformer	11.04	0.4995	0.6536	11.30	0.5041	0.6506	11.22	0.5033	0.6509	11.31	0.5043	0.6506
U-Net	7.85	0.3051	0.7659	7.88	0.3049	0.7671	7.87	0.3049	0.7666	7.89	0.3044	0.7666
Degradation-specific restoration												
Ada-Deblur	**14.14**	**0.5352**	0.6255	**14.10**	**0.5341**	0.6272	**14.07**	0.5327	0.6285	**14.03**	0.5316	0.6292
DehazeFormer	13.29	0.5202	0.6667	13.28	0.5231	0.6651	13.25	0.5249	0.6654	13.22	0.5257	0.6642
OKNet	12.96	0.4728	0.6533	12.95	0.4738	0.6533	12.93	0.4743	0.6532	12.91	0.4739	0.6549
DnCNN	8.86	0.3862	0.6764	8.87	0.3862	0.6762	8.84	0.3850	0.6772	8.85	0.3847	0.6773
Enhancement-oriented restoration												
Retinexformer	11.28	0.4332	0.6507	11.42	0.4367	0.6502	11.49	0.4384	0.6487	11.61	0.4412	0.6480
HVI-CIDNet	13.07	0.5111	0.6365	13.13	0.5107	0.6366	13.14	0.5130	0.6353	13.20	0.5139	0.6345
IRNeXt	13.25	0.4637	0.6616	13.32	0.4668	0.6590	13.36	0.4687	0.6575	13.37	0.4696	0.6568
DEA-Net	10.82	0.4344	0.7082	10.81	0.4329	0.7090	10.79	0.4341	0.7102	10.80	0.4347	0.7093
SFHformer	8.44	0.3019	0.8463	8.41	0.3007	0.8461	8.33	0.2977	0.8478	8.28	0.2958	0.8481
DeepSN-Net	7.72	0.2685	0.7439	7.69	0.2665	0.7469	7.63	0.2641	0.7490	7.58	0.2623	0.7510
DarkIR	5.72	0.0505	0.8625	5.73	0.0506	0.8616	5.74	0.0507	0.8610	5.75	0.0510	0.8600

Table A30 (continued).

Method	589.7 nits			610.5 nits			621.2 nits			632.0 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Proposed method												
Recall(Ours)	**19.52**	**0.6783**	**0.4621**	**19.47**	**0.6799**	**0.4624**	**19.46**	**0.6796**	**0.4626**	**19.38**	**0.6792**	**0.4636**

Table A30 (continued).

Method	643.1 nits			654.3 nits			665.7 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.63	0.4884	**0.5937**	12.64	0.4898	**0.5926**	12.80	0.4944	**0.5906**
UniProcessor	11.86	0.4157	0.6730	11.83	0.4170	0.6717	11.84	0.4181	0.6718
AST	11.20	0.4864	0.6668	11.19	0.4833	0.6678	11.24	0.4861	0.6653
OneRestore	9.28	0.3936	0.7114	9.27	0.3931	0.7114	9.27	0.3925	0.7115
General restoration backbones									
Restormer	**13.99**	0.5028	0.6312	**14.05**	0.5043	0.6291	**14.07**	0.5063	0.6310
X-Restormer	13.22	**0.5324**	0.6321	13.22	**0.5326**	0.6318	13.27	**0.5353**	0.6310
NAFNet	12.79	0.4667	0.6039	12.78	0.4663	0.6048	12.78	0.4678	0.6039
Pixel2Pixel	11.00	0.3828	0.6423	11.01	0.3795	0.6453	11.04	0.3885	0.6379
ConvIR	12.35	0.4285	0.6697	12.37	0.4293	0.6682	12.38	0.4302	0.6663
Uformer	11.03	0.5007	0.6531	11.22	0.5041	0.6505	11.25	0.5051	0.6502
U-Net	7.90	0.3043	0.7650	7.92	0.3032	0.7651	7.93	0.3032	0.7647
Degradation-specific restoration									
Ada-Deblur	13.98	0.5294	0.6311	13.94	0.5279	0.6319	13.92	0.5269	0.6321
DehazeFormer	13.19	0.5267	0.6634	13.16	0.5279	0.6641	13.12	0.5288	0.6642
OKNet	12.89	0.4737	0.6554	12.91	0.4758	0.6548	12.93	0.4779	0.6530
DnCNN	8.84	0.3843	0.6777	8.83	0.3836	0.6782	8.83	0.3831	0.6786
Enhancement-oriented restoration									
Retinexformer	11.72	0.4430	0.6453	11.84	0.4473	0.6432	11.98	0.4516	0.6418
HVI-CIDNet	13.25	0.5146	0.6333	13.28	0.5147	0.6330	13.27	0.5144	0.6331
IRNeXt	13.40	0.4710	0.6555	13.41	0.4718	0.6549	13.41	0.4725	0.6542
DEA-Net	10.83	0.4370	0.7095	10.83	0.4378	0.7102	10.86	0.4378	0.7075
SFHformer	8.22	0.2942	0.8491	8.19	0.2927	0.8504	8.14	0.2913	0.8500
DeepSN-Net	7.57	0.2613	0.7520	7.54	0.2598	0.7534	7.49	0.2580	0.7549
DarkIR	5.75	0.0514	0.8595	5.76	0.0516	0.8593	5.77	0.0519	0.8586
Proposed method									
Recall(Ours)	**19.30**	**0.6786**	**0.4646**	**19.24**	**0.6782**	**0.4654**	**19.12**	**0.6759**	**0.4671**

Table A30 (continued).

Method	677.4 nits			689.2 nits			701.3 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.95	0.4962	**0.5906**	13.03	0.4970	**0.5902**	13.14	0.5006	**0.5901**
UniProcessor	11.83	0.4173	0.6717	11.83	0.4199	0.6711	11.85	0.4202	0.6708
AST	11.22	0.4852	0.6659	11.25	0.4856	0.6660	11.27	0.4872	0.6642
OneRestore	9.26	0.3920	0.7112	9.25	0.3915	0.7117	9.24	0.3910	0.7120
General restoration backbones									
Restormer	**14.06**	0.5058	0.6292	**14.09**	0.5081	0.6258	**14.07**	0.5074	0.6318
X-Restormer	13.27	**0.5360**	0.6301	13.27	**0.5364**	0.6296	13.25	**0.5370**	0.6295
NAFNet	12.79	0.4681	0.6035	12.79	0.4686	0.6040	12.79	0.4671	0.6043
Pixel2Pixel	10.82	0.3814	0.6481	10.82	0.3814	0.6476	10.90	0.3847	0.6472
ConvIR	12.40	0.4309	0.6649	12.42	0.4317	0.6636	12.43	0.4324	0.6620
Uformer	11.16	0.5034	0.6506	11.29	0.5058	0.6500	11.25	0.5055	0.6499
U-Net	7.93	0.3027	0.7653	7.94	0.3022	0.7652	7.96	0.3032	0.7658
Degradation-specific restoration									
Ada-Deblur	13.87	0.5255	0.6330	13.83	0.5243	0.6338	13.79	0.5232	0.6342
DehazeFormer	13.09	0.5299	0.6641	13.05	0.5310	0.6644	13.00	0.5309	0.6647
OKNet	12.93	0.4783	0.6537	12.91	0.4782	0.6542	12.84	0.4774	0.6560
DnCNN	8.82	0.3828	0.6789	8.81	0.3824	0.6794	8.80	0.3821	0.6796

Table A30 (continued).

Method	677.4 nits			689.2 nits			701.3 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Enhancement-oriented restoration									
Retinexformer	12.23	0.4558	0.6397	12.29	0.4583	0.6394	12.53	0.4636	0.6382
HVI-CIDNet	13.29	0.5158	0.6327	13.34	0.5165	0.6323	13.33	0.5170	0.6301
IRNeXt	13.42	0.4736	0.6529	13.42	0.4745	0.6518	13.41	0.4752	0.6507
DEA-Net	10.87	0.4392	0.7078	10.88	0.4392	0.7070	10.88	0.4401	0.7067
SFHformer	8.09	0.2892	0.8504	8.05	0.2878	0.8511	7.97	0.2855	0.8517
DeepSN-Net	7.47	0.2569	0.7555	7.45	0.2553	0.7572	7.42	0.2541	0.7581
DarkIR	5.77	0.0523	0.8582	5.78	0.0524	0.8578	5.79	0.0530	0.8572
Proposed method									
Recall(Ours)	**19.02**	**0.6748**	**0.4687**	**18.86**	**0.6724**	**0.4708**	**18.68**	**0.6698**	**0.4724**

D.3.2 Game Display-Luminance Variation

Appendix Table A31 and Figure A44 report the Game sweep.

Game PSNR peaks at 19.205 dB at 579.6 nits equivalent luminance and changes gradually toward both ends, while RECALL leads all three metrics at the 18 recorded conditions.

The game-luminance curves extend the low-signal content evaluation with a broad intensity sweep and a clear RECALL lead at every recorded point. Their gradual variation around the strongest region shows that the dark canvas and principal object contours remain recoverable as the recorded wall-image exposure changes.

The trajectory extends the complete model's advantage to low-light game content across the full recorded luminance range.

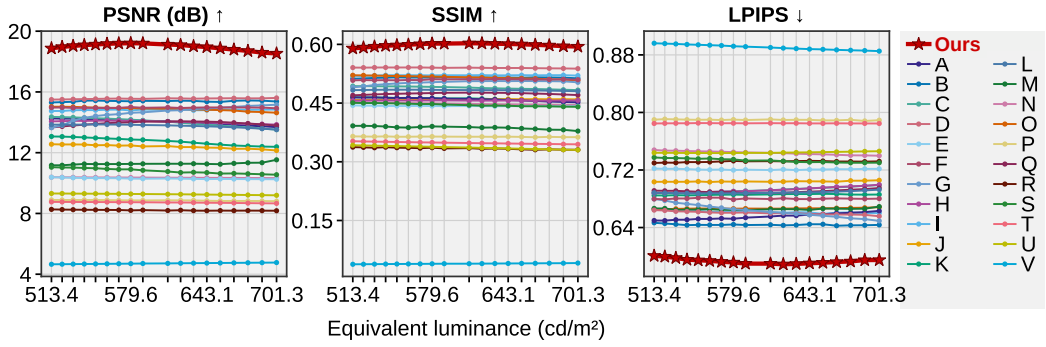


Figure A44: Game Equivalent-Luminance Variation curves, generated from the same values as Appendix Table A31. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Equivalent luminance uses a nominal 600 cd/m^2 reference; 1 nit equals 1 cd/m^2. Method letters follow Section D.

Table A31: Full Game Display-Luminance Variation results, with 23 methods and 18 conditions.

Method	513.4 nits			522.3 nits			531.5 nits			540.8 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	15.31	0.5124	**0.6466**	15.33	0.5131	**0.6456**	15.35	0.5143	**0.6445**	15.43	0.5148	**0.6434**
UniProcessor	13.07	0.4648	0.6847	13.06	0.4647	0.6846	13.04	0.4643	0.6850	13.01	0.4638	0.6848
AST	12.56	0.4579	0.7035	12.54	0.4579	0.7036	12.54	0.4582	0.7036	12.54	0.4581	0.7036
OneRestore	10.39	0.4520	0.7478	10.38	0.4516	0.7470	10.38	0.4511	0.7468	10.38	0.4508	0.7464

Table A31 (continued).

Method	513.4 nits			522.3 nits			531.5 nits			540.8 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones												
Restormer	14.74	0.5197	0.6650	14.75	0.5192	0.6654	14.79	0.5204	0.6633	14.81	0.5211	0.6633
X-Restormer	15.03	0.5210	0.6656	15.03	0.5208	0.6656	15.01	0.5201	0.6659	14.99	0.5195	0.6662
NAFNet	14.25	0.4645	0.6498	14.24	0.4641	0.6496	14.24	0.4645	0.6508	14.21	0.4635	0.6509
Pixel2Pixel	11.17	0.3918	0.6666	11.17	0.3919	0.6665	11.22	0.3914	0.6644	11.26	0.3901	0.6649
ConvIR	14.36	0.4933	0.6881	14.34	0.4933	0.6880	14.32	0.4931	0.6879	14.30	0.4928	0.6882
Uformer	10.38	0.4440	0.7220	10.37	0.4435	0.7217	10.35	0.4433	0.7216	10.33	0.4429	0.7212
U-Net	8.89	0.3649	0.7899	8.89	0.3646	0.7907	8.89	0.3642	0.7904	8.88	0.3650	0.7900
Degradation-specific restoration												
Ada-Deblur	**15.50**	**0.5407**	0.6642	**15.50**	**0.5406**	0.6637	**15.52**	**0.5409**	0.6625	**15.53**	**0.5410**	0.6623
DehazeFormer	14.06	0.4561	0.6879	14.08	0.4564	0.6881	14.09	0.4567	0.6879	14.09	0.4565	0.6886
OKNet	13.66	0.4698	0.6913	13.73	0.4709	0.6911	13.79	0.4721	0.6910	13.84	0.4731	0.6904
DnCNN	8.27	0.3374	0.7298	8.25	0.3368	0.7302	8.25	0.3359	0.7301	8.24	0.3373	0.7310
Enhancement-oriented restoration												
Retinexformer	13.64	0.4903	0.6797	13.80	0.4925	0.6776	14.11	0.4963	0.6745	14.29	0.4982	0.6729
HVI-CIDNet	14.97	0.5081	0.6797	14.98	0.5087	0.6792	14.95	0.5083	0.6804	14.95	0.5086	0.6804
IRNeXt	13.84	0.4831	0.6884	13.85	0.4834	0.6881	13.85	0.4838	0.6878	13.85	0.4841	0.6876
DEA-Net	11.04	0.4507	0.7374	11.03	0.4500	0.7367	11.02	0.4501	0.7365	10.99	0.4496	0.7362
SFHformer	8.76	0.3525	0.7847	8.76	0.3520	0.7848	8.76	0.3515	0.7849	8.75	0.3511	0.7849
DeepSN-Net	9.31	0.3423	0.7439	9.31	0.3417	0.7439	9.31	0.3412	0.7438	9.30	0.3407	0.7436
DarkIR	4.65	0.0381	0.8962	4.66	0.0382	0.8957	4.67	0.0385	0.8952	4.67	0.0387	0.8945
Proposed method												
Recall(Ours)	**18.87**	**0.5897**	**0.6007**	**18.96**	**0.5918**	**0.5996**	**19.03**	**0.5943**	**0.5978**	**19.08**	**0.5965**	**0.5953**

Table A31 (continued).

Method	550.2 nits			559.8 nits			569.6 nits			579.6 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	15.43	0.5158	**0.6437**	15.41	0.5152	**0.6436**	15.40	0.5152	**0.6436**	15.39	0.5152	**0.6443**
UniProcessor	12.97	0.4629	0.6850	12.94	0.4628	0.6854	12.91	0.4625	0.6856	12.87	0.4624	0.6858
AST	12.49	0.4576	0.7041	12.50	0.4580	0.7033	12.46	0.4582	0.7040	12.48	0.4586	0.7038
OneRestore	10.37	0.4504	0.7459	10.37	0.4500	0.7457	10.37	0.4496	0.7454	10.36	0.4492	0.7448
General restoration backbones												
Restormer	14.80	0.5211	0.6629	14.83	0.5211	0.6619	14.84	0.5210	0.6617	14.78	0.5207	0.6625
X-Restormer	14.97	0.5190	0.6665	14.96	0.5187	0.6664	14.95	0.5181	0.6663	14.94	0.5175	0.6662
NAFNet	14.19	0.4630	0.6520	14.17	0.4633	0.6520	14.15	0.4626	0.6526	14.14	0.4623	0.6522
Pixel2Pixel	11.25	0.3880	0.6651	11.25	0.3874	0.6655	11.25	0.3889	0.6647	11.26	0.3904	0.6645
ConvIR	14.27	0.4927	0.6890	14.24	0.4923	0.6893	14.21	0.4919	0.6900	14.18	0.4913	0.6903
Uformer	10.33	0.4425	0.7206	10.32	0.4425	0.7204	10.32	0.4428	0.7207	10.29	0.4424	0.7198
U-Net	8.89	0.3639	0.7898	8.88	0.3640	0.7899	8.87	0.3643	0.7894	8.86	0.3644	0.7901
Degradation-specific restoration												
Ada-Deblur	**15.54**	**0.5409**	0.6619	**15.56**	**0.5410**	0.6610	**15.56**	**0.5410**	0.6605	**15.55**	**0.5405**	0.6606
DehazeFormer	14.11	0.4564	0.6888	14.11	0.4565	0.6896	14.10	0.4564	0.6900	14.09	0.4567	0.6903
OKNet	13.89	0.4737	0.6897	13.94	0.4744	0.6893	13.98	0.4750	0.6893	14.00	0.4756	0.6891
DnCNN	8.24	0.3360	0.7310	8.23	0.3356	0.7311	8.23	0.3348	0.7319	8.20	0.3360	0.7326
Enhancement-oriented restoration												
Retinexformer	14.41	0.5002	0.6712	14.49	0.5017	0.6692	14.54	0.5023	0.6673	14.63	0.5034	0.6654
HVI-CIDNet	14.95	0.5082	0.6813	14.94	0.5090	0.6816	14.95	0.5088	0.6815	15.01	0.5108	0.6789
IRNeXt	13.86	0.4841	0.6874	13.85	0.4841	0.6877	13.85	0.4841	0.6876	13.84	0.4838	0.6876
DEA-Net	10.98	0.4490	0.7356	10.93	0.4484	0.7360	10.90	0.4475	0.7350	10.91	0.4477	0.7347
SFHformer	8.75	0.3506	0.7852	8.75	0.3501	0.7851	8.74	0.3496	0.7850	8.74	0.3493	0.7850
DeepSN-Net	9.30	0.3401	0.7436	9.29	0.3395	0.7435	9.29	0.3389	0.7435	9.28	0.3383	0.7436
DarkIR	4.68	0.0389	0.8940	4.68	0.0390	0.8935	4.69	0.0391	0.8930	4.70	0.0394	0.8920
Proposed method												
Recall(Ours)	**19.13**	**0.5976**	**0.5945**	**19.16**	**0.5992**	**0.5937**	**19.19**	**0.6006**	**0.5924**	**19.21**	**0.6019**	**0.5915**

Table A31 (continued).

Method	589.7 nits			610.5 nits			621.2 nits			632.0 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	15.41	0.5156	**0.6435**	15.40	0.5153	**0.6438**	15.42	0.5157	**0.6430**	15.41	0.5154	**0.6435**
UniProcessor	12.85	0.4618	0.6855	12.77	0.4620	0.6861	12.73	0.4611	0.6864	12.66	0.4601	0.6866
AST	12.41	0.4585	0.7040	12.44	0.4593	0.7036	12.37	0.4591	0.7038	12.37	0.4595	0.7044
OneRestore	10.36	0.4487	0.7444	10.35	0.4480	0.7439	10.35	0.4475	0.7434	10.35	0.4471	0.7427
General restoration backbones												
Restormer	14.84	0.5211	0.6612	14.82	0.5210	0.6612	14.86	0.5214	0.6605	14.79	0.5208	0.6614
X-Restormer	14.91	0.5170	0.6664	14.89	0.5159	0.6662	14.87	0.5152	0.6663	14.85	0.5142	0.6666
NAFNet	14.10	0.4614	0.6537	14.06	0.4607	0.6554	14.01	0.4597	0.6566	13.98	0.4591	0.6566
Pixel2Pixel	11.27	0.3898	0.6643	11.27	0.3887	0.6654	11.27	0.3873	0.6656	11.28	0.3877	0.6654
ConvIR	14.13	0.4908	0.6909	14.05	0.4896	0.6918	13.97	0.4884	0.6929	13.91	0.4878	0.6938
Uformer	10.29	0.4422	0.7204	10.30	0.4424	0.7199	10.29	0.4422	0.7208	10.27	0.4418	0.7198
U-Net	8.86	0.3642	0.7894	8.87	0.3639	0.7904	8.86	0.3640	0.7895	8.86	0.3638	0.7898
Degradation-specific restoration												
Ada-Deblur	**15.54**	**0.5400**	0.6609	**15.58**	**0.5405**	0.6597	**15.57**	**0.5400**	0.6601	**15.56**	**0.5397**	0.6602
DehazeFormer	14.08	0.4567	0.6904	14.05	0.4563	0.6919	14.03	0.4562	0.6924	14.00	0.4562	0.6933
OKNet	14.05	0.4763	0.6876	14.05	0.4766	0.6885	14.07	0.4765	0.6884	14.06	0.4763	0.6892
DnCNN	8.22	0.3342	0.7320	8.19	0.3348	0.7323	8.21	0.3332	0.7320	8.19	0.3339	0.7323
Enhancement-oriented restoration												
Retinexformer	14.66	0.5042	0.6643	14.78	0.5060	0.6616	14.80	0.5060	0.6607	14.86	0.5063	0.6593
HVI-CIDNet	14.96	0.5106	0.6804	14.98	0.5110	0.6796	14.94	0.5108	0.6807	14.97	0.5113	0.6796
IRNeXt	13.82	0.4835	0.6879	13.80	0.4832	0.6882	13.78	0.4831	0.6886	13.76	0.4830	0.6887
DEA-Net	10.84	0.4463	0.7331	10.76	0.4446	0.7333	10.69	0.4433	0.7323	10.71	0.4437	0.7312
SFHformer	8.74	0.3488	0.7849	8.72	0.3479	0.7851	8.72	0.3474	0.7850	8.71	0.3471	0.7850
DeepSN-Net	9.28	0.3375	0.7438	9.27	0.3364	0.7437	9.26	0.3355	0.7441	9.25	0.3348	0.7443
DarkIR	4.70	0.0396	0.8914	4.71	0.0396	0.8903	4.72	0.0398	0.8894	4.73	0.0400	0.8887
Proposed method												
Recall(Ours)	**19.20**	**0.6019**	**0.5898**	**19.12**	**0.6028**	**0.5898**	**19.09**	**0.6025**	**0.5889**	**19.01**	**0.6016**	**0.5895**

Table A31 (continued).

Method	643.1 nits			654.3 nits			665.7 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.36	0.5152	**0.6446**	15.34	0.5148	**0.6446**	15.42	0.5159	**0.6425**
UniProcessor	12.59	0.4585	0.6866	12.53	0.4575	0.6869	12.47	0.4566	0.6866
AST	12.34	0.4602	0.7042	12.32	0.4598	0.7041	12.26	0.4601	0.7037
OneRestore	10.35	0.4468	0.7421	10.34	0.4464	0.7417	10.34	0.4460	0.7412
General restoration backbones									
Restormer	14.80	0.5208	0.6611	14.85	0.5213	0.6589	14.85	0.5209	0.6606
X-Restormer	14.83	0.5136	0.6667	14.80	0.5132	0.6667	14.78	0.5126	0.6670
NAFNet	13.94	0.4578	0.6580	13.89	0.4568	0.6585	13.84	0.4554	0.6597
Pixel2Pixel	11.26	0.3871	0.6645	11.24	0.3852	0.6663	11.30	0.3839	0.6663
ConvIR	13.84	0.4870	0.6943	13.78	0.4865	0.6952	13.72	0.4859	0.6960
Uformer	10.26	0.4421	0.7207	10.27	0.4421	0.7207	10.27	0.4421	0.7211
U-Net	8.84	0.3641	0.7897	8.82	0.3636	0.7889	8.82	0.3627	0.7890
Degradation-specific restoration									
Ada-Deblur	**15.57**	**0.5397**	0.6587	**15.58**	**0.5396**	0.6584	**15.59**	**0.5392**	0.6581
DehazeFormer	13.98	0.4565	0.6945	13.96	0.4564	0.6955	13.93	0.4562	0.6965
OKNet	14.04	0.4759	0.6899	14.02	0.4754	0.6906	13.97	0.4743	0.6916
DnCNN	8.18	0.3332	0.7327	8.19	0.3317	0.7325	8.18	0.3306	0.7318
Enhancement-oriented restoration									
Retinexformer	14.91	0.5060	0.6577	14.97	0.5063	0.6564	15.01	0.5062	0.6549
HVI-CIDNet	14.98	0.5110	0.6795	14.98	0.5108	0.6801	14.98	0.5104	0.6805
IRNeXt	13.74	0.4828	0.6888	13.71	0.4826	0.6893	13.67	0.4822	0.6899
DEA-Net	10.69	0.4431	0.7309	10.63	0.4419	0.7311	10.63	0.4419	0.7304
SFHformer	8.71	0.3467	0.7848	8.70	0.3462	0.7847	8.69	0.3458	0.7849
DeepSN-Net	9.24	0.3341	0.7445	9.23	0.3333	0.7449	9.23	0.3326	0.7452
DarkIR	4.73	0.0402	0.8881	4.74	0.0404	0.8877	4.75	0.0406	0.8870

Table A31 (continued).

Method	643.1 nits			654.3 nits			665.7 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Proposed method									
Recall(Ours)	**18.95**	**0.6010**	**0.5903**	**18.87**	**0.6001**	**0.5911**	**18.79**	**0.5988**	**0.5921**

Table A31 (continued).

Method	677.4 nits			689.2 nits			701.3 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.44	0.5155	**0.6431**	15.43	0.5151	**0.6432**	15.37	0.5132	**0.6437**
UniProcessor	12.44	0.4566	0.6859	12.40	0.4564	0.6857	12.39	0.4566	0.6859
AST	12.26	0.4597	0.7051	12.22	0.4600	0.7051	12.15	0.4595	0.7057
OneRestore	10.34	0.4457	0.7404	10.33	0.4453	0.7403	10.33	0.4451	0.7398
General restoration backbones									
Restormer	14.82	0.5212	0.6610	14.83	0.5213	0.6601	14.84	0.5202	0.6601
X-Restormer	14.70	0.5106	0.6673	14.68	0.5099	0.6675	14.63	0.5081	0.6683
NAFNet	13.78	0.4539	0.6605	13.74	0.4529	0.6615	13.68	0.4520	0.6631
Pixel2Pixel	11.33	0.3820	0.6660	11.34	0.3817	0.6662	11.53	0.3785	0.6691
ConvIR	13.66	0.4851	0.6968	13.59	0.4841	0.6979	13.51	0.4832	0.6990
Uformer	10.26	0.4419	0.7211	10.26	0.4418	0.7215	10.25	0.4419	0.7216
U-Net	8.82	0.3637	0.7898	8.82	0.3630	0.7882	8.81	0.3629	0.7892
Degradation-specific restoration									
Ada-Deblur	**15.58**	**0.5388**	0.6580	**15.58**	**0.5385**	0.6577	**15.60**	**0.5380**	0.6557
DehazeFormer	13.91	0.4564	0.6972	13.88	0.4567	0.6981	13.85	0.4570	0.6995
OKNet	13.92	0.4733	0.6926	13.86	0.4719	0.6935	13.79	0.4705	0.6949
DnCNN	8.19	0.3317	0.7318	8.18	0.3309	0.7316	8.18	0.3307	0.7320
Enhancement-oriented restoration									
Retinexformer	15.08	0.5059	0.6529	15.12	0.5055	0.6517	15.16	0.5030	0.6493
HVI-CIDNet	14.98	0.5102	0.6802	14.97	0.5109	0.6798	14.92	0.5097	0.6802
IRNeXt	13.63	0.4817	0.6906	13.58	0.4811	0.6916	13.52	0.4802	0.6927
DEA-Net	10.61	0.4417	0.7300	10.58	0.4409	0.7301	10.55	0.4405	0.7302
SFHformer	8.68	0.3454	0.7848	8.67	0.3449	0.7847	8.66	0.3446	0.7846
DeepSN-Net	9.22	0.3318	0.7454	9.21	0.3310	0.7459	9.19	0.3303	0.7461
DarkIR	4.75	0.0408	0.8864	4.76	0.0409	0.8860	4.77	0.0412	0.8852
Proposed method									
Recall(Ours)	**18.70**	**0.5974**	**0.5929**	**18.59**	**0.5954**	**0.5947**	**18.53**	**0.5943**	**0.5948**

D.3.3 Software Display-Luminance Variation

Appendix Table A32 and Figure A45 report the Software sweep.

Software PSNR reaches 21.607 dB at 579.6 nits equivalent luminance and changes gradually toward both ends, while RECALL leads all three metrics at the 18 recorded conditions.

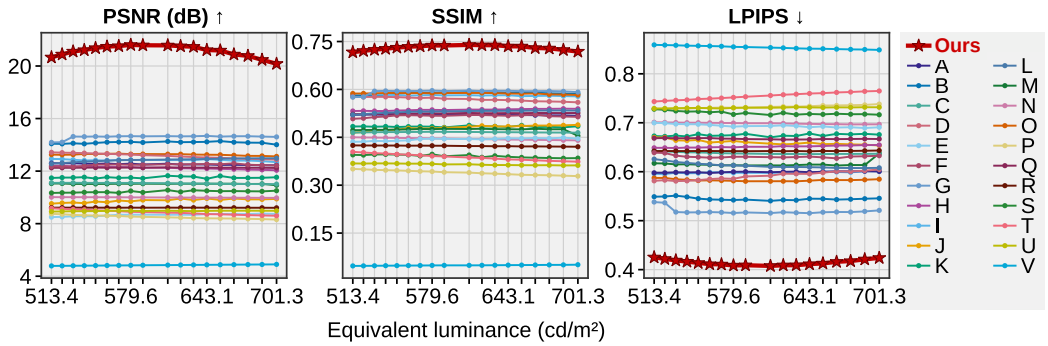


Figure A45: Software Equivalent-Luminance Variation curves, generated from the same values as Appendix Table A32. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Equivalent luminance uses a nominal 600 cd/m^2 reference; 1 nit equals 1 cd/m^2. Method letters follow Section D.

The software-luminance curves test the dense software layout across the recorded change in wall-image exposure, with RECALL leading all three metrics at every point. Their gradual variation around the strongest region shows that panel organization, tool regions, and page hierarchy remain recoverable as the wall-light strength changes.

The complete model sustains the strongest recorded coarse software structure across the luminance range.

Table A32: Full Software Display-Luminance Variation results, with 23 methods and 18 conditions.

Method	513.4 nits			522.3 nits			531.5 nits			540.8 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	14.08	0.5802	0.5489	14.07	0.5806	0.5494	14.12	0.5813	0.5511	14.08	0.5830	0.5486
UniProcessor	11.48	0.4839	0.6729	11.51	0.4841	0.6721	11.51	0.4831	0.6738	11.54	0.4839	0.6720
AST	9.52	0.4650	0.6701	9.57	0.4665	0.6700	9.61	0.4724	0.6641	9.56	0.4729	0.6636
OneRestore	10.02	0.4500	0.7010	10.02	0.4495	0.7007	10.02	0.4491	0.7005	10.01	0.4487	0.7002
General restoration backbones												
Restormer	12.93	0.5854	0.5958	12.91	0.5862	0.5949	12.86	0.5838	0.5980	12.81	0.5833	0.5968
X-Restormer	13.25	**0.5870**	0.5873	13.24	**0.5872**	0.5873	13.25	0.5879	0.5846	13.31	0.5888	0.5835
NAFNet	12.60	0.5205	0.5978	12.59	0.5209	0.5978	12.60	0.5211	0.5987	12.57	0.5204	0.5985
Pixel2Pixel	11.06	0.4722	0.6172	11.06	0.4727	0.6168	11.03	0.4734	0.6149	11.02	0.4733	0.6152
ConvIR	11.10	0.4646	0.6427	11.11	0.4653	0.6415	11.11	0.4659	0.6405	11.11	0.4663	0.6397
Uformer	8.50	0.4359	0.6998	8.52	0.4364	0.6992	8.56	0.4389	0.6975	8.57	0.4379	0.6971
U-Net	8.75	0.3508	0.7287	8.72	0.3497	0.7285	8.67	0.3480	0.7294	8.64	0.3471	0.7289
Degradation-specific restoration												
Ada-Deblur	13.43	0.5769	0.5814	13.40	0.5762	0.5828	13.39	0.5767	0.5808	13.37	0.5765	0.5813
DehazeFormer	12.40	0.5324	0.6488	12.40	0.5328	0.6488	12.36	0.5324	0.6484	12.34	0.5323	0.6493
OKNet	12.25	0.5225	0.6684	12.25	0.5227	0.6688	12.25	0.5230	0.6685	12.26	0.5238	0.6683
DnCNN	9.22	0.4246	0.6422	9.22	0.4244	0.6422	9.22	0.4242	0.6422	9.22	0.4242	0.6422
Enhancement-oriented restoration												
Retinexformer	**14.18**	0.5758	**0.5381**	**14.20**	0.5764	**0.5365**	**14.63**	**0.5946**	**0.5176**	**14.62**	**0.5953**	**0.5169**
HVI-CIDNet	12.35	0.5080	0.6390	12.35	0.5096	0.6382	12.33	0.5132	0.6329	12.39	0.5151	0.6305
IRNeXt	12.56	0.5204	0.6257	12.61	0.5225	0.6231	12.67	0.5251	0.6199	12.72	0.5265	0.6179
DEA-Net	10.34	0.3950	0.7277	10.35	0.3944	0.7264	10.36	0.3961	0.7241	10.39	0.3966	0.7228
SFHformer	9.17	0.4044	0.7434	9.13	0.4025	0.7447	9.09	0.4002	0.7459	9.06	0.3992	0.7467
DeepSN-Net	8.92	0.3682	0.7291	8.93	0.3678	0.7292	8.95	0.3683	0.7296	8.95	0.3683	0.7301
DarkIR	4.78	0.0471	0.8591	4.79	0.0473	0.8587	4.80	0.0476	0.8582	4.80	0.0479	0.8575
Proposed method												
Recall(Ours)	**20.66**	**0.7165**	**0.4251**	**20.88**	**0.7208**	**0.4220**	**21.10**	**0.7243**	**0.4188**	**21.21**	**0.7274**	**0.4164**

Table A32 (continued).

Method	550.2 nits			559.8 nits			569.6 nits			579.6 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	14.14	0.5866	0.5450	14.20	0.5888	0.5434	14.22	0.5887	0.5428	14.22	0.5897	0.5422
UniProcessor	11.43	0.4822	0.6767	11.54	0.4834	0.6733	11.49	0.4837	0.6739	11.50	0.4833	0.6746
AST	9.68	0.4737	0.6649	9.63	0.4784	0.6596	9.76	0.4776	0.6612	9.70	0.4776	0.6629
OneRestore	10.01	0.4481	0.7001	10.01	0.4477	0.6999	10.01	0.4472	0.6997	10.00	0.4465	0.6994
General restoration backbones												
Restormer	12.83	0.5821	0.5971	12.80	0.5806	0.5988	12.85	0.5816	0.5989	12.85	0.5824	0.5977
X-Restormer	13.30	0.5889	0.5820	13.32	0.5882	0.5824	13.33	0.5886	0.5820	13.29	0.5879	0.5814
NAFNet	12.55	0.5206	0.5988	12.58	0.5224	0.5975	12.53	0.5206	0.5987	12.57	0.5210	0.5998
Pixel2Pixel	11.02	0.4742	0.6145	11.03	0.4746	0.6141	11.04	0.4761	0.6130	11.03	0.4755	0.6132
ConvIR	11.10	0.4663	0.6395	11.10	0.4665	0.6387	11.10	0.4669	0.6378	11.10	0.4671	0.6374
Uformer	8.56	0.4392	0.6969	8.62	0.4404	0.6956	8.68	0.4447	0.6940	8.68	0.4457	0.6921
U-Net	8.62	0.3461	0.7300	8.61	0.3450	0.7304	8.58	0.3436	0.7312	8.54	0.3428	0.7306
Degradation-specific restoration												
Ada-Deblur	13.34	0.5758	0.5828	13.31	0.5745	0.5849	13.29	0.5731	0.5863	13.26	0.5741	0.5855
DehazeFormer	12.33	0.5337	0.6493	12.31	0.5346	0.6499	12.31	0.5359	0.6503	12.30	0.5360	0.6498
OKNet	12.27	0.5239	0.6686	12.26	0.5240	0.6687	12.26	0.5247	0.6676	12.27	0.5252	0.6674
DnCNN	9.22	0.4241	0.6423	9.22	0.4237	0.6423	9.21	0.4239	0.6422	9.22	0.4236	0.6421

Table A32 (continued).

Method	550.2 nits			559.8 nits			569.6 nits			579.6 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Enhancement-oriented restoration												
Retinexformer	**14.64**	**0.5947**	**0.5171**	**14.62**	**0.5948**	**0.5176**	**14.65**	**0.5951**	**0.5170**	**14.66**	**0.5963**	**0.5157**
HVI-CIDNet	12.50	0.5187	0.6298	12.49	0.5192	0.6287	12.51	0.5185	0.6292	12.48	0.5175	0.6305
IRNeXt	12.75	0.5281	0.6162	12.79	0.5296	0.6150	12.83	0.5303	0.6131	12.84	0.5308	0.6128
DEA-Net	10.40	0.3958	0.7232	10.40	0.3949	0.7214	10.34	0.3918	0.7229	10.49	0.3969	0.7170
SFHformer	9.02	0.3968	0.7484	8.99	0.3958	0.7493	8.95	0.3934	0.7504	8.90	0.3913	0.7518
DeepSN-Net	8.96	0.3679	0.7303	8.97	0.3674	0.7298	8.99	0.3675	0.7292	8.97	0.3667	0.7304
DarkIR	4.81	0.0480	0.8571	4.81	0.0482	0.8567	4.82	0.0484	0.8562	4.83	0.0487	0.8550
Proposed method												
Recall(Ours)	**21.37**	**0.7310**	**0.4137**	**21.48**	**0.7337**	**0.4113**	**21.52**	**0.7353**	**0.4107**	**21.61**	**0.7377**	**0.4085**

Table A32 (continued).

Method	589.7 nits			610.5 nits			621.2 nits			632.0 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	14.18	0.5892	0.5431	14.26	0.5917	0.5405	14.20	0.5899	0.5423	14.21	0.5911	0.5418
UniProcessor	11.45	0.4809	0.6775	11.65	0.4874	0.6702	11.60	0.4838	0.6736	11.58	0.4842	0.6729
AST	9.80	0.4796	0.6603	9.78	0.4829	0.6573	9.91	0.4860	0.6558	9.79	0.4839	0.6571
OneRestore	10.00	0.4461	0.6990	9.99	0.4448	0.6990	9.99	0.4444	0.6986	9.98	0.4436	0.6982
General restoration backbones												
Restormer	12.85	0.5813	0.5977	12.84	0.5819	0.5976	12.84	0.5809	0.5981	12.84	0.5815	0.5964
X-Restormer	13.30	0.5885	0.5805	13.29	0.5889	0.5806	13.29	0.5890	0.5806	13.26	0.5884	0.5804
NAFNet	12.50	0.5197	0.6001	12.56	0.5219	0.5989	12.49	0.5200	0.5998	12.51	0.5206	0.6002
Pixel2Pixel	11.04	0.4765	0.6129	11.03	0.4761	0.6130	11.04	0.4767	0.6128	11.04	0.4756	0.6136
ConvIR	11.09	0.4671	0.6371	11.08	0.4667	0.6363	11.06	0.4664	0.6362	11.06	0.4660	0.6363
Uformer	8.68	0.4451	0.6932	8.68	0.4445	0.6934	8.68	0.4437	0.6948	8.67	0.4449	0.6934
U-Net	8.52	0.3407	0.7312	8.48	0.3394	0.7324	8.46	0.3373	0.7329	8.42	0.3361	0.7330
Degradation-specific restoration												
Ada-Deblur	13.21	0.5708	0.5904	13.16	0.5701	0.5918	13.11	0.5672	0.5959	13.07	0.5673	0.5958
DehazeFormer	12.26	0.5354	0.6510	12.25	0.5367	0.6509	12.21	0.5367	0.6523	12.20	0.5368	0.6518
OKNet	12.26	0.5247	0.6666	12.28	0.5263	0.6662	12.27	0.5254	0.6657	12.27	0.5254	0.6658
DnCNN	9.22	0.4236	0.6419	9.22	0.4225	0.6422	9.21	0.4225	0.6419	9.22	0.4219	0.6423
Enhancement-oriented restoration												
Retinexformer	**14.65**	**0.5948**	**0.5168**	**14.66**	**0.5964**	**0.5155**	**14.65**	**0.5947**	**0.5173**	**14.65**	**0.5956**	**0.5162**
HVI-CIDNet	12.49	0.5173	0.6305	12.52	0.5198	0.6297	12.52	0.5197	0.6293	12.52	0.5186	0.6300
IRNeXt	12.85	0.5310	0.6122	12.88	0.5323	0.6100	12.89	0.5326	0.6097	12.90	0.5326	0.6097
DEA-Net	10.38	0.3906	0.7201	10.56	0.3944	0.7158	10.42	0.3873	0.7203	10.54	0.3919	0.7167
SFHformer	8.88	0.3900	0.7532	8.84	0.3865	0.7557	8.82	0.3853	0.7572	8.78	0.3832	0.7584
DeepSN-Net	8.96	0.3651	0.7307	8.99	0.3656	0.7307	8.97	0.3639	0.7311	8.95	0.3631	0.7319
DarkIR	4.83	0.0489	0.8546	4.84	0.0489	0.8535	4.85	0.0490	0.8529	4.86	0.0493	0.8520
Proposed method												
Recall(Ours)	**21.58**	**0.7375**	**0.4090**	**21.57**	**0.7395**	**0.4076**	**21.51**	**0.7385**	**0.4089**	**21.47**	**0.7385**	**0.4091**

Table A32 (continued).

Method	643.1 nits			654.3 nits			665.7 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.23	0.5891	0.5449	14.28	0.5903	0.5447	14.20	0.5899	0.5431
UniProcessor	11.42	0.4822	0.6782	11.63	0.4873	0.6729	11.48	0.4818	0.6773
AST	9.92	0.4839	0.6596	9.80	0.4852	0.6563	9.91	0.4867	0.6569
OneRestore	9.98	0.4430	0.6977	9.98	0.4425	0.6973	9.97	0.4420	0.6971
General restoration backbones									
Restormer	12.91	0.5818	0.5979	12.86	0.5790	0.6005	12.80	0.5795	0.5995
X-Restormer	13.25	0.5873	0.5817	13.24	0.5864	0.5833	13.20	0.5874	0.5829
NAFNet	12.50	0.5204	0.5990	12.47	0.5197	0.5998	12.48	0.5192	0.6009
Pixel2Pixel	11.04	0.4752	0.6146	11.04	0.4750	0.6145	11.04	0.4767	0.6127
ConvIR	11.05	0.4660	0.6360	11.04	0.4657	0.6361	11.03	0.4653	0.6364
Uformer	8.73	0.4467	0.6909	8.74	0.4464	0.6926	8.73	0.4477	0.6903
U-Net	8.41	0.3345	0.7338	8.40	0.3325	0.7351	8.39	0.3318	0.7354

Table A32 (continued).

Method	643.1 nits			654.3 nits			665.7 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Degradation-specific restoration									
Ada-Deblur	13.04	0.5665	0.5956	13.01	0.5650	0.5981	12.96	0.5628	0.6007
DehazeFormer	12.20	0.5376	0.6518	12.17	0.5383	0.6526	12.15	0.5390	0.6535
OKNet	12.27	0.5259	0.6659	12.26	0.5255	0.6668	12.26	0.5261	0.6666
DnCNN	9.22	0.4222	0.6418	9.21	0.4214	0.6424	9.21	0.4215	0.6422
Enhancement-oriented restoration									
Retinexformer	**14.68**	**0.5956**	**0.5153**	**14.63**	**0.5945**	**0.5172**	**14.65**	**0.5946**	**0.5177**
HVI-CIDNet	12.54	0.5175	0.6309	12.52	0.5188	0.6293	12.59	0.5213	0.6274
IRNeXt	12.92	0.5330	0.6093	12.95	0.5331	0.6088	12.96	0.5335	0.6078
DEA-Net	10.50	0.3889	0.7180	10.47	0.3870	0.7172	10.48	0.3861	0.7184
SFHformer	8.73	0.3807	0.7597	8.71	0.3797	0.7605	8.68	0.3781	0.7619
DeepSN-Net	8.97	0.3631	0.7314	8.98	0.3626	0.7311	8.98	0.3624	0.7315
DarkIR	4.87	0.0496	0.8514	4.87	0.0498	0.8511	4.88	0.0500	0.8505
Proposed method									
Recall(Ours)	**21.22**	**0.7350**	**0.4113**	**21.18**	**0.7347**	**0.4127**	**20.88**	**0.7298**	**0.4159**

Table A32 (continued).

Method	677.4 nits			689.2 nits			701.3 nits		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.17	0.5876	0.5438	14.16	0.5872	0.5448	14.01	0.5863	0.5456
UniProcessor	11.48	0.4829	0.6763	11.49	0.4812	0.6774	11.53	0.4847	0.6757
AST	9.85	0.4868	0.6559	9.85	0.4875	0.6552	9.88	0.4890	0.6536
OneRestore	9.97	0.4415	0.6966	9.97	0.4409	0.6968	9.96	0.4404	0.6968
General restoration backbones									
Restormer	12.81	0.5803	0.5987	12.76	0.5791	0.6010	12.68	0.5782	0.6008
X-Restormer	13.16	0.5844	0.5828	13.16	0.5838	0.5836	13.12	0.5826	0.5848
NAFNet	12.46	0.5188	0.6007	12.44	0.5187	0.6011	12.44	0.5175	0.6006
Pixel2Pixel	11.02	0.4752	0.6137	11.03	0.4753	0.6136	10.92	0.4548	0.6373
ConvIR	11.02	0.4649	0.6363	11.01	0.4648	0.6365	11.01	0.4645	0.6366
Uformer	8.73	0.4465	0.6909	8.76	0.4489	0.6893	8.74	0.4457	0.6908
U-Net	8.37	0.3311	0.7358	8.35	0.3298	0.7365	8.31	0.3284	0.7381
Degradation-specific restoration									
Ada-Deblur	12.93	0.5623	0.6004	12.91	0.5613	0.6021	12.87	0.5595	0.6046
DehazeFormer	12.12	0.5391	0.6535	12.10	0.5397	0.6544	12.07	0.5392	0.6546
OKNet	12.26	0.5261	0.6668	12.25	0.5259	0.6671	12.24	0.5261	0.6668
DnCNN	9.21	0.4212	0.6424	9.21	0.4208	0.6428	9.21	0.4204	0.6433
Enhancement-oriented restoration									
Retinexformer	**14.66**	**0.5949**	**0.5176**	**14.63**	**0.5939**	**0.5189**	**14.60**	**0.5916**	**0.5210**
HVI-CIDNet	12.49	0.5161	0.6310	12.45	0.5151	0.6316	12.42	0.5141	0.6326
IRNeXt	12.97	0.5338	0.6076	12.98	0.5339	0.6075	12.98	0.5335	0.6079
DEA-Net	10.47	0.3851	0.7174	10.46	0.3844	0.7176	10.51	0.3848	0.7164
SFHformer	8.65	0.3762	0.7628	8.63	0.3750	0.7641	8.60	0.3737	0.7649
DeepSN-Net	8.99	0.3627	0.7313	8.98	0.3618	0.7318	8.98	0.3621	0.7316
DarkIR	4.89	0.0503	0.8499	4.89	0.0504	0.8496	4.90	0.0509	0.8488
Proposed method									
Recall(Ours)	**20.77**	**0.7285**	**0.4175**	**20.47**	**0.7238**	**0.4210**	**20.17**	**0.7185**	**0.4240**

D.4 Transport-Spread Variation

We vary the spatial spread of the wall observation to examine reconstruction as screen evidence becomes more dispersed. The spread parameter is expressed in pixels at the 256-pixel reference scale. Browser and Software span ten spread widths from 0.5 to 3 px, Figure spans 0.05 to 0.5 px, and Game spans 0.5 to 1.5 px, with screen content and the remaining conditions fixed. The Browser sweeps in Tables A33 and A41 cover overlapping spread values, with a wider interval in Table A33.

D.4.1 Browser Transport-Spread Variation

Appendix Table A33 and Figure A46 report the Browser sweep.

As the recorded transport-spread width increases, Browser PSNR decreases from 19.356 to 17.490 dB, while RECALL leads all three metrics at the 10 recorded conditions.

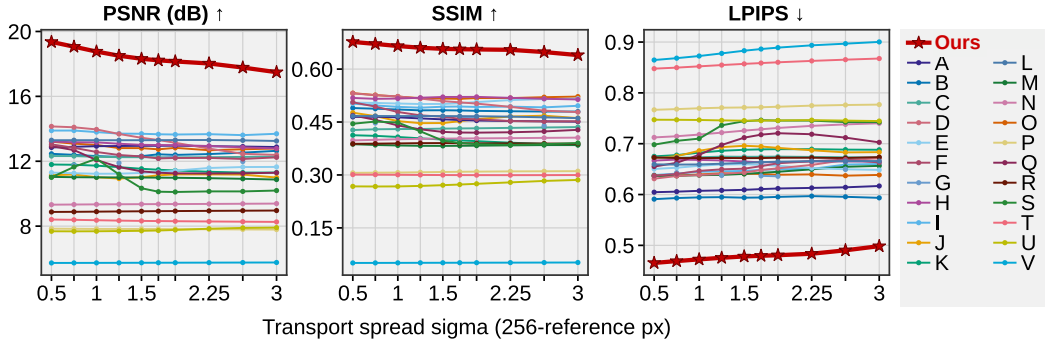


Figure A46: Browser Transport-Spread Variation curves, generated from the same values as Appendix Table A33. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Pixel values use a 256-px reference short side. Method letters follow Section D.

Table A33: Full Browser Transport-Spread Variation results, with 23 methods and 10 conditions.

Method	(0.5 px)			(0.75 px)			(1 px)			(1.25 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	12.46	0.4896	**0.5909**	12.40	0.4877	**0.5931**	12.32	0.4855	**0.5944**	12.27	0.4831	**0.5949**
UniProcessor	11.80	0.4126	0.6751	11.78	0.4108	0.6776	11.73	0.4076	0.6824	11.64	0.4038	0.6861
AST	11.14	0.4765	0.6717	11.18	0.4667	0.6755	11.02	0.4526	0.6861	10.93	0.4468	0.6933
OneRestore	9.32	0.3979	0.7124	9.33	0.3996	0.7147	9.34	0.4012	0.7180	9.35	0.4023	0.7218
General restoration backbones												
Restormer	13.89	0.5022	0.6384	13.89	0.4970	0.6412	13.80	0.4930	0.6448	**13.70**	0.4906	0.6456
X-Restormer	13.21	**0.5318**	0.6373	13.09	**0.5264**	0.6372	13.00	0.5221	0.6395	12.81	0.5176	0.6417
NAFNet	12.85	0.4645	0.6046	12.89	0.4651	0.6057	12.93	0.4633	0.6073	12.94	0.4602	0.6082
Pixel2Pixel	11.03	0.3872	0.6367	11.02	0.3849	0.6369	11.01	0.3836	0.6381	11.00	0.3826	0.6386
ConvIR	12.32	0.4273	0.6734	12.32	0.4294	0.6723	12.27	0.4300	0.6733	12.25	0.4302	0.6746
Uformer	11.30	0.5049	0.6503	11.26	0.5041	0.6527	11.23	0.5024	0.6565	11.23	0.5010	0.6592
U-Net	7.84	0.3060	0.7667	7.83	0.3065	0.7681	7.83	0.3068	0.7697	7.82	0.3076	0.7709
Degradation-specific restoration												
Ada-Deblur	**14.15**	0.5313	0.6312	**14.09**	0.5260	0.6365	**13.96**	**0.5226**	0.6384	13.68	0.5165	0.6406
DehazeFormer	13.21	0.5182	0.6668	13.17	0.5157	0.6687	13.16	0.5165	0.6681	13.08	**0.5189**	0.6671
OKNet	12.93	0.4689	0.6551	12.69	0.4562	0.6623	12.08	0.4403	0.6782	11.64	0.4293	0.6974
DnCNN	8.88	0.3882	0.6730	8.88	0.3887	0.6718	8.89	0.3894	0.6717	8.91	0.3901	0.6720
Enhancement-oriented restoration												
Retinexformer	N/A	N/A	N/A	11.76	0.4471	0.6430	N/A	N/A	N/A	11.89	0.4567	0.6377
HVI-CIDNet	13.04	0.5059	0.6369	12.83	0.4938	0.6404	12.57	0.4784	0.6466	12.38	0.4689	0.6496
IRNeXt	13.30	0.4668	0.6594	13.30	0.4670	0.6589	13.30	0.4669	0.6592	13.30	0.4669	0.6606
DEA-Net	11.01	0.4450	0.6981	11.65	0.4513	0.7056	12.16	0.4486	0.7100	11.19	0.4236	0.7361
SFHformer	8.41	0.3010	0.8477	8.39	0.3008	0.8497	8.37	0.3005	0.8522	8.34	0.3001	0.8547
DeepSN-Net	7.68	0.2676	0.7472	7.68	0.2673	0.7470	7.68	0.2676	0.7467	7.70	0.2689	0.7459
DarkIR	5.73	0.0507	0.8646	5.73	0.0508	0.8683	5.74	0.0509	0.8725	5.74	0.0510	0.8777
Proposed method												
Recall(Ours)	**19.36**	**0.6770**	**0.4654**	**19.06**	**0.6714**	**0.4691**	**18.76**	**0.6654**	**0.4724**	**18.51**	**0.6605**	**0.4756**

Table A33 (continued).

Method	(1.5 px)			(1.6875 px)			(1.875 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.31	0.4834	**0.5938**	12.43	0.4828	**0.5942**	12.39	0.4816	**0.5954**
UniProcessor	11.54	0.4003	0.6880	11.48	0.3980	0.6889	11.43	0.3958	0.6893
AST	11.02	0.4471	0.6959	11.13	0.4523	0.6945	11.19	0.4583	0.6918
OneRestore	9.35	0.4030	0.7257	9.36	0.4034	0.7284	9.36	0.4037	0.7310

Table A33 (continued).

Method	(1.5 px)			(1.6875 px)			(1.875 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones									
Restormer	**13.70**	0.4934	0.6465	**13.66**	0.4939	0.6485	**13.65**	0.4927	0.6498
X-Restormer	12.81	0.5165	0.6408	12.73	0.5157	0.6405	12.83	0.5178	0.6389
NAFNet	12.95	0.4576	0.6092	12.95	0.4557	0.6107	12.96	0.4542	0.6119
Pixel2Pixel	11.00	0.3823	0.6406	10.99	0.3826	0.6427	10.98	0.3830	0.6448
ConvIR	12.25	0.4313	0.6742	12.24	0.4318	0.6744	12.24	0.4322	0.6746
Uformer	11.28	0.5012	0.6596	11.34	0.5032	0.6585	11.42	0.5066	0.6565
U-Net	7.82	0.3084	0.7713	7.82	0.3090	0.7717	7.82	0.3094	0.7728
Degradation-specific restoration									
Ada-Deblur	13.45	0.5093	0.6433	13.31	0.5058	0.6482	13.14	0.5022	0.6516
DehazeFormer	13.01	**0.5210**	0.6650	13.00	**0.5211**	0.6634	12.99	**0.5213**	0.6635
OKNet	11.38	0.4220	0.7119	11.29	0.4202	0.7178	11.26	0.4199	0.7206
DnCNN	8.92	0.3903	0.6716	8.92	0.3898	0.6718	8.93	0.3896	0.6724
Enhancement-oriented restoration									
Retinexformer	N/A	N/A	N/A	12.18	0.4614	0.6367	12.28	0.4636	0.6359
HVI-CIDNet	12.30	0.4650	0.6509	12.17	0.4592	0.6558	12.20	0.4578	0.6615
IRNeXt	13.30	0.4668	0.6624	13.30	0.4667	0.6637	13.31	0.4664	0.6646
DEA-Net	10.34	0.3974	0.7443	10.12	0.3907	0.7463	10.11	0.3872	0.7455
SFHformer	8.32	0.2997	0.8571	8.31	0.2996	0.8587	8.30	0.2995	0.8602
DeepSN-Net	7.71	0.2711	0.7453	7.73	0.2728	0.7454	7.76	0.2749	0.7457
DarkIR	5.74	0.0512	0.8830	5.74	0.0512	0.8862	5.75	0.0513	0.8890
Proposed method									
Recall(Ours)	**18.32**	**0.6574**	**0.4782**	**18.22**	**0.6563**	**0.4795**	**18.15**	**0.6557**	**0.4806**

Table A33 (continued).

Method	(2.25 px)			(2.625 px)			(3 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.44	0.4806	**0.5969**	12.53	0.4797	**0.5955**	12.64	0.4796	**0.5935**
UniProcessor	11.35	0.3915	0.6892	11.30	0.3880	0.6884	11.30	0.3857	0.6881
AST	11.19	0.4656	0.6871	11.18	0.4679	0.6829	11.00	0.4612	0.6834
OneRestore	9.37	0.4043	0.7351	9.38	0.4051	0.7380	9.39	0.4058	0.7402
General restoration backbones									
Restormer	**13.67**	0.4937	0.6504	**13.61**	0.4915	0.6590	**13.69**	0.4960	0.6602
X-Restormer	12.68	0.5179	0.6396	12.74	**0.5204**	0.6371	12.78	**0.5220**	0.6386
NAFNet	12.93	0.4529	0.6130	12.91	0.4520	0.6142	12.88	0.4509	0.6168
Pixel2Pixel	10.96	0.3838	0.6496	10.92	0.3846	0.6546	10.87	0.3846	0.6564
ConvIR	12.25	0.4334	0.6740	12.27	0.4345	0.6734	12.29	0.4356	0.6728
Uformer	11.59	0.5122	0.6520	11.64	0.5150	0.6497	11.65	0.5161	0.6485
U-Net	7.81	0.3101	0.7749	7.80	0.3104	0.7761	7.79	0.3107	0.7769
Degradation-specific restoration									
Ada-Deblur	12.78	0.4930	0.6583	12.46	0.4822	0.6679	12.39	0.4781	0.6713
DehazeFormer	12.94	**0.5185**	0.6653	12.86	0.5159	0.6652	12.79	0.5139	0.6647
OKNet	11.25	0.4209	0.7187	11.25	0.4233	0.7120	11.29	0.4278	0.7027
DnCNN	8.94	0.3895	0.6724	8.95	0.3891	0.6719	8.96	0.3885	0.6736
Enhancement-oriented restoration									
Retinexformer	N/A	N/A	N/A	11.98	0.4395	0.6495	N/A	N/A	N/A
HVI-CIDNet	12.21	0.4528	0.6655	12.14	0.4516	0.6688	12.24	0.4521	0.6631
IRNeXt	13.31	0.4653	0.6656	13.29	0.4632	0.6656	13.25	0.4611	0.6658
DEA-Net	10.14	0.3853	0.7455	10.14	0.3872	0.7425	10.19	0.3905	0.7424
SFHformer	8.29	0.2994	0.8629	8.27	0.2995	0.8654	8.26	0.2997	0.8676
DeepSN-Net	7.84	0.2789	0.7464	7.89	0.2831	0.7455	7.91	0.2859	0.7446
DarkIR	5.75	0.0515	0.8935	5.75	0.0517	0.8968	5.76	0.0519	0.9003
Proposed method									
Recall(Ours)	**18.03**	**0.6546**	**0.4835**	**17.78**	**0.6483**	**0.4903**	**17.49**	**0.6397**	**0.4985**

The Browser transport-spread curves show a gradual decline in reconstruction quality. RECALL remains first at every spread width, supporting recovery of page sections and block boundaries throughout the recorded range.

The sustained ordering supports the complete model's advantage in coarse layout recovery across the recorded spread range.

D.4.2 Figure-Content Transport-Spread Variation

Appendix Table A34 and Figure A47 report the Figure sweep.

Figure PSNR changes from 19.938 to 19.861 dB across the spread range, with an intermediate maximum of 20.27 dB at 0.25 px; RECALL leads all three metrics at the 10 recorded conditions.

The chart transport-spread curves remain tightly grouped across the modest recorded spread widths, with RECALL first on every metric and condition. This stability supports recovery of the overall chart brightness, color, and regional arrangement.

The result complements the Browser transport-spread sweep, extending the comparison from broad page blocks to compact chart structure.

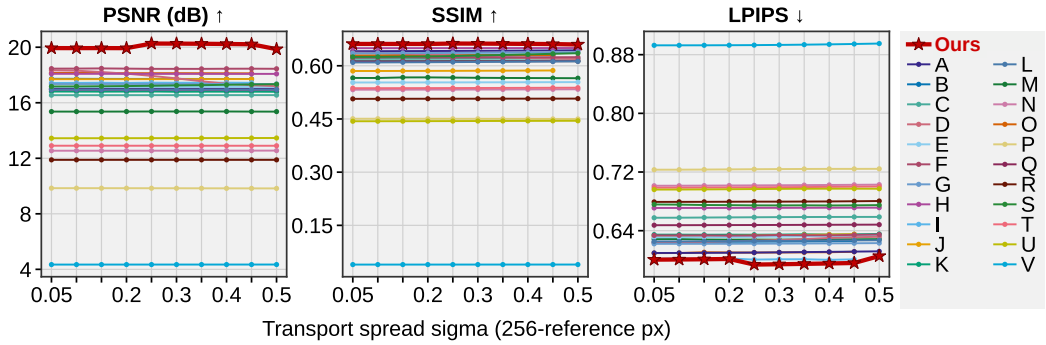


Figure A47: Figure-Content Transport-Spread Variation curves, generated from the same values as Appendix Table A34. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Pixel values use a 256-px reference short side. Method letters follow Section D.

Table A34: Full Figure-Content Transport-Spread Variation results, with 23 methods and 10 conditions.

Method	(0.05 px)			(0.1 px)			(0.15 px)			(0.2 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	17.73	0.6283	0.6240	17.73	0.6284	0.6241	17.72	0.6289	0.6247	17.72	0.6290	0.6249
UniProcessor	16.81	0.6132	0.6346	16.81	0.6131	0.6346	16.80	0.6133	0.6345	16.81	0.6130	0.6346
AST	17.70	0.5853	0.6322	17.70	0.5853	0.6324	17.70	0.5854	0.6326	17.70	0.5856	0.6329
OneRestore	12.54	0.5326	0.7013	12.55	0.5326	0.7013	12.55	0.5327	0.7015	12.55	0.5328	0.7016
General restoration backbones												
Restormer	17.43	0.6231	**0.6017**	17.43	0.6230	**0.6022**	17.44	0.6233	**0.6019**	17.43	0.6229	**0.6021**
X-Restormer	18.14	0.6291	0.6094	18.15	0.6292	0.6095	18.14	0.6301	0.6106	18.13	0.6299	0.6103
NAFNet	17.02	0.6411	0.6096	17.02	0.6412	0.6096	17.02	0.6414	0.6098	17.02	0.6416	0.6099
Pixel2Pixel	15.36	0.5657	0.6285	15.36	0.5656	0.6286	15.36	0.5672	0.6280	15.37	0.5673	0.6278
ConvIR	16.55	0.6196	0.6576	16.55	0.6197	0.6577	16.55	0.6197	0.6579	16.55	0.6198	0.6581
Uformer	17.15	0.5529	0.6311	17.15	0.5529	0.6311	17.15	0.5530	0.6312	17.14	0.5531	0.6314
U-Net	9.85	0.4507	0.7231	9.85	0.4507	0.7232	9.85	0.4506	0.7234	9.84	0.4506	0.7236
Degradation-specific restoration												
Ada-Deblur	18.33	0.6368	0.6236	18.31	0.6363	0.6237	18.21	0.6343	0.6246	18.10	0.6321	0.6256
DehazeFormer	18.08	**0.6497**	0.6710	18.08	**0.6497**	0.6710	18.08	**0.6497**	0.6710	18.08	**0.6498**	0.6710
OKNet	16.94	0.6124	0.6475	16.94	0.6124	0.6475	16.94	0.6124	0.6476	16.94	0.6125	0.6477
DnCNN	11.89	0.5067	0.6792	11.89	0.5068	0.6793	11.89	0.5070	0.6794	11.89	0.5070	0.6795

Table A34 (continued).

Method	(0.05 px)			(0.1 px)			(0.15 px)			(0.2 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Enhancement-oriented restoration												
Retinexformer	17.35	0.6354	0.6221	17.35	0.6355	0.6221	17.35	0.6357	0.6221	17.35	0.6359	0.6222
HVI-CIDNet	**18.46**	0.6231	0.6336	**18.46**	0.6233	0.6335	**18.47**	0.6242	0.6336	**18.46**	0.6234	0.6333
IRNeXt	16.95	0.6094	0.6253	16.95	0.6095	0.6254	16.95	0.6097	0.6255	16.95	0.6100	0.6257
DEA-Net	17.18	0.6250	0.6758	17.18	0.6252	0.6756	17.19	0.6258	0.6750	17.20	0.6265	0.6748
SFHformer	12.91	0.5368	0.6986	12.91	0.5368	0.6987	12.90	0.5369	0.6988	12.90	0.5370	0.6989
DeepSN-Net	13.44	0.4436	0.6961	13.44	0.4436	0.6961	13.45	0.4438	0.6963	13.45	0.4439	0.6965
DarkIR	4.34	0.0394	0.8928	4.34	0.0394	0.8928	4.34	0.0394	0.8928	4.34	0.0394	0.8929
Proposed method												
Recall(Ours)	**19.94**	**0.6615**	**0.6005**	**19.94**	**0.6616**	**0.6007**	**19.94**	**0.6616**	**0.6010**	**19.93**	**0.6615**	**0.6014**

Table A34 (continued).

Method	(0.25 px)			(0.3 px)			(0.35 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	17.72	0.6293	0.6250	17.72	0.6297	0.6251	17.71	0.6300	0.6253
UniProcessor	16.81	0.6133	0.6345	16.79	0.6131	0.6347	16.80	0.6131	0.6351
AST	17.70	0.5858	0.6333	17.70	0.5860	0.6338	17.70	0.5862	0.6342
OneRestore	12.55	0.5329	0.7018	12.55	0.5330	0.7019	12.55	0.5332	0.7021
General restoration backbones									
Restormer	17.45	0.6232	**0.6006**	17.44	0.6233	**0.6010**	17.45	0.6234	**0.6010**
X-Restormer	18.13	0.6299	0.6101	18.13	0.6299	0.6103	18.13	0.6298	0.6104
NAFNet	17.02	0.6418	0.6102	17.02	0.6422	0.6105	17.02	0.6425	0.6108
Pixel2Pixel	15.37	0.5667	0.6279	15.37	0.5661	0.6278	15.37	0.5657	0.6280
ConvIR	16.55	0.6199	0.6583	16.55	0.6199	0.6585	16.55	0.6200	0.6586
Uformer	17.14	0.5531	0.6316	17.14	0.5533	0.6318	17.15	0.5534	0.6321
U-Net	9.84	0.4505	0.7238	9.84	0.4505	0.7240	9.84	0.4504	0.7242
Degradation-specific restoration									
Ada-Deblur	17.94	0.6295	0.6264	17.76	0.6267	0.6273	17.55	0.6238	0.6286
DehazeFormer	18.08	**0.6498**	0.6711	18.08	**0.6499**	0.6712	18.08	**0.6499**	0.6712
OKNet	16.94	0.6126	0.6477	16.94	0.6126	0.6478	16.94	0.6127	0.6479
DnCNN	11.89	0.5071	0.6796	11.89	0.5071	0.6796	11.89	0.5072	0.6797
Enhancement-oriented restoration									
Retinexformer	17.35	0.6361	0.6223	17.35	0.6364	0.6224	17.35	0.6368	0.6225
HVI-CIDNet	**18.44**	0.6234	0.6334	**18.44**	0.6233	0.6340	**18.44**	0.6236	0.6337
IRNeXt	16.95	0.6103	0.6259	16.95	0.6107	0.6261	16.95	0.6112	0.6263
DEA-Net	17.22	0.6274	0.6745	17.25	0.6289	0.6745	17.27	0.6306	0.6746
SFHformer	12.90	0.5372	0.6991	12.90	0.5374	0.6993	12.90	0.5375	0.6995
DeepSN-Net	13.45	0.4441	0.6968	13.45	0.4442	0.6970	13.45	0.4444	0.6972
DarkIR	4.34	0.0394	0.8930	4.34	0.0394	0.8933	4.34	0.0395	0.8937
Proposed method									
Recall(Ours)	**20.27**	**0.6627**	**0.5938**	**20.26**	**0.6625**	**0.5942**	**20.25**	**0.6621**	**0.5947**

Table A34 (continued).

Method	(0.4 px)			(0.45 px)			(0.5 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	17.71	0.6304	0.6256	17.71	0.6308	0.6259	N/A	N/A	N/A
UniProcessor	16.80	0.6132	0.6347	16.80	0.6133	0.6350	16.79	0.6131	0.6355
AST	17.71	0.5865	0.6347	17.71	0.5868	0.6352	N/A	N/A	N/A
OneRestore	12.55	0.5333	0.7023	12.55	0.5335	0.7026	12.55	0.5337	0.7028
General restoration backbones									
Restormer	17.45	0.6230	**0.6003**	17.44	0.6229	**0.6009**	N/A	N/A	N/A
X-Restormer	18.12	0.6299	0.6106	18.12	0.6301	0.6113	N/A	N/A	N/A
NAFNet	17.02	0.6429	0.6111	17.02	0.6433	0.6115	17.02	0.6437	**0.6119**
Pixel2Pixel	15.37	0.5654	0.6282	15.36	0.5652	0.6283	15.36	0.5649	0.6285
ConvIR	16.55	0.6201	0.6587	16.55	0.6202	0.6588	16.55	0.6203	0.6588
Uformer	17.15	0.5536	0.6325	17.15	0.5537	0.6326	17.15	0.5539	0.6326
U-Net	9.83	0.4503	0.7243	9.83	0.4501	0.7243	9.83	0.4500	0.7243

Table A34 (continued).

Method	(0.4 px)			(0.45 px)			(0.5 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Degradation-specific restoration									
Ada-Deblur	17.37	0.6215	0.6301	17.26	0.6201	0.6311	17.20	0.6191	0.6317
DehazeFormer	18.08	**0.6500**	0.6713	18.08	**0.6501**	0.6713	18.08	**0.6501**	0.6714
OKNet	16.94	0.6128	0.6480	16.94	0.6129	0.6482	16.94	0.6130	0.6483
DnCNN	11.89	0.5073	0.6799	11.89	0.5073	0.6801	11.89	0.5074	0.6804
Enhancement-oriented restoration									
Retinexformer	17.35	0.6372	0.6227	17.35	0.6377	0.6229	17.35	0.6382	0.6231
HVI-CIDNet	**18.45**	0.6238	0.6337	**18.45**	0.6241	0.6343	**18.45**	0.6243	0.6348
IRNeXt	16.95	0.6116	0.6266	16.95	0.6121	0.6267	16.95	0.6126	0.6269
DEA-Net	17.29	0.6321	0.6744	17.32	0.6338	0.6746	17.34	0.6354	0.6749
SFHformer	12.90	0.5377	0.6997	12.90	0.5380	0.7000	12.90	0.5382	0.7003
DeepSN-Net	13.46	0.4446	0.6973	13.46	0.4447	0.6972	13.46	0.4449	0.6972
DarkIR	4.35	0.0395	0.8941	4.35	0.0395	0.8946	4.35	0.0395	0.8952
Proposed method									
Recall(Ours)	**20.23**	**0.6617**	**0.5953**	**20.21**	**0.6612**	**0.5960**	**19.86**	**0.6600**	**0.6054**

D.4.3 Game Transport-Spread Variation

Appendix Table A35 and Figure A48 report the Game sweep.

Game PSNR decreases from 18.917 to 18.094 dB as the recorded transport-spread width increases, while RECALL leads all three metrics at the 10 recorded conditions.

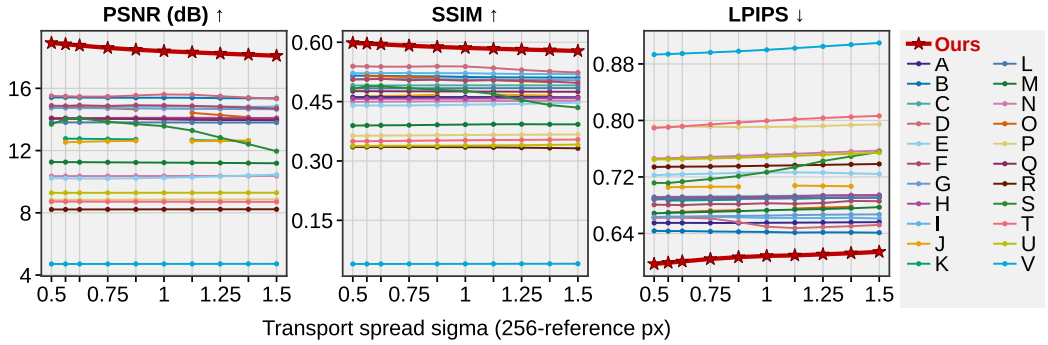


Figure A48: Game Transport-Spread Variation curves, generated from the same values as Appendix Table A35. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Pixel values use a 256-px reference short side. Method letters follow Section D.

The game transport-spread curves decline smoothly, with RECALL leading at every spread width. The result supports recovery of the canvas and principal object contours across the recorded spread range.

The result extends the coarse recovery of low-light game content across the recorded transport-spread conditions.

Table A35: Full Game Transport-Spread Variation results, with 23 methods and 10 conditions.

Method	(0.5 px)			(0.5625 px)			(0.625 px)			(0.75 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	15.41	0.5157	**0.6437**	15.42	0.5153	**0.6433**	15.41	0.5150	**0.6434**	15.40	0.5141	**0.6429**
UniProcessor	N/A	N/A	N/A	12.76	0.4627	0.6865	12.76	0.4628	0.6867	12.74	0.4629	0.6872
AST	N/A	N/A	N/A	12.54	0.4632	0.7054	12.56	0.4637	0.7058	12.60	0.4654	0.7062
OneRestore	10.36	0.4493	0.7461	10.36	0.4495	0.7466	10.36	0.4497	0.7472	10.36	0.4502	0.7484

Table A35 (continued).

Method	(0.5 px)			(0.5625 px)			(0.625 px)			(0.75 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones												
Restormer	14.84	0.5219	0.6631	14.83	0.5217	0.6640	14.84	0.5221	0.6636	14.84	0.5222	0.6636
X-Restormer	N/A	N/A	N/A	14.81	0.5143	0.6698	14.79	0.5138	0.6705	14.72	0.5123	0.6721
NAFNet	14.07	0.4614	0.6550	14.06	0.4614	0.6550	14.06	0.4615	0.6550	14.05	0.4616	0.6549
Pixel2Pixel	11.26	0.3894	0.6685	11.26	0.3898	0.6692	11.25	0.3901	0.6696	11.24	0.3904	0.6706
ConvIR	14.08	0.4907	0.6917	14.07	0.4908	0.6918	14.07	0.4909	0.6920	14.07	0.4909	0.6923
Uformer	10.23	0.4406	0.7226	10.22	0.4403	0.7232	10.21	0.4402	0.7237	10.20	0.4405	0.7247
U-Net	8.83	0.3635	0.7906	8.83	0.3637	0.7911	8.83	0.3640	0.7914	8.84	0.3646	0.7911
Degradation-specific restoration												
Ada-Deblur	**15.51**	**0.5394**	0.6621	**15.49**	**0.5388**	0.6625	**15.47**	**0.5383**	0.6624	**15.47**	**0.5382**	0.6613
DehazeFormer	14.09	0.4571	0.6907	14.09	0.4571	0.6910	14.09	0.4572	0.6912	14.10	0.4573	0.6913
OKNet	14.05	0.4764	0.6883	14.05	0.4763	0.6885	14.05	0.4762	0.6887	14.04	0.4760	0.6891
DnCNN	8.21	0.3355	0.7342	8.21	0.3355	0.7344	8.22	0.3354	0.7346	8.22	0.3354	0.7348
Enhancement-oriented restoration												
Retinexformer	14.73	0.5067	0.6633	14.74	0.5070	0.6634	14.73	0.5073	0.6637	14.72	0.5071	0.6644
HVI-CIDNet	14.89	0.5059	0.6807	14.87	0.5062	0.6805	14.91	0.5075	0.6801	14.87	0.5041	0.6816
IRNeXt	13.81	0.4834	0.6887	13.81	0.4834	0.6888	13.81	0.4835	0.6889	13.81	0.4836	0.6891
DEA-Net	13.70	0.4823	0.7115	14.02	0.4885	0.7115	14.08	0.4887	0.7134	13.86	0.4838	0.7171
SFHformer	8.72	0.3497	0.7893	8.72	0.3500	0.7904	8.72	0.3503	0.7917	8.72	0.3510	0.7943
DeepSN-Net	9.28	0.3380	0.7447	9.28	0.3381	0.7449	9.28	0.3382	0.7452	9.28	0.3384	0.7461
DarkIR	4.71	0.0397	0.8933	4.71	0.0398	0.8940	4.71	0.0398	0.8947	4.71	0.0398	0.8963
Proposed method												
Recall(Ours)	**18.92**	**0.5982**	**0.5968**	**18.84**	**0.5965**	**0.5986**	**18.75**	**0.5947**	**0.6004**	**18.60**	**0.5911**	**0.6039**

Table A35 (continued).

Method	(0.875 px)			(1 px)			(1.125 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.39	0.5137	**0.6424**	15.40	0.5123	**0.6421**	15.39	0.5114	**0.6413**
UniProcessor	12.72	0.4632	0.6877	N/A	N/A	N/A	12.67	0.4633	0.6891
AST	12.63	0.4673	0.7062	N/A	N/A	N/A	12.60	0.4678	0.7078
OneRestore	10.36	0.4506	0.7497	10.37	0.4510	0.7512	10.37	0.4514	0.7528
General restoration backbones									
Restormer	14.85	0.5218	0.6628	14.84	0.5218	0.6620	14.84	0.5207	0.6619
X-Restormer	14.65	0.5106	0.6729	N/A	N/A	N/A	14.42	0.5046	0.6753
NAFNet	14.03	0.4615	0.6548	14.00	0.4615	0.6551	13.98	0.4615	0.6553
Pixel2Pixel	11.23	0.3913	0.6716	11.23	0.3920	0.6728	11.22	0.3927	0.6738
ConvIR	14.07	0.4910	0.6925	14.07	0.4911	0.6930	14.07	0.4911	0.6934
Uformer	10.22	0.4411	0.7257	10.25	0.4421	0.7263	10.29	0.4431	0.7264
U-Net	8.84	0.3651	0.7907	8.85	0.3656	0.7908	8.85	0.3660	0.7912
Degradation-specific restoration									
Ada-Deblur	**15.54**	**0.5392**	0.6561	**15.61**	**0.5388**	0.6497	**15.59**	**0.5349**	0.6475
DehazeFormer	14.10	0.4575	0.6915	14.11	0.4577	0.6919	14.11	0.4578	0.6926
OKNet	14.04	0.4758	0.6893	14.03	0.4755	0.6896	14.02	0.4754	0.6899
DnCNN	8.22	0.3352	0.7352	8.22	0.3348	0.7359	8.22	0.3343	0.7365
Enhancement-oriented restoration									
Retinexformer	14.71	0.5068	0.6648	14.70	0.5062	0.6652	14.68	0.5057	0.6660
HVI-CIDNet	14.91	0.5053	0.6815	14.90	0.5029	0.6828	14.87	0.5041	0.6821
IRNeXt	13.81	0.4837	0.6893	13.81	0.4838	0.6896	13.80	0.4839	0.6900
DEA-Net	13.70	0.4799	0.7212	13.57	0.4772	0.7268	13.29	0.4694	0.7338
SFHformer	8.71	0.3517	0.7970	8.71	0.3523	0.7995	8.71	0.3528	0.8017
DeepSN-Net	9.29	0.3386	0.7473	9.29	0.3389	0.7486	9.29	0.3393	0.7499
DarkIR	4.71	0.0399	0.8980	4.71	0.0400	0.9000	4.72	0.0401	0.9023
Proposed method									
Recall(Ours)	**18.48**	**0.5882**	**0.6065**	**18.39**	**0.5857**	**0.6082**	**18.31**	**0.5837**	**0.6090**

Table A35 (continued).

Method	(1.25 px)			(1.375 px)			(1.5 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.37	0.5111	**0.6416**	15.36	0.5108	**0.6415**	**15.36**	0.5107	**0.6411**
UniProcessor	12.64	0.4633	0.6900	12.62	0.4632	0.6908	N/A	N/A	N/A
AST	12.62	0.4664	0.7073	12.65	0.4656	0.7069	N/A	N/A	N/A
OneRestore	10.37	0.4518	0.7544	10.37	0.4522	0.7559	10.37	0.4525	0.7574
General restoration backbones									
Restormer	14.84	0.5198	0.6618	14.81	0.5198	0.6622	14.83	0.5194	0.6613
X-Restormer	14.28	0.5017	0.6767	14.15	0.4991	0.6777	N/A	N/A	N/A
NAFNet	13.97	0.4614	0.6555	13.95	0.4612	0.6558	13.94	0.4610	0.6560
Pixel2Pixel	11.21	0.3929	0.6745	11.20	0.3926	0.6757	11.18	0.3926	0.6772
ConvIR	14.06	0.4911	0.6937	14.06	0.4911	0.6941	14.06	0.4912	0.6944
Uformer	10.34	0.4442	0.7262	10.40	0.4456	0.7251	10.45	0.4472	0.7242
U-Net	8.85	0.3663	0.7922	8.86	0.3666	0.7935	8.86	0.3670	0.7945
Degradation-specific restoration									
Ada-Deblur	**15.50**	**0.5301**	0.6490	**15.41**	**0.5264**	0.6503	15.33	**0.5236**	0.6521
DehazeFormer	14.10	0.4581	0.6937	14.10	0.4584	0.6942	14.10	0.4589	0.6943
OKNet	14.01	0.4751	0.6903	14.00	0.4750	0.6907	13.99	0.4749	0.6910
DnCNN	8.23	0.3336	0.7371	8.23	0.3328	0.7378	8.23	0.3320	0.7383
Enhancement-oriented restoration									
Retinexformer	14.67	0.5050	0.6665	14.67	0.5046	0.6668	14.66	0.5041	0.6670
HVI-CIDNet	14.82	0.5026	0.6831	14.76	0.5006	0.6861	14.70	0.4973	0.6857
IRNeXt	13.80	0.4840	0.6903	13.80	0.4841	0.6905	13.80	0.4841	0.6907
DEA-Net	12.84	0.4538	0.7426	12.42	0.4413	0.7491	11.96	0.4348	0.7554
SFHformer	8.71	0.3533	0.8035	8.70	0.3537	0.8051	8.70	0.3540	0.8064
DeepSN-Net	9.29	0.3399	0.7513	9.29	0.3406	0.7529	9.29	0.3414	0.7544
DarkIR	4.72	0.0402	0.9048	4.72	0.0403	0.9073	4.72	0.0404	0.9097
Proposed method									
Recall(Ours)	**18.23**	**0.5817**	**0.6104**	**18.17**	**0.5799**	**0.6120**	**18.09**	**0.5780**	**0.6140**

D.4.4 Software Transport-Spread Variation

Appendix Table A36 and Figure A49 report the Software sweep.

Larger recorded transport-spread widths lower Software PSNR from 21.352 to 17.974 dB, while RECALL leads all three metrics at the 10 recorded conditions.

The software transport-spread curves show declining reconstruction quality for a layout with many adjacent panels, and RECALL retains the strongest result at every spread width. The trajectory supports recovery of broad tool regions and page hierarchy across the recorded conditions.

The complete model supports coarse software recovery across the recorded transport-spread widths.

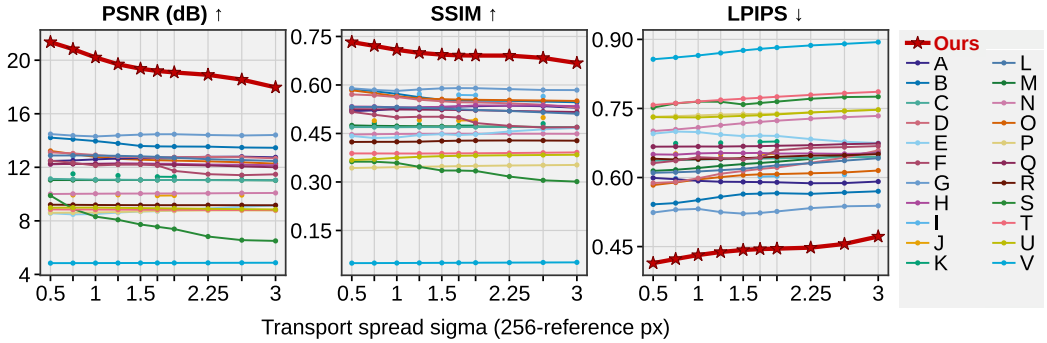


Figure A49: Software Transport-Spread Variation curves, generated from the same values as Appendix Table A36. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Pixel values use a 256-px reference short side. Method letters follow Section D.

Table A36: Full Software Transport-Spread Variation results, with 23 methods and 10 conditions.

Method	(0.5 px)			(0.75 px)			(1 px)			(1.25 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	14.22	0.5877	0.5417	14.10	0.5807	0.5445	13.96	0.5725	0.5509	13.79	0.5623	0.5581
UniProcessor	N/A	N/A	N/A	11.51	0.4816	0.6740	N/A	N/A	N/A	11.38	0.4772	0.6751
AST	N/A	N/A	N/A	9.93	0.4893	0.6514	N/A	N/A	N/A	9.94	0.4916	0.6497
OneRestore	10.01	0.4466	0.7009	10.02	0.4478	0.7043	10.03	0.4486	0.7085	10.04	0.4490	0.7134
General restoration backbones												
Restormer	N/A	N/A	N/A	12.82	0.5798	0.5982	N/A	N/A	N/A	12.66	0.5720	0.6007
X-Restormer	13.22	0.5835	0.5835	12.99	0.5746	0.5892	12.78	0.5652	0.5958	12.64	0.5585	0.6009
NAFNet	12.47	0.5190	0.5992	12.51	0.5214	0.5963	12.59	0.5264	0.5928	12.65	0.5299	0.5908
Pixel2Pixel	11.05	0.4751	0.6145	11.05	0.4736	0.6168	11.05	0.4730	0.6207	11.05	0.4725	0.6254
ConvIR	11.14	0.4697	0.6365	11.11	0.4697	0.6377	11.08	0.4694	0.6392	11.07	0.4697	0.6397
Uformer	8.57	0.4421	0.6952	8.48	0.4360	0.6998	8.51	0.4377	0.6987	8.62	0.4450	0.6933
U-Net	8.60	0.3432	0.7319	8.62	0.3444	0.7334	8.63	0.3459	0.7349	8.66	0.3470	0.7367
Degradation-specific restoration												
Ada-Deblur	13.12	0.5708	0.5882	13.04	0.5681	0.5903	12.92	0.5627	0.5983	12.80	0.5543	0.6082
DehazeFormer	12.22	0.5332	0.6502	12.27	0.5329	0.6497	12.27	0.5307	0.6525	12.30	0.5308	0.6533
OKNet	12.26	0.5249	0.6670	12.25	0.5248	0.6672	12.24	0.5241	0.6674	12.23	0.5238	0.6672
DnCNN	9.21	0.4238	0.6408	9.20	0.4241	0.6393	9.19	0.4242	0.6397	9.18	0.4247	0.6408
Enhancement-oriented restoration												
Retinexformer	**14.48**	**0.5898**	**0.5239**	**14.37**	**0.5847**	**0.5301**	**14.31**	**0.5816**	**0.5319**	**14.38**	**0.5862**	**0.5249**
HVI-CIDNet	12.50	0.5168	0.6312	12.33	0.5079	0.6363	12.13	0.4998	0.6441	12.20	0.5016	0.6422
IRNeXt	12.88	0.5321	0.6103	12.89	0.5319	0.6114	12.88	0.5310	0.6131	12.86	0.5293	0.6159
DEA-Net	9.89	0.3627	0.7519	8.89	0.3627	0.7609	8.31	0.3589	0.7648	8.08	0.3467	0.7645
SFHformer	8.85	0.3883	0.7575	8.85	0.3882	0.7613	8.84	0.3881	0.7652	8.84	0.3880	0.7684
DeepSN-Net	8.98	0.3674	0.7313	8.99	0.3703	0.7307	8.99	0.3747	0.7306	8.97	0.3778	0.7322
DarkIR	4.84	0.0490	0.8568	4.84	0.0492	0.8607	4.85	0.0494	0.8651	4.85	0.0496	0.8705
Proposed method												
Recall(Ours)	**21.35**	**0.7326**	**0.4141**	**20.83**	**0.7209**	**0.4231**	**20.21**	**0.7086**	**0.4316**	**19.70**	**0.6993**	**0.4382**

Table A36 (continued).

Method	(1.5 px)			(1.6875 px)			(1.875 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	13.59	0.5541	0.5641	13.56	0.5521	0.5651	13.55	0.5513	0.5660
UniProcessor	N/A	N/A	N/A	11.30	0.4745	0.6774	11.29	0.4744	0.6782
AST	N/A	N/A	N/A	9.88	0.4900	0.6505	9.90	0.4908	0.6508
OneRestore	10.04	0.4491	0.7179	10.04	0.4492	0.7208	10.05	0.4493	0.7234
General restoration backbones									
Restormer	N/A	N/A	N/A	12.59	0.5691	0.6019	12.59	0.5682	0.6028
X-Restormer	12.57	0.5561	0.6053	12.53	0.5550	0.6069	12.50	0.5542	0.6074
NAFNet	12.69	0.5320	0.5905	12.71	0.5331	0.5901	12.74	0.5343	0.5896
Pixel2Pixel	11.05	0.4723	0.6292	11.05	0.4720	0.6316	11.05	0.4717	0.6343
ConvIR	11.06	0.4698	0.6405	11.06	0.4699	0.6411	11.05	0.4699	0.6416
Uformer	8.70	0.4478	0.6899	8.72	0.4452	0.6909	8.78	0.4470	0.6904
U-Net	8.71	0.3481	0.7379	8.74	0.3489	0.7382	8.76	0.3497	0.7387
Degradation-specific restoration									
Ada-Deblur	12.75	0.5495	0.6142	12.73	0.5465	0.6186	12.75	0.5460	0.6217
DehazeFormer	12.29	0.5325	0.6531	12.27	0.5341	0.6534	12.26	0.5368	0.6520
OKNet	12.22	0.5232	0.6678	12.20	0.5227	0.6681	12.18	0.5219	0.6690
DnCNN	9.17	0.4266	0.6421	9.17	0.4277	0.6435	9.17	0.4280	0.6450
Enhancement-oriented restoration									
Retinexformer	**14.44**	**0.5895**	**0.5216**	**14.47**	**0.5903**	**0.5231**	**14.47**	**0.5901**	**0.5263**
HVI-CIDNet	12.21	0.5018	0.6396	12.14	0.4994	0.6431	11.73	0.4823	0.6592
IRNeXt	12.82	0.5272	0.6189	12.78	0.5250	0.6227	12.71	0.5227	0.6264
DEA-Net	7.73	0.3354	0.7586	7.56	0.3354	0.7618	7.39	0.3341	0.7648
SFHformer	8.83	0.3882	0.7711	8.83	0.3884	0.7732	8.83	0.3887	0.7753
DeepSN-Net	8.95	0.3799	0.7339	8.94	0.3809	0.7352	8.93	0.3817	0.7371
DarkIR	4.85	0.0499	0.8760	4.86	0.0501	0.8795	4.86	0.0503	0.8822

Table A36 (continued).

Method	(1.5 px)			(1.6875 px)			(1.875 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Proposed method									
Recall(Ours)	**19.36**	**0.6938**	**0.4426**	**19.20**	**0.6916**	**0.4446**	**19.09**	**0.6909**	**0.4455**

Table A36 (continued).

Method	(2.25 px)			(2.625 px)			(3 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	13.54	0.5509	0.5645	13.48	0.5486	0.5674	13.46	0.5466	0.5701
UniProcessor	N/A	N/A	N/A	11.38	0.4803	0.6753	N/A	N/A	N/A
AST	N/A	N/A	N/A	9.93	0.4991	0.6477	N/A	N/A	N/A
OneRestore	10.06	0.4493	0.7278	10.07	0.4492	0.7311	10.08	0.4490	0.7339
General restoration backbones									
Restormer	N/A	N/A	N/A	12.45	0.5647	0.6062	N/A	N/A	N/A
X-Restormer	12.45	0.5530	0.6092	12.37	0.5520	0.6110	12.28	0.5506	0.6152
NAFNet	12.79	0.5359	0.5876	12.80	0.5344	0.5879	12.75	0.5294	0.5913
Pixel2Pixel	11.05	0.4713	0.6404	11.04	0.4700	0.6478	11.03	0.4683	0.6548
ConvIR	11.04	0.4699	0.6428	11.04	0.4697	0.6439	11.03	0.4693	0.6449
Uformer	8.93	0.4562	0.6835	9.06	0.4627	0.6777	9.15	0.4671	0.6749
U-Net	8.78	0.3509	0.7414	8.78	0.3518	0.7442	8.77	0.3527	0.7474
Degradation-specific restoration									
Ada-Deblur	12.78	0.5434	0.6319	12.76	0.5389	0.6433	12.67	0.5300	0.6589
DehazeFormer	12.21	0.5362	0.6522	12.19	0.5364	0.6513	12.15	0.5346	0.6529
OKNet	12.14	0.5199	0.6702	12.07	0.5180	0.6724	12.00	0.5164	0.6739
DnCNN	9.17	0.4283	0.6476	9.17	0.4281	0.6483	9.17	0.4277	0.6508
Enhancement-oriented restoration									
Retinexformer	**14.41**	**0.5872**	**0.5335**	**14.38**	**0.5845**	**0.5375**	**14.41**	**0.5841**	**0.5386**
HVI-CIDNet	11.49	0.4735	0.6647	11.41	0.4685	0.6660	11.48	0.4694	0.6683
IRNeXt	12.61	0.5195	0.6311	12.54	0.5152	0.6367	12.47	0.5110	0.6419
DEA-Net	6.83	0.3167	0.7711	6.56	0.3051	0.7747	6.50	0.3011	0.7756
SFHformer	8.82	0.3895	0.7794	8.81	0.3905	0.7830	8.80	0.3914	0.7862
DeepSN-Net	8.90	0.3827	0.7412	8.87	0.3834	0.7446	8.85	0.3841	0.7470
DarkIR	4.86	0.0506	0.8869	4.87	0.0510	0.8903	4.87	0.0514	0.8941
Proposed method									
Recall(Ours)	**18.91**	**0.6908**	**0.4477**	**18.55**	**0.6836**	**0.4558**	**17.97**	**0.6677**	**0.4719**

D.5 Shot-Noise Variation

Shot-noise variation tests whether dispersed screen evidence remains readable across changing noise conditions. Browser, Figure, Game, and Software each span ten conditions labeled by photon budgets from 512 to 8192 photons, with lower budgets corresponding to stronger shot noise. Screen content and the remaining imaging conditions stay fixed within every sweep.

D.5.1 Browser Shot-Noise Variation

Appendix Table A37 and Figure A51 report the Browser sweep.

The Browser shot-noise sweep produces a nearly level reconstruction trajectory. RECALL leads every reported metric at every photon setting, supporting stable coarse webpage recovery across this interval.

Figure A51 shows smaller quality changes than the Browser blur and ambient-light sweeps. The nearly level trajectory preserves RECALL's ordering from the complete table and distinguishes this noise response from the larger changes under blur and reduced screen contrast.

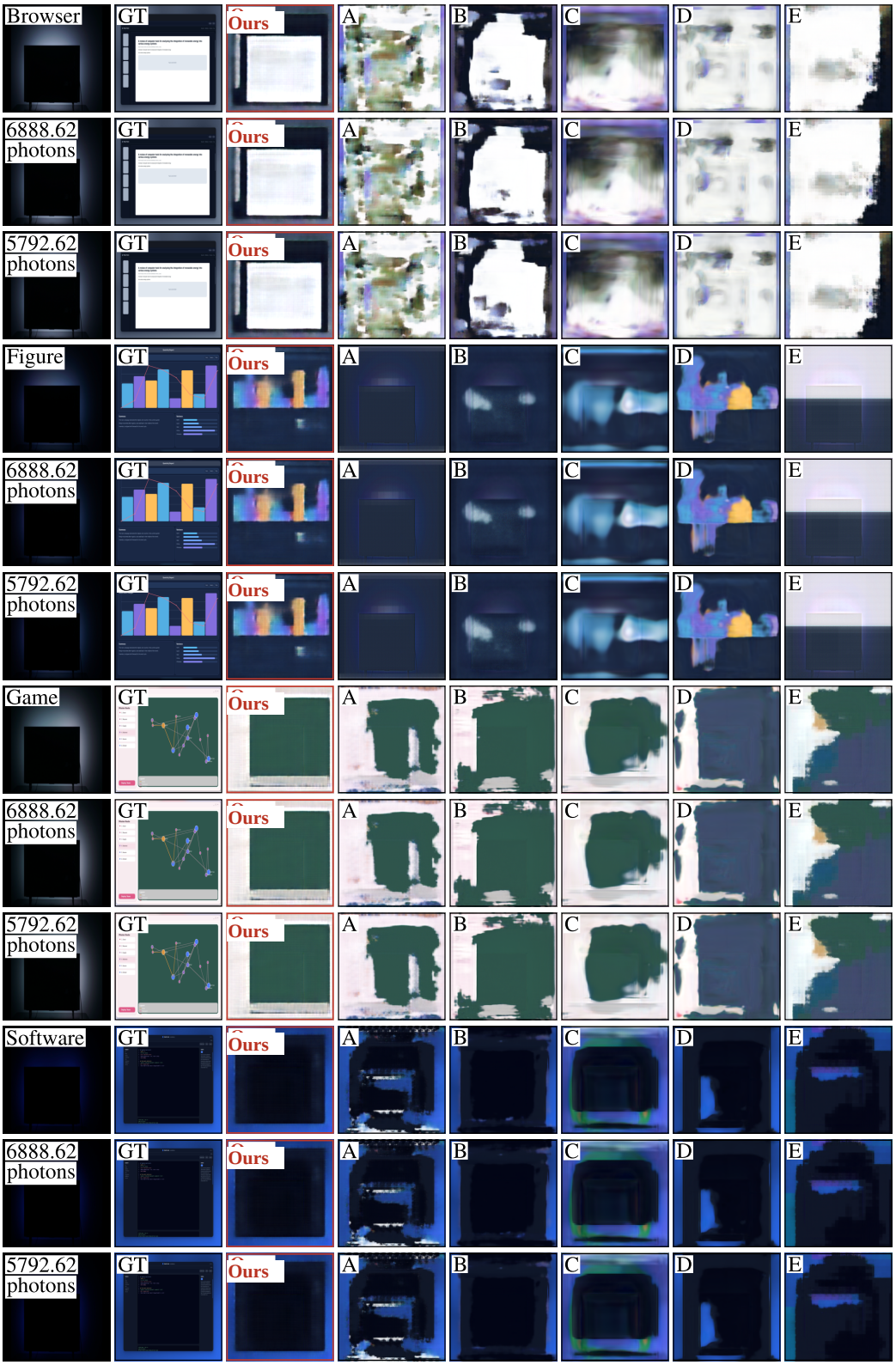


Figure A50: Shot-noise robustness on Browser, Figure, Game, and Software. Each three-row block shows the reference acquisition, 6888.62 photons, and 5792.62 photons.

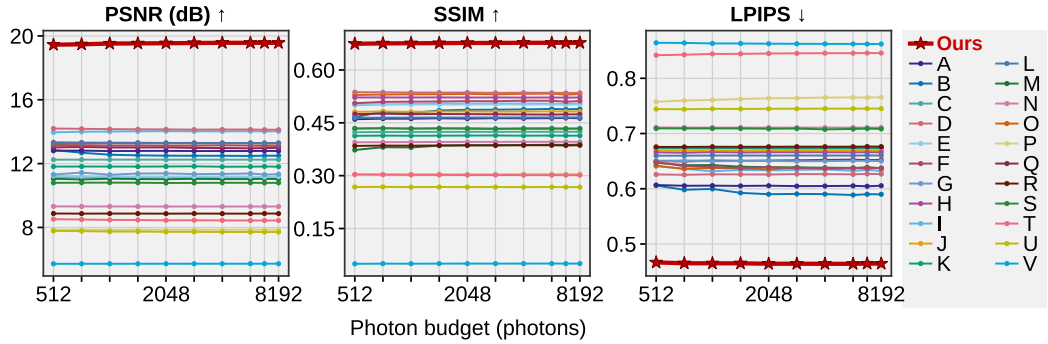


Figure A51: Browser shot-noise curves paired with Table A37, showing degradation and method ordering over the photon budgets. The $\log_2$ axis uses exact Poisson expectations per native RGB element at linear full scale 1; table headers give rounded integers. Method letters follow Section D.

Table A37: Complete Browser shot-noise sweep for 22 external methods and Recall(Ours) over ten photon-budget conditions from 512 to 8192. Headers give rounded Poisson expectations per native RGB element at linear full scale 1, in photons.

Method	512 photons			724 photons			1024 photons			1448 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	12.85	0.4661	**0.6059**	12.68	0.4816	**0.5981**	12.56	0.4774	**0.5997**	12.52	0.4851	**0.5926**
UniProcessor	11.81	0.4130	0.6735	11.82	0.4137	0.6732	11.82	0.4133	0.6734	11.81	0.4135	0.6733
AST	11.15	0.4812	0.6694	11.16	0.4820	0.6692	11.14	0.4812	0.6694	11.15	0.4819	0.6692
OneRestore	9.32	0.3946	0.7109	9.32	0.3950	0.7108	9.31	0.3954	0.7107	9.31	0.3956	0.7107
General restoration backbones												
Restormer	13.96	0.5001	0.6409	14.00	0.5025	0.6360	14.01	0.5031	0.6317	14.03	0.5045	0.6341
X-Restormer	13.22	0.5290	0.6416	13.24	0.5303	0.6360	13.28	0.5310	0.6375	13.28	0.5311	0.6370
NAFNet	12.81	0.4601	0.6068	12.81	0.4618	0.6054	12.78	0.4616	0.6057	12.79	0.4628	0.6052
Pixel2Pixel	11.05	0.3729	0.6471	11.01	0.3808	0.6427	11.05	0.3801	0.6428	11.03	0.3852	0.6400
ConvIR	12.24	0.4234	0.6752	12.25	0.4239	0.6751	12.25	0.4240	0.6756	12.25	0.4243	0.6756
Uformer	11.23	0.5023	0.6511	11.21	0.5023	0.6515	11.21	0.5022	0.6519	11.19	0.5021	0.6513
U-Net	7.86	0.3038	0.7575	7.86	0.3040	0.7598	7.85	0.3041	0.7608	7.86	0.3044	0.7625
Degradation-specific restoration												
Ada-Deblur	**14.20**	**0.5370**	0.6259	**14.18**	**0.5367**	0.6253	**14.16**	**0.5361**	0.6261	**14.15**	**0.5358**	0.6260
DehazeFormer	13.34	0.5219	0.6660	13.32	0.5219	0.6652	13.31	0.5219	0.6663	13.31	0.5220	0.6657
OKNet	13.01	0.4747	0.6500	13.04	0.4759	0.6494	13.01	0.4745	0.6507	13.01	0.4750	0.6504
DnCNN	8.87	0.3844	0.6758	8.86	0.3854	0.6757	8.87	0.3852	0.6760	8.87	0.3857	0.6760
Enhancement-oriented restoration												
Retinexformer	11.31	0.4330	0.6497	11.44	0.4350	0.6506	11.30	0.4337	0.6499	11.38	0.4348	0.6502
HVI-CIDNet	13.15	0.5057	0.6486	13.14	0.5093	0.6409	13.13	0.5101	0.6392	13.14	0.5106	0.6377
IRNeXt	13.28	0.4643	0.6600	13.28	0.4647	0.6599	13.28	0.4648	0.6602	13.28	0.4650	0.6602
DEA-Net	10.80	0.4342	0.7093	10.80	0.4343	0.7092	10.81	0.4336	0.7092	10.80	0.4338	0.7092
SFHformer	8.52	0.3034	0.8418	8.49	0.3029	0.8427	8.47	0.3023	0.8441	8.47	0.3023	0.8442
DeepSN-Net	7.78	0.2677	0.7442	7.77	0.2682	0.7440	7.74	0.2675	0.7447	7.74	0.2680	0.7445
DarkIR	5.72	0.0498	0.8643	5.72	0.0502	0.8640	5.72	0.0501	0.8632	5.73	0.0503	0.8631
Proposed method												
Recall(Ours)	**19.45**	**0.6744**	**0.4666**	**19.47**	**0.6753**	**0.4651**	**19.52**	**0.6759**	**0.4650**	**19.53**	**0.6762**	**0.4650**

Table A37 (continued).

Method	2048 photons			2896 photons			4096 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.50	0.4870	**0.5901**	12.49	0.4872	**0.5907**	12.49	0.4880	**0.5903**
UniProcessor	11.82	0.4138	0.6729	11.83	0.4141	0.6728	11.80	0.4135	0.6731
AST	11.16	0.4823	0.6692	11.14	0.4817	0.6694	11.15	0.4822	0.6694
OneRestore	9.31	0.3958	0.7108	9.31	0.3959	0.7107	9.31	0.3960	0.7108

Table A37 (continued).

Method	2048 photons			2896 photons			4096 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones									
Restormer	14.03	0.5041	0.6334	14.02	0.5043	0.6340	14.02	0.5045	0.6351
X-Restormer	13.27	0.5322	0.6351	13.27	0.5309	0.6387	13.28	0.5323	0.6361
NAFNet	12.80	0.4620	0.6056	12.79	0.4630	0.6048	12.79	0.4627	0.6050
Pixel2Pixel	11.02	0.3861	0.6391	11.04	0.3867	0.6387	11.03	0.3870	0.6382
ConvIR	12.25	0.4243	0.6759	12.25	0.4244	0.6760	12.25	0.4245	0.6761
Uformer	11.19	0.5021	0.6517	11.19	0.5022	0.6518	11.19	0.5021	0.6519
U-Net	7.86	0.3047	0.7638	7.86	0.3045	0.7643	7.86	0.3049	0.7651
Degradation-specific restoration									
Ada-Deblur	**14.14**	**0.5358**	0.6258	**14.13**	**0.5351**	0.6266	**14.14**	**0.5355**	0.6265
DehazeFormer	13.29	0.5218	0.6660	13.30	0.5219	0.6661	13.29	0.5217	0.6660
OKNet	13.02	0.4747	0.6508	12.98	0.4743	0.6514	12.98	0.4738	0.6521
DnCNN	8.86	0.3861	0.6759	8.87	0.3857	0.6761	8.86	0.3862	0.6760
Enhancement-oriented restoration									
Retinexformer	11.39	0.4351	0.6503	11.34	0.4338	0.6498	11.35	0.4349	0.6500
HVI-CIDNet	13.11	0.5114	0.6391	13.12	0.5113	0.6375	13.15	0.5128	0.6372
IRNeXt	13.29	0.4650	0.6602	13.28	0.4652	0.6602	13.29	0.4652	0.6602
DEA-Net	10.79	0.4332	0.7087	10.79	0.4327	0.7090	10.80	0.4331	0.7075
SFHformer	8.44	0.3017	0.8449	8.45	0.3019	0.8452	8.44	0.3016	0.8455
DeepSN-Net	7.72	0.2677	0.7449	7.72	0.2677	0.7449	7.72	0.2676	0.7451
DarkIR	5.73	0.0504	0.8626	5.73	0.0503	0.8625	5.73	0.0504	0.8623
Proposed method									
Recall(Ours)	**19.54**	**0.6766**	**0.4643**	**19.56**	**0.6767**	**0.4643**	**19.57**	**0.6772**	**0.4642**

Table A37 (continued).

Method	5793 photons			6889 photons			8192 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.48	0.4893	**0.5887**	12.49	0.4883	**0.5901**	12.50	0.4891	**0.5900**
UniProcessor	11.81	0.4138	0.6729	11.82	0.4136	0.6731	11.81	0.4135	0.6732
AST	11.16	0.4824	0.6693	11.14	0.4821	0.6694	11.15	0.4821	0.6694
OneRestore	9.31	0.3960	0.7108	9.31	0.3960	0.7107	9.31	0.3961	0.7108
General restoration backbones									
Restormer	14.03	0.5042	0.6324	14.02	0.5033	0.6342	14.02	0.5041	0.6321
X-Restormer	13.28	0.5329	0.6368	13.25	0.5303	0.6390	13.26	0.5317	0.6373
NAFNet	12.79	0.4631	0.6053	12.79	0.4636	0.6046	12.79	0.4630	0.6056
Pixel2Pixel	11.03	0.3878	0.6378	11.05	0.3874	0.6383	11.03	0.3882	0.6374
ConvIR	12.25	0.4245	0.6761	12.25	0.4246	0.6762	12.25	0.4246	0.6762
Uformer	11.19	0.5022	0.6519	11.16	0.5016	0.6523	11.18	0.5021	0.6520
U-Net	7.86	0.3049	0.7653	7.86	0.3049	0.7651	7.86	0.3051	0.7657
Degradation-specific restoration									
Ada-Deblur	**14.13**	**0.5352**	0.6261	**14.12**	**0.5346**	0.6269	**14.12**	**0.5351**	0.6266
DehazeFormer	13.29	0.5218	0.6659	13.29	0.5215	0.6661	13.29	0.5218	0.6660
OKNet	12.96	0.4734	0.6528	12.97	0.4739	0.6518	12.99	0.4740	0.6521
DnCNN	8.87	0.3863	0.6759	8.87	0.3857	0.6762	8.87	0.3862	0.6761
Enhancement-oriented restoration									
Retinexformer	11.38	0.4350	0.6508	11.31	0.4334	0.6503	11.33	0.4342	0.6501
HVI-CIDNet	13.13	0.5126	0.6377	13.11	0.5099	0.6368	13.11	0.5118	0.6375
IRNeXt	13.29	0.4653	0.6601	13.28	0.4652	0.6603	13.28	0.4653	0.6602
DEA-Net	10.80	0.4331	0.7083	10.79	0.4336	0.7089	10.79	0.4334	0.7084
SFHformer	8.44	0.3016	0.8455	8.43	0.3015	0.8457	8.43	0.3015	0.8457
DeepSN-Net	7.72	0.2677	0.7451	7.71	0.2675	0.7452	7.71	0.2676	0.7452
DarkIR	5.73	0.0505	0.8623	5.73	0.0504	0.8621	5.73	0.0504	0.8621
Proposed method									
Recall(Ours)	**19.57**	**0.6771**	**0.4641**	**19.57**	**0.6770**	**0.4646**	**19.57**	**0.6771**	**0.4645**

D.5.2 Figure-Content Shot-Noise Variation

Appendix Table A38 and Figure A52 report the Figure sweep.

Figure PSNR changes only from 20.220 to 20.261 dB as the photon budget increases, and the complete curve remains nearly level; RECALL leads all three metrics at the 10 recorded conditions.

The chart shot-noise curves remain nearly level across the photon budgets while RECALL leads every recorded point. The result supports stable coarse chart reconstruction across the recorded noise conditions.

Together, the three Figure-content experiments support coarse chart brightness, color, and layout recovery across wall texture, transport spread, and photon-budget conditions.

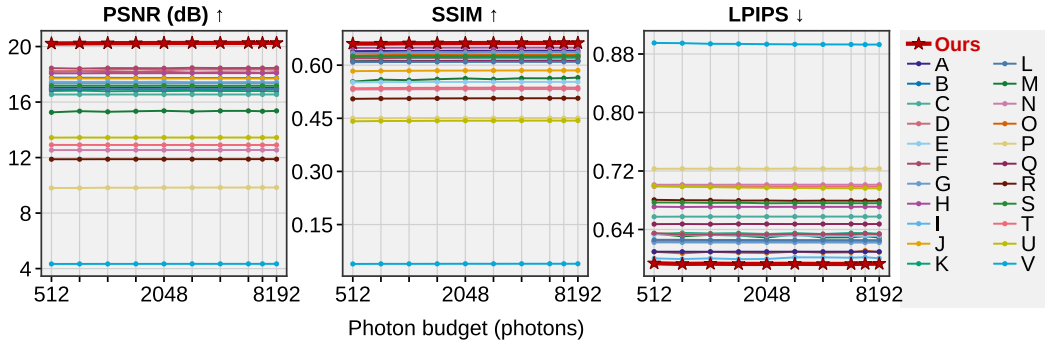


Figure A52: Figure-Content Shot-Noise Variation curves, generated from the same values as Appendix Table A38. Higher PSNR and SSIM and lower LPIPS indicate better restoration. The $\log_2$ axis uses exact Poisson expectations per native RGB element at linear full scale 1; table headers give rounded integers. Method letters follow Section D.

Table A38: Full Figure-Content Shot-Noise Variation results, with 23 methods and 10 conditions. Headers give rounded Poisson expectations per native RGB element at linear full scale 1, in photons.

Method	512 photons			724 photons			1024 photons			1448 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	17.76	0.6242	0.6240	17.75	0.6254	0.6237	17.74	0.6263	0.6243	17.74	0.6269	0.6241
UniProcessor	16.80	0.6113	0.6337	16.83	0.6122	0.6352	16.78	0.6116	0.6345	16.79	0.6118	0.6349
AST	17.70	0.5831	0.6343	17.70	0.5838	0.6338	17.70	0.5842	0.6333	17.70	0.5845	0.6330
OneRestore	12.54	0.5313	0.7012	12.54	0.5317	0.7012	12.54	0.5319	0.7012	12.54	0.5321	0.7012
General restoration backbones												
Restormer	17.46	0.6226	**0.6005**	17.45	0.6216	**0.5995**	17.46	0.6231	**0.6005**	17.45	0.6231	**0.5994**
X-Restormer	18.19	0.6278	0.6095	18.22	0.6285	0.6074	18.17	0.6290	0.6095	18.18	0.6290	0.6083
NAFNet	17.02	0.6397	0.6096	17.02	0.6401	0.6096	17.02	0.6404	0.6095	17.02	0.6406	0.6096
Pixel2Pixel	15.26	0.5535	0.6344	15.34	0.5591	0.6306	15.30	0.5577	0.6327	15.34	0.5603	0.6318
ConvIR	16.54	0.6186	0.6574	16.54	0.6190	0.6576	16.55	0.6191	0.6576	16.55	0.6193	0.6576
Uformer	17.17	0.5516	0.6333	17.17	0.5521	0.6327	17.16	0.5522	0.6322	17.16	0.5525	0.6319
U-Net	9.81	0.4502	0.7230	9.81	0.4502	0.7232	9.83	0.4505	0.7231	9.82	0.4504	0.7232
Degradation-specific restoration												
Ada-Deblur	18.23	0.6348	0.6241	18.21	0.6347	0.6239	18.32	0.6366	0.6237	18.36	0.6375	0.6229
DehazeFormer	18.07	**0.6490**	0.6711	18.07	**0.6491**	0.6708	18.08	**0.6494**	0.6710	18.08	**0.6494**	0.6709
OKNet	16.93	0.6104	0.6473	16.93	0.6111	0.6475	16.94	0.6114	0.6473	16.94	0.6117	0.6475
DnCNN	11.88	0.5049	0.6806	11.88	0.5056	0.6800	11.88	0.5058	0.6799	11.88	0.5061	0.6795
Enhancement-oriented restoration												
Retinexformer	17.35	0.6334	0.6223	17.35	0.6340	0.6223	17.35	0.6345	0.6222	17.35	0.6348	0.6222
HVI-CIDNet	**18.44**	0.6201	0.6350	**18.41**	0.6197	0.6332	**18.45**	0.6218	0.6329	**18.44**	0.6217	0.6330
IRNeXt	16.96	0.6085	0.6259	16.96	0.6088	0.6259	16.95	0.6089	0.6256	16.95	0.6091	0.6256
DEA-Net	17.18	0.6256	0.6770	17.18	0.6253	0.6769	17.18	0.6254	0.6765	17.17	0.6252	0.6766
SFHformer	12.91	0.5348	0.6989	12.91	0.5354	0.6988	12.91	0.5357	0.6987	12.91	0.5361	0.6986
DeepSN-Net	13.44	0.4415	0.6996	13.44	0.4424	0.6986	13.44	0.4425	0.6979	13.44	0.4429	0.6974
DarkIR	4.33	0.0388	0.8951	4.34	0.0391	0.8948	4.34	0.0391	0.8939	4.34	0.0392	0.8938
Proposed method												
Recall(Ours)	**20.22**	**0.6608**	**0.5938**	**20.23**	**0.6610**	**0.5930**	**20.24**	**0.6619**	**0.5933**	**20.25**	**0.6620**	**0.5929**

Table A38 (continued).

Method	2048 photons			2896 photons			4096 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	17.74	0.6272	0.6239	17.73	0.6277	0.6245	17.73	0.6277	0.6239
UniProcessor	16.79	0.6123	0.6338	16.81	0.6125	0.6349	16.80	0.6124	0.6338
AST	17.70	0.5847	0.6328	17.70	0.5849	0.6327	17.70	0.5850	0.6326
OneRestore	12.54	0.5323	0.7013	12.54	0.5324	0.7013	12.54	0.5324	0.7012
General restoration backbones									
Restormer	17.47	0.6230	**0.5997**	17.43	0.6237	**0.6019**	17.43	0.6228	**0.6019**
X-Restormer	18.18	0.6284	0.6078	18.12	0.6291	0.6096	18.15	0.6288	0.6084
NAFNet	17.02	0.6408	0.6096	17.02	0.6409	0.6096	17.02	0.6409	0.6096
Pixel2Pixel	15.37	0.5626	0.6290	15.32	0.5603	0.6331	15.36	0.5630	0.6291
ConvIR	16.55	0.6194	0.6576	16.55	0.6195	0.6576	16.55	0.6195	0.6577
Uformer	17.15	0.5525	0.6317	17.15	0.5527	0.6315	17.15	0.5527	0.6314
U-Net	9.84	0.4506	0.7230	9.84	0.4506	0.7233	9.84	0.4506	0.7232
Degradation-specific restoration									
Ada-Deblur	18.30	0.6358	0.6236	18.36	0.6378	0.6235	18.34	0.6370	0.6231
DehazeFormer	18.08	**0.6495**	0.6709	18.08	**0.6496**	0.6710	18.08	**0.6496**	0.6710
OKNet	16.94	0.6119	0.6475	16.94	0.6121	0.6474	16.94	0.6121	0.6475
DnCNN	11.88	0.5064	0.6796	11.89	0.5065	0.6793	11.89	0.5065	0.6794
Enhancement-oriented restoration									
Retinexformer	17.35	0.6349	0.6222	17.35	0.6352	0.6221	17.35	0.6351	0.6222
HVI-CIDNet	**18.44**	0.6216	0.6329	**18.47**	0.6232	0.6335	**18.45**	0.6224	0.6333
IRNeXt	16.95	0.6091	0.6255	16.95	0.6092	0.6255	16.95	0.6093	0.6254
DEA-Net	17.18	0.6253	0.6759	17.17	0.6250	0.6761	17.17	0.6247	0.6760
SFHformer	12.91	0.5363	0.6987	12.91	0.5364	0.6986	12.91	0.5365	0.6986
DeepSN-Net	13.44	0.4432	0.6970	13.44	0.4432	0.6968	13.44	0.4434	0.6965
DarkIR	4.34	0.0393	0.8934	4.34	0.0393	0.8932	4.34	0.0394	0.8931
Proposed method									
Recall(Ours)	**20.25**	**0.6623**	**0.5929**	**20.26**	**0.6625**	**0.5931**	**20.26**	**0.6626**	**0.5929**

Table A38 (continued).

Method	5793 photons			6889 photons			8192 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	17.73	0.6278	0.6238	17.73	0.6281	0.6247	17.73	0.6281	0.6242
UniProcessor	16.79	0.6129	0.6351	16.80	0.6125	0.6349	16.78	0.6123	0.6342
AST	17.70	0.5851	0.6325	17.70	0.5851	0.6324	17.70	0.5851	0.6324
OneRestore	12.54	0.5325	0.7013	12.54	0.5325	0.7012	12.54	0.5325	0.7013
General restoration backbones									
Restormer	17.44	0.6229	**0.6014**	17.43	0.6237	**0.6020**	17.43	0.6234	**0.6006**
X-Restormer	18.14	0.6285	0.6086	18.11	0.6293	0.6111	18.16	0.6294	0.6091
NAFNet	17.02	0.6410	0.6096	17.02	0.6410	0.6096	17.02	0.6410	0.6096
Pixel2Pixel	15.36	0.5628	0.6294	15.34	0.5634	0.6309	15.36	0.5648	0.6289
ConvIR	16.55	0.6196	0.6577	16.55	0.6196	0.6576	16.55	0.6196	0.6576
Uformer	17.15	0.5528	0.6313	17.15	0.5528	0.6312	17.15	0.5528	0.6313
U-Net	9.84	0.4506	0.7232	9.84	0.4507	0.7232	9.84	0.4506	0.7232
Degradation-specific restoration									
Ada-Deblur	18.34	0.6370	0.6233	18.35	0.6375	0.6240	18.33	0.6368	0.6236
DehazeFormer	18.08	**0.6496**	0.6709	18.08	**0.6497**	0.6711	18.08	**0.6496**	0.6710
OKNet	16.94	0.6122	0.6475	16.94	0.6122	0.6474	16.94	0.6123	0.6475
DnCNN	11.89	0.5066	0.6794	11.89	0.5067	0.6792	11.89	0.5066	0.6793
Enhancement-oriented restoration									
Retinexformer	17.35	0.6352	0.6221	17.35	0.6354	0.6221	17.35	0.6353	0.6221
HVI-CIDNet	**18.46**	0.6229	0.6330	**18.45**	0.6239	0.6343	**18.46**	0.6233	0.6335
IRNeXt	16.95	0.6093	0.6254	16.95	0.6093	0.6254	16.95	0.6093	0.6254
DEA-Net	17.18	0.6251	0.6760	17.18	0.6251	0.6759	17.17	0.6251	0.6760
SFHformer	12.91	0.5366	0.6986	12.91	0.5366	0.6985	12.91	0.5366	0.6987
DeepSN-Net	13.44	0.4435	0.6964	13.44	0.4434	0.6964	13.44	0.4435	0.6963
DarkIR	4.34	0.0394	0.8930	4.34	0.0393	0.8929	4.34	0.0394	0.8929

Table A38 (continued).

Method	5793 photons			6889 photons			8192 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Proposed method									
Recall(Ours)	**20.26**	**0.6626**	**0.5929**	**20.26**	**0.6628**	**0.5931**	**20.26**	**0.6627**	**0.5932**

D.5.3 Game Shot-Noise Variation

Appendix Table A39 and Figure A53 report the Game sweep.

Game PSNR changes gradually from 18.974 to 19.108 dB as the photon budget increases, and the complete curve remains nearly level; RECALL leads all three metrics at the 10 recorded conditions.

The game shot-noise curves remain nearly level across the sampled photon budgets while RECALL leads every condition. This flat trajectory shows that random local fluctuations leave the broad canvas and principal object recovery comparatively stable over the recorded range.

The complete model supports coarse game recovery through the recorded noise conditions.

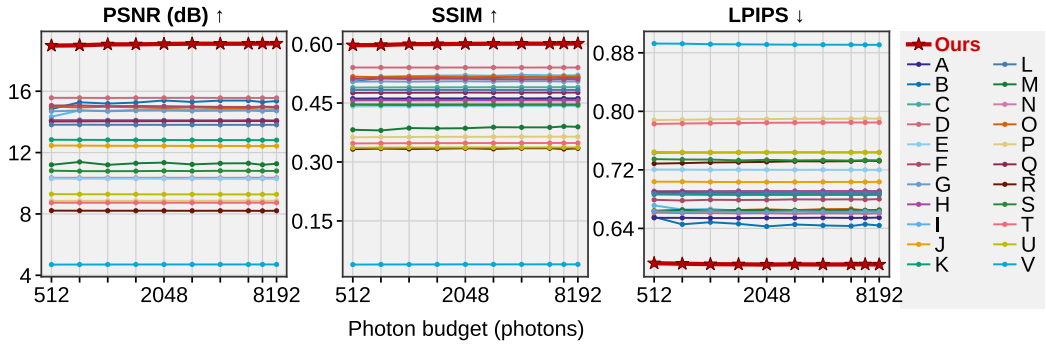


Figure A53: Game Shot-Noise Variation curves, generated from the same values as Appendix Table A39. Higher PSNR and SSIM and lower LPIPS indicate better restoration. The $\log_2$ axis uses exact Poisson expectations per native RGB element at linear full scale 1; table headers give rounded integers. Method letters follow Section D.

Table A39: Full Game Shot-Noise Variation results, with 23 methods and 10 conditions. Headers give rounded Poisson expectations per native RGB element at linear full scale 1, in photons.

Method	512 photons			724 photons			1024 photons			1448 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	14.84	0.5061	0.6556	15.28	0.5131	**0.6456**	15.19	0.5129	**0.6485**	15.26	0.5134	**0.6462**
UniProcessor	12.84	0.4611	0.6864	12.83	0.4613	0.6861	12.83	0.4613	0.6859	12.82	0.4615	0.6858
AST	12.46	0.4573	0.7038	12.45	0.4579	0.7038	12.44	0.4580	0.7035	12.44	0.4581	0.7034
OneRestore	10.36	0.4471	0.7431	10.36	0.4475	0.7435	10.36	0.4477	0.7435	10.36	0.4479	0.7437
General restoration backbones												
Restormer	14.34	0.5077	0.6714	14.75	0.5176	0.6658	14.72	0.5182	0.6665	14.78	0.5196	0.6643
X-Restormer	15.00	0.5172	0.6640	14.94	0.5158	0.6646	14.99	0.5169	0.6644	14.95	0.5169	0.6651
NAFNet	14.11	0.4608	**0.6544**	14.11	0.4610	0.6544	14.09	0.4608	0.6542	14.09	0.4611	0.6541
Pixel2Pixel	11.20	0.3819	0.6640	11.39	0.3803	0.6653	11.20	0.3863	0.6641	11.30	0.3854	0.6649
ConvIR	14.12	0.4893	0.6907	14.12	0.4896	0.6908	14.10	0.4898	0.6908	14.10	0.4898	0.6910
Uformer	10.30	0.4413	0.7205	10.30	0.4417	0.7204	10.30	0.4417	0.7201	10.30	0.4421	0.7202
U-Net	8.85	0.3627	0.7881	8.86	0.3634	0.7885	8.86	0.3634	0.7890	8.86	0.3639	0.7893
Degradation-specific restoration												
Ada-Deblur	**15.57**	**0.5404**	0.6615	**15.57**	**0.5403**	0.6609	**15.56**	**0.5402**	0.6609	**15.57**	**0.5403**	0.6605
DehazeFormer	14.08	0.4567	0.6907	14.08	0.4567	0.6909	14.07	0.4567	0.6908	14.07	0.4566	0.6910
OKNet	14.03	0.4758	0.6891	14.03	0.4761	0.6890	14.04	0.4761	0.6885	14.04	0.4763	0.6885
DnCNN	8.22	0.3325	0.7285	8.21	0.3341	0.7292	8.21	0.3331	0.7301	8.21	0.3338	0.7304

Table A39 (continued).

Method	512 photons			724 photons			1024 photons			1448 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Enhancement-oriented restoration												
Retinexformer	14.69	0.5042	0.6635	14.74	0.5049	0.6620	14.69	0.5044	0.6635	14.73	0.5049	0.6625
HVI-CIDNet	15.07	0.5120	0.6791	15.07	0.5123	0.6781	15.03	0.5114	0.6791	15.04	0.5117	0.6789
IRNeXt	13.82	0.4829	0.6879	13.82	0.4832	0.6878	13.81	0.4831	0.6882	13.81	0.4832	0.6880
DEA-Net	10.82	0.4458	0.7347	10.79	0.4452	0.7342	10.79	0.4450	0.7341	10.79	0.4451	0.7330
SFHformer	8.73	0.3472	0.7828	8.73	0.3475	0.7833	8.73	0.3478	0.7838	8.73	0.3479	0.7841
DeepSN-Net	9.29	0.3361	0.7445	9.28	0.3364	0.7442	9.28	0.3365	0.7441	9.28	0.3367	0.7439
DarkIR	4.70	0.0390	0.8926	4.70	0.0392	0.8924	4.70	0.0392	0.8917	4.70	0.0394	0.8916
Proposed method												
Recall(Ours)	**18.97**	**0.5970**	**0.5924**	**18.99**	**0.5976**	**0.5917**	**19.05**	**0.5998**	**0.5911**	**19.06**	**0.5999**	**0.5909**

Table A39 (continued).

Method	2048 photons			2896 photons			4096 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.40	0.5154	**0.6427**	15.30	0.5140	**0.6454**	15.39	0.5158	**0.6441**
UniProcessor	12.82	0.4615	0.6858	12.81	0.4616	0.6857	12.81	0.4617	0.6858
AST	12.44	0.4585	0.7033	12.43	0.4584	0.7034	12.43	0.4587	0.7035
OneRestore	10.36	0.4481	0.7438	10.36	0.4481	0.7439	10.36	0.4482	0.7439
General restoration backbones									
Restormer	14.82	0.5204	0.6636	14.78	0.5193	0.6633	14.84	0.5215	0.6622
X-Restormer	14.91	0.5157	0.6661	14.95	0.5172	0.6651	14.90	0.5159	0.6663
NAFNet	14.09	0.4611	0.6543	14.08	0.4610	0.6544	14.08	0.4608	0.6545
Pixel2Pixel	11.35	0.3859	0.6651	11.23	0.3884	0.6645	11.30	0.3881	0.6650
ConvIR	14.10	0.4900	0.6911	14.10	0.4901	0.6911	14.10	0.4901	0.6912
Uformer	10.29	0.4421	0.7202	10.30	0.4422	0.7201	10.29	0.4423	0.7202
U-Net	8.86	0.3640	0.7894	8.86	0.3640	0.7898	8.86	0.3643	0.7898
Degradation-specific restoration									
Ada-Deblur	**15.57**	**0.5403**	0.6606	**15.57**	**0.5404**	0.6602	**15.56**	**0.5402**	0.6605
DehazeFormer	14.07	0.4567	0.6911	14.07	0.4567	0.6910	14.07	0.4568	0.6911
OKNet	14.05	0.4766	0.6884	14.05	0.4764	0.6884	14.05	0.4765	0.6881
DnCNN	8.21	0.3348	0.7309	8.21	0.3334	0.7317	8.21	0.3349	0.7316
Enhancement-oriented restoration									
Retinexformer	14.74	0.5054	0.6625	14.72	0.5048	0.6633	14.73	0.5055	0.6629
HVI-CIDNet	15.02	0.5116	0.6790	15.00	0.5102	0.6797	14.98	0.5106	0.6795
IRNeXt	13.81	0.4832	0.6883	13.81	0.4831	0.6883	13.81	0.4832	0.6881
DEA-Net	10.81	0.4452	0.7337	10.80	0.4451	0.7330	10.81	0.4455	0.7332
SFHformer	8.73	0.3481	0.7844	8.73	0.3482	0.7845	8.73	0.3482	0.7847
DeepSN-Net	9.28	0.3368	0.7439	9.28	0.3368	0.7438	9.27	0.3369	0.7438
DarkIR	4.71	0.0395	0.8913	4.71	0.0394	0.8911	4.71	0.0395	0.8911
Proposed method									
Recall(Ours)	**19.08**	**0.6004**	**0.5906**	**19.10**	**0.6009**	**0.5909**	**19.09**	**0.6010**	**0.5907**

Table A39 (continued).

Method	5793 photons			6889 photons			8192 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.39	0.5152	**0.6433**	15.29	0.5139	**0.6456**	15.36	0.5143	**0.6440**
UniProcessor	12.81	0.4617	0.6858	12.81	0.4617	0.6858	12.81	0.4617	0.6858
AST	12.43	0.4586	0.7035	12.43	0.4586	0.7034	12.43	0.4587	0.7036
OneRestore	10.36	0.4483	0.7440	10.36	0.4483	0.7440	10.36	0.4483	0.7440
General restoration backbones									
Restormer	14.84	0.5206	0.6619	14.79	0.5200	0.6632	14.80	0.5209	0.6617
X-Restormer	14.89	0.5157	0.6666	14.96	0.5176	0.6649	14.92	0.5167	0.6655
NAFNet	14.08	0.4611	0.6544	14.08	0.4611	0.6544	14.08	0.4611	0.6548
Pixel2Pixel	11.30	0.3880	0.6651	11.20	0.3905	0.6646	11.27	0.3893	0.6647
ConvIR	14.10	0.4902	0.6911	14.10	0.4902	0.6911	14.09	0.4902	0.6912
Uformer	10.29	0.4423	0.7201	10.29	0.4423	0.7200	10.29	0.4423	0.7200
U-Net	8.86	0.3643	0.7899	8.86	0.3642	0.7902	8.86	0.3643	0.7899

Table A39 (continued).

Method	5793 photons			6889 photons			8192 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Degradation-specific restoration									
Ada-Deblur	**15.56**	**0.5403**	0.6603	**15.56**	**0.5403**	0.6600	**15.56**	**0.5402**	0.6606
DehazeFormer	14.07	0.4567	0.6911	14.07	0.4566	0.6912	14.07	0.4567	0.6910
OKNet	14.05	0.4765	0.6882	14.05	0.4765	0.6881	14.05	0.4765	0.6883
DnCNN	8.21	0.3349	0.7318	8.20	0.3330	0.7326	8.21	0.3346	0.7321
Enhancement-oriented restoration									
Retinexformer	14.74	0.5056	0.6626	14.70	0.5045	0.6632	14.72	0.5052	0.6630
HVI-CIDNet	14.97	0.5104	0.6797	15.00	0.5104	0.6794	14.97	0.5104	0.6801
IRNeXt	13.81	0.4833	0.6881	13.81	0.4832	0.6881	13.81	0.4833	0.6881
DEA-Net	10.81	0.4455	0.7327	10.80	0.4454	0.7331	10.80	0.4452	0.7331
SFHformer	8.73	0.3483	0.7848	8.73	0.3483	0.7847	8.73	0.3483	0.7848
DeepSN-Net	9.27	0.3369	0.7438	9.28	0.3369	0.7437	9.27	0.3369	0.7437
DarkIR	4.71	0.0396	0.8910	4.71	0.0395	0.8908	4.71	0.0395	0.8909
Proposed method									
Recall(Ours)	**19.10**	**0.6009**	**0.5908**	**19.11**	**0.6013**	**0.5909**	**19.11**	**0.6012**	**0.5906**

D.5.4 Software Shot-Noise Variation

Appendix Table A40 and Figure A54 report the Software sweep.

Software PSNR changes only from 21.202 to 21.337 dB as the photon budget increases, and the complete curve remains nearly level; RECALL leads all three metrics at the 10 recorded conditions.

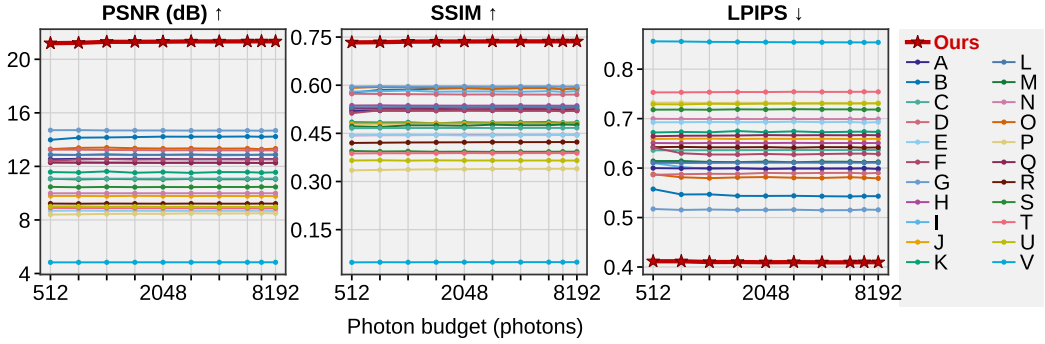


Figure A54: Software Shot-Noise Variation curves, generated from the same values as Appendix Table A40. Higher PSNR and SSIM and lower LPIPS indicate better restoration. The $\log_2$ axis uses exact Poisson expectations per native RGB element at linear full scale 1; table headers give rounded integers. Method letters follow Section D.

Table A40: Full Software Shot-Noise Variation results, with 23 methods and 10 conditions. Headers give rounded Poisson expectations per native RGB element at linear full scale 1, in photons.

Method	512 photons			724 photons			1024 photons			1448 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	13.98	0.5765	0.5576	14.15	0.5856	0.5467	14.16	0.5866	0.5470	14.19	0.5894	0.5438
UniProcessor	11.58	0.4851	0.6719	11.54	0.4839	0.6731	11.63	0.4844	0.6724	11.53	0.4813	0.6748
AST	9.79	0.4806	0.6587	9.79	0.4804	0.6594	9.78	0.4810	0.6596	9.80	0.4815	0.6587
OneRestore	9.99	0.4437	0.6996	9.99	0.4442	0.6993	9.99	0.4445	0.6992	9.99	0.4448	0.6992
General restoration backbones												
Restormer	12.90	0.5801	0.6102	12.84	0.5811	0.6022	12.93	0.5833	0.5981	12.84	0.5797	0.6002
X-Restormer	13.29	0.5917	0.5876	13.38	0.5943	0.5814	13.40	0.5939	0.5796	13.36	0.5918	0.5811
NAFNet	12.54	0.5199	0.5999	12.56	0.5207	0.5993	12.56	0.5206	0.5996	12.56	0.5211	0.5994
Pixel2Pixel	11.07	0.4721	0.6142	11.03	0.4701	0.6143	11.07	0.4749	0.6125	11.04	0.4750	0.6121
ConvIR	11.08	0.4660	0.6359	11.08	0.4664	0.6360	11.08	0.4665	0.6362	11.08	0.4667	0.6362
Uformer	8.68	0.4440	0.6925	8.70	0.4451	0.6927	8.68	0.4443	0.6931	8.68	0.4449	0.6928
U-Net	8.40	0.3348	0.7322	8.42	0.3361	0.7324	8.45	0.3372	0.7317	8.46	0.3379	0.7321

Table A40 (continued).

Method	512 photons			724 photons			1024 photons			1448 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Degradation-specific restoration												
Ada-Deblur	13.25	0.5733	0.5864	13.24	0.5727	0.5876	13.23	0.5721	0.5884	13.22	0.5716	0.5883
DehazeFormer	12.30	0.5369	0.6507	12.29	0.5373	0.6503	12.28	0.5367	0.6507	12.27	0.5365	0.6508
OKNet	12.29	0.5272	0.6643	12.28	0.5267	0.6654	12.28	0.5260	0.6656	12.28	0.5261	0.6659
DnCNN	9.22	0.4201	0.6424	9.21	0.4209	0.6428	9.22	0.4216	0.6420	9.22	0.4220	0.6421
Enhancement-oriented restoration												
Retinexformer	**14.70**	**0.5952**	**0.5173**	**14.71**	**0.5966**	**0.5154**	**14.69**	**0.5959**	**0.5163**	**14.68**	**0.5960**	**0.5155**
HVI-CIDNet	12.42	0.5128	0.6418	12.51	0.5218	0.6300	12.55	0.5222	0.6275	12.51	0.5202	0.6274
IRNeXt	12.86	0.5313	0.6108	12.87	0.5313	0.6104	12.87	0.5317	0.6106	12.87	0.5315	0.6108
DEA-Net	10.47	0.3951	0.7181	10.44	0.3935	0.7183	10.47	0.3942	0.7180	10.45	0.3927	0.7188
SFHformer	8.90	0.3875	0.7530	8.89	0.3879	0.7531	8.88	0.3880	0.7535	8.87	0.3882	0.7538
DeepSN-Net	9.01	0.3655	0.7290	9.01	0.3662	0.7288	8.99	0.3651	0.7299	9.00	0.3660	0.7296
DarkIR	4.83	0.0481	0.8562	4.83	0.0486	0.8559	4.84	0.0484	0.8551	4.84	0.0486	0.8550
Proposed method												
Recall(Ours)	**21.20**	**0.7334**	**0.4116**	**21.23**	**0.7340**	**0.4116**	**21.30**	**0.7356**	**0.4100**	**21.30**	**0.7361**	**0.4102**

Table A40 (continued).

Method	2048 photons			2896 photons			4096 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.22	0.5906	0.5437	14.22	0.5890	0.5440	14.22	0.5906	0.5431
UniProcessor	11.57	0.4845	0.6726	11.52	0.4835	0.6742	11.58	0.4845	0.6726
AST	9.79	0.4809	0.6594	9.79	0.4813	0.6589	9.79	0.4813	0.6592
OneRestore	9.99	0.4450	0.6991	9.99	0.4451	0.6990	9.99	0.4452	0.6990
General restoration backbones									
Restormer	12.86	0.5806	0.5990	12.90	0.5807	0.5991	12.83	0.5796	0.5993
X-Restormer	13.34	0.5913	0.5819	13.34	0.5899	0.5805	13.33	0.5911	0.5801
NAFNet	12.56	0.5211	0.5985	12.54	0.5209	0.5992	12.54	0.5209	0.5991
Pixel2Pixel	11.03	0.4736	0.6132	11.06	0.4770	0.6118	11.04	0.4753	0.6130
ConvIR	11.08	0.4667	0.6364	11.08	0.4668	0.6364	11.08	0.4669	0.6365
Uformer	8.68	0.4437	0.6929	8.67	0.4439	0.6937	8.68	0.4444	0.6928
U-Net	8.46	0.3384	0.7319	8.49	0.3392	0.7317	8.48	0.3394	0.7318
Degradation-specific restoration									
Ada-Deblur	13.21	0.5710	0.5902	13.21	0.5712	0.5896	13.20	0.5709	0.5901
DehazeFormer	12.26	0.5364	0.6506	12.27	0.5364	0.6510	12.27	0.5365	0.6506
OKNet	12.27	0.5254	0.6666	12.28	0.5256	0.6663	12.28	0.5260	0.6665
DnCNN	9.21	0.4222	0.6424	9.22	0.4227	0.6414	9.22	0.4227	0.6423
Enhancement-oriented restoration									
Retinexformer	**14.68**	**0.5965**	**0.5155**	**14.67**	**0.5958**	**0.5159**	**14.68**	**0.5963**	**0.5148**
HVI-CIDNet	12.52	0.5214	0.6286	12.53	0.5212	0.6274	12.53	0.5206	0.6284
IRNeXt	12.87	0.5314	0.6110	12.87	0.5316	0.6110	12.87	0.5316	0.6109
DEA-Net	10.46	0.3931	0.7185	10.45	0.3923	0.7191	10.46	0.3927	0.7187
SFHformer	8.87	0.3885	0.7537	8.87	0.3883	0.7542	8.87	0.3884	0.7540
DeepSN-Net	8.98	0.3655	0.7301	8.99	0.3655	0.7303	8.98	0.3654	0.7305
DarkIR	4.84	0.0488	0.8546	4.84	0.0486	0.8544	4.84	0.0488	0.8543
Proposed method									
Recall(Ours)	**21.32**	**0.7361**	**0.4096**	**21.33**	**0.7365**	**0.4099**	**21.33**	**0.7365**	**0.4094**

Table A40 (continued).

Method	5793 photons			6889 photons			8192 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.23	0.5908	0.5427	14.21	0.5887	0.5432	14.23	0.5906	0.5432
UniProcessor	11.57	0.4854	0.6734	11.53	0.4834	0.6737	11.56	0.4842	0.6731
AST	9.78	0.4812	0.6589	9.79	0.4812	0.6590	9.78	0.4807	0.6593
OneRestore	9.99	0.4453	0.6990	9.99	0.4453	0.6990	9.99	0.4453	0.6990

Table A40 (continued).

Method	5793 photons			6889 photons			8192 photons		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones									
Restormer	12.84	0.5816	0.5989	12.87	0.5792	0.5999	12.90	0.5817	0.5975
X-Restormer	13.34	0.5910	0.5815	13.28	0.5876	0.5805	13.33	0.5903	0.5792
NAFNet	12.55	0.5211	0.5993	12.55	0.5206	0.5994	12.55	0.5210	0.5986
Pixel2Pixel	11.04	0.4755	0.6128	11.06	0.4775	0.6120	11.04	0.4763	0.6125
ConvIR	11.08	0.4669	0.6365	11.08	0.4669	0.6365	11.08	0.4670	0.6365
Uformer	8.68	0.4446	0.6932	8.69	0.4451	0.6921	8.67	0.4444	0.6929
U-Net	8.49	0.3395	0.7319	8.51	0.3399	0.7314	8.49	0.3398	0.7318
Degradation-specific restoration									
Ada-Deblur	13.20	0.5708	0.5903	13.19	0.5708	0.5894	13.20	0.5708	0.5901
DehazeFormer	12.26	0.5363	0.6506	12.26	0.5363	0.6507	12.26	0.5362	0.6506
OKNet	12.27	0.5256	0.6663	12.26	0.5252	0.6667	12.27	0.5257	0.6664
DnCNN	9.21	0.4228	0.6422	9.22	0.4230	0.6413	9.22	0.4229	0.6418
Enhancement-oriented restoration									
Retinexformer	**14.68**	**0.5965**	**0.5150**	**14.67**	**0.5957**	**0.5161**	**14.68**	**0.5961**	**0.5156**
HVI-CIDNet	12.51	0.5203	0.6292	12.52	0.5189	0.6292	12.52	0.5203	0.6285
IRNeXt	12.87	0.5317	0.6110	12.87	0.5317	0.6108	12.87	0.5318	0.6108
DEA-Net	10.46	0.3927	0.7187	10.47	0.3930	0.7183	10.47	0.3929	0.7185
SFHformer	8.86	0.3885	0.7541	8.86	0.3883	0.7543	8.86	0.3884	0.7542
DeepSN-Net	8.98	0.3655	0.7304	8.98	0.3652	0.7306	8.98	0.3653	0.7306
DarkIR	4.84	0.0489	0.8542	4.84	0.0487	0.8541	4.84	0.0488	0.8541
Proposed method									
Recall(Ours)	**21.34**	**0.7366**	**0.4094**	**21.34**	**0.7367**	**0.4097**	**21.34**	**0.7366**	**0.4096**

The software shot-noise curves remain nearly level while RECALL leads every photon budget, showing stable recovery of the panel hierarchy across the recorded random local fluctuations. This stability is especially valuable for dense interfaces, where genuine tool boundaries must remain coherent across the full layout.

The trajectory extends the complete model's coarse software reconstruction across the recorded noise range.

D.6 Focus-Blur Variation

Focus-blur variation tests coarse recovery as edges and fine lines soften. Browser, Game, and Software each span ten conditions labeled by Gaussian sigma from 0.25 to 1.5 px at the 256-px reference scale, with content and the remaining imaging conditions fixed. The common range directly compares the persistence of webpage blocks, game objects, and software-panel hierarchy.

D.6.1 Browser Focus-Blur Variation

Appendix Table A41 and Figure A55 report the Browser sweep.

Increasing focus blur lowers Browser PSNR from 19.506 to 18.317 dB, while RECALL leads all three metrics at the 10 recorded conditions.

Increasing focus blur progressively attenuates high-frequency screen evidence while preserving the broader webpage arrangement. RECALL remains strongest across the blur range, indicating that regional identity continues to guide restoration as fine boundaries soften.

CASR combines smooth page layout and residual boundary evidence under one content anchor. RAL allocates local and context-augmented capabilities by restoration utility. The continuous lead across blur levels supports recovery of webpage layout and principal contours.

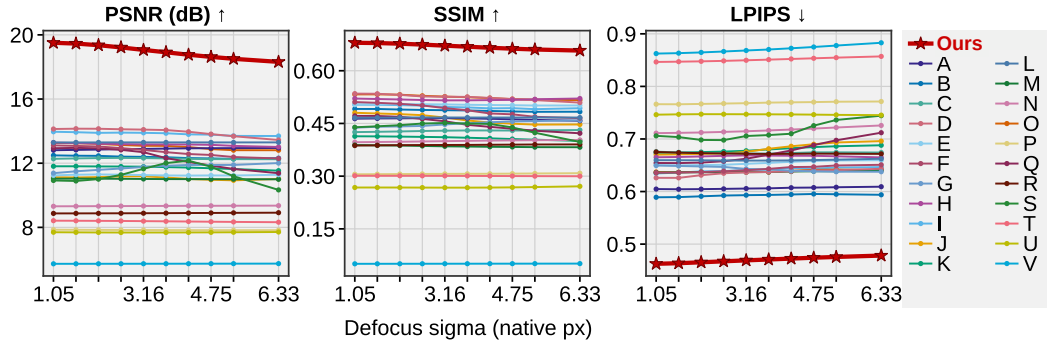


Figure A55: Browser Focus-Blur Variation curves, generated from the same values as Appendix Table A41. Higher PSNR and SSIM and lower LPIPS indicate better restoration. The plotted native-pixel sigma equals the tabulated 256-reference-pixel sigma multiplied by $1080/256$. Method letters follow Section D.

Table A41: Full Browser Focus-Blur Variation results, with 23 methods and 10 conditions. Headers give Gaussian σ in pixels at the 256-px reference scale; native-pixel σ equals the table value multiplied by $1080/256$.

Method	(0.25 px)			(0.375 px)			(0.5 px)			(0.625 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	12.49	0.4913	**0.5891**	12.47	0.4912	**0.5894**	12.46	0.4896	**0.5909**	12.41	0.4884	**0.5924**
UniProcessor	11.81	0.4135	0.6735	11.81	0.4132	0.6741	11.80	0.4126	0.6751	11.79	0.4118	0.6760
AST	11.13	0.4804	0.6702	11.11	0.4783	0.6708	11.14	0.4765	0.6717	11.18	0.4735	0.6723
OneRestore	9.31	0.3966	0.7111	9.32	0.3972	0.7116	9.32	0.3979	0.7123	9.33	0.3987	0.7134
General restoration backbones												
Restormer	13.96	0.5036	0.6344	13.93	0.5032	0.6360	13.89	0.5022	0.6384	13.91	0.5008	0.6389
X-Restormer	13.26	0.5327	0.6372	13.25	0.5328	0.6366	13.21	**0.5318**	0.6373	13.13	**0.5287**	0.6372
NAFNet	12.81	0.4635	0.6047	12.83	0.4642	0.6044	12.85	0.4645	0.6046	12.88	0.4651	0.6051
Pixel2Pixel	11.03	0.3886	0.6361	11.04	0.3877	0.6365	11.03	0.3872	0.6367	11.03	0.3860	0.6369
ConvIR	12.27	0.4253	0.6758	12.30	0.4262	0.6746	12.32	0.4273	0.6734	12.33	0.4285	0.6726
Uformer	11.24	0.5036	0.6503	11.28	0.5044	0.6498	11.30	0.5049	0.6503	11.29	0.5047	0.6509
U-Net	7.86	0.3054	0.7661	7.85	0.3056	0.7660	7.84	0.3060	0.7667	7.84	0.3063	0.7674
Degradation-specific restoration												
Ada-Deblur	**14.13**	**0.5349**	0.6261	**14.15**	**0.5345**	0.6260	**14.15**	0.5313	0.6311	**14.12**	0.5269	0.6348
DehazeFormer	13.28	0.5208	0.6652	13.25	0.5195	0.6657	13.21	0.5182	0.6668	13.19	0.5167	0.6679
OKNet	12.93	0.4716	0.6543	12.95	0.4712	0.6541	12.93	0.4689	0.6551	12.83	0.4629	0.6577
DnCNN	8.87	0.3870	0.6753	8.87	0.3877	0.6740	8.88	0.3882	0.6730	8.88	0.3886	0.6725
Enhancement-oriented restoration												
Retinexformer	11.38	0.4379	0.6495	11.49	0.4406	0.6486	11.59	0.4415	0.6478	11.67	0.4430	0.6468
HVI-CIDNet	13.11	0.5108	0.6358	13.08	0.5087	0.6363	13.04	0.5059	0.6369	12.94	0.5012	0.6386
IRNeXt	13.29	0.4660	0.6596	13.29	0.4665	0.6596	13.30	0.4668	0.6594	13.30	0.4670	0.6591
DEA-Net	10.92	0.4391	0.7060	10.89	0.4419	0.7036	11.01	0.4450	0.6981	11.27	0.4498	0.6978
SFHformer	8.42	0.3012	0.8465	8.41	0.3011	0.8470	8.41	0.3010	0.8477	8.40	0.3010	0.8486
DeepSN-Net	7.70	0.2677	0.7462	7.69	0.2677	0.7469	7.68	0.2676	0.7472	7.68	0.2675	0.7471
DarkIR	5.73	0.0505	0.8624	5.73	0.0506	0.8633	5.73	0.0507	0.8646	5.73	0.0507	0.8664
Proposed method												
Recall(Ours)	**19.51**	**0.6796**	**0.4625**	**19.46**	**0.6788**	**0.4637**	**19.36**	**0.6770**	**0.4654**	**19.22**	**0.6744**	**0.4673**

Table A41 (continued).

Method	(0.75 px)			(0.875 px)			(1 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.40	0.4877	**0.5931**	12.37	0.4870	**0.5936**	12.32	0.4855	**0.5944**
UniProcessor	11.78	0.4109	0.6776	11.76	0.4093	0.6801	11.73	0.4076	0.6824
AST	11.18	0.4667	0.6755	11.11	0.4585	0.6813	11.02	0.4526	0.6861
OneRestore	9.33	0.3996	0.7147	9.34	0.4004	0.7162	9.34	0.4012	0.7179

Table A41 (continued).

Method	(0.75 px)			(0.875 px)			(1 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones									
Restormer	13.89	0.4970	0.6412	13.87	0.4956	0.6416	13.80	0.4930	0.6448
X-Restormer	13.09	**0.5264**	0.6372	13.08	0.5247	0.6371	13.00	0.5221	0.6395
NAFNet	12.89	0.4651	0.6057	12.91	0.4645	0.6061	12.93	0.4633	0.6073
Pixel2Pixel	11.02	0.3849	0.6369	11.01	0.3843	0.6371	11.01	0.3836	0.6381
ConvIR	12.32	0.4294	0.6723	12.30	0.4301	0.6723	12.27	0.4300	0.6733
Uformer	11.26	0.5041	0.6528	11.24	0.5031	0.6545	11.23	0.5024	0.6565
U-Net	7.83	0.3065	0.7681	7.83	0.3067	0.7692	7.83	0.3068	0.7697
Degradation-specific restoration									
Ada-Deblur	**14.09**	0.5260	0.6365	**14.07**	**0.5256**	0.6372	**13.96**	**0.5226**	0.6384
DehazeFormer	13.17	0.5157	0.6687	13.17	0.5158	0.6684	13.16	0.5165	0.6681
OKNet	12.69	0.4562	0.6623	12.32	0.4460	0.6702	12.08	0.4403	0.6782
DnCNN	8.88	0.3887	0.6718	8.89	0.3889	0.6715	8.89	0.3894	0.6717
Enhancement-oriented restoration									
Retinexformer	11.76	0.4471	0.6430	11.84	0.4506	0.6421	11.89	0.4535	0.6396
HVI-CIDNet	12.83	0.4938	0.6404	12.69	0.4874	0.6432	12.57	0.4784	0.6466
IRNeXt	13.30	0.4670	0.6589	13.30	0.4669	0.6590	13.30	0.4669	0.6592
DEA-Net	11.65	0.4513	0.7056	12.01	0.4498	0.7074	12.16	0.4486	0.7100
SFHformer	8.39	0.3008	0.8497	8.38	0.3007	0.8509	8.37	0.3005	0.8522
DeepSN-Net	7.68	0.2673	0.7470	7.68	0.2673	0.7469	7.68	0.2676	0.7467
DarkIR	5.73	0.0508	0.8683	5.73	0.0508	0.8702	5.74	0.0509	0.8725
Proposed method									
Recall(Ours)	**19.06**	**0.6714**	**0.4691**	**18.91**	**0.6684**	**0.4708**	**18.76**	**0.6654**	**0.4724**

Table A41 (continued).

Method	(1.125 px)			(1.25 px)			(1.5 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.30	0.4842	**0.5954**	12.27	0.4831	**0.5949**	12.31	0.4834	**0.5938**
UniProcessor	11.69	0.4057	0.6846	11.64	0.4038	0.6861	11.54	0.4004	0.6880
AST	10.97	0.4492	0.6900	10.93	0.4468	0.6933	11.02	0.4471	0.6959
OneRestore	9.35	0.4018	0.7198	9.35	0.4023	0.7218	9.35	0.4030	0.7257
General restoration backbones									
Restormer	13.78	0.4936	0.6435	**13.70**	0.4906	0.6456	**13.70**	0.4934	0.6465
X-Restormer	12.88	0.5192	0.6413	12.81	0.5176	0.6417	12.81	0.5165	0.6408
NAFNet	12.94	0.4618	0.6076	12.94	0.4602	0.6082	12.95	0.4576	0.6092
Pixel2Pixel	11.01	0.3831	0.6387	11.00	0.3826	0.6386	11.00	0.3823	0.6406
ConvIR	12.25	0.4298	0.6746	12.25	0.4302	0.6746	12.25	0.4313	0.6743
Uformer	11.24	0.5019	0.6581	11.23	0.5010	0.6592	11.28	0.5012	0.6596
U-Net	7.83	0.3072	0.7702	7.82	0.3076	0.7709	7.82	0.3084	0.7713
Degradation-specific restoration									
Ada-Deblur	**13.81**	**0.5196**	0.6402	13.68	0.5165	0.6406	13.45	0.5093	0.6433
DehazeFormer	13.15	0.5170	0.6680	13.08	**0.5189**	0.6671	13.01	**0.5210**	0.6650
OKNet	11.85	0.4349	0.6883	11.64	0.4293	0.6974	11.38	0.4220	0.7119
DnCNN	8.90	0.3897	0.6721	8.91	0.3901	0.6720	8.92	0.3903	0.6716
Enhancement-oriented restoration									
Retinexformer	11.89	0.4555	0.6384	11.89	0.4567	0.6377	12.01	0.4587	0.6377
HVI-CIDNet	12.51	0.4759	0.6470	12.38	0.4689	0.6496	12.30	0.4650	0.6509
IRNeXt	13.30	0.4669	0.6599	13.30	0.4669	0.6606	13.30	0.4668	0.6624
DEA-Net	11.78	0.4386	0.7253	11.19	0.4236	0.7361	10.34	0.3974	0.7443
SFHformer	8.35	0.3003	0.8535	8.34	0.3001	0.8547	8.32	0.2997	0.8571
DeepSN-Net	7.69	0.2681	0.7463	7.70	0.2689	0.7459	7.71	0.2711	0.7453
DarkIR	5.74	0.0510	0.8750	5.74	0.0510	0.8777	5.74	0.0512	0.8830
Proposed method									
Recall(Ours)	**18.63**	**0.6628**	**0.4741**	**18.51**	**0.6605**	**0.4756**	**18.32**	**0.6574**	**0.4782**

D.6.2 Game Focus-Blur Variation

Appendix Table A42 and Figure A56 report the Game sweep.

Game PSNR decreases from 19.148 to 18.094 dB as focus blur increases, while RECALL leads all three metrics at the 10 recorded conditions.

Increasing focus blur attenuates object-edge and fine-line cues while the canvas remains a broad cue, and RECALL preserves the strongest trajectory across the range. The result shows that principal object contours can be recovered from the remaining layout evidence as high frequencies soften.

The complete model sustains coarse object-layout recovery through increasing blur.

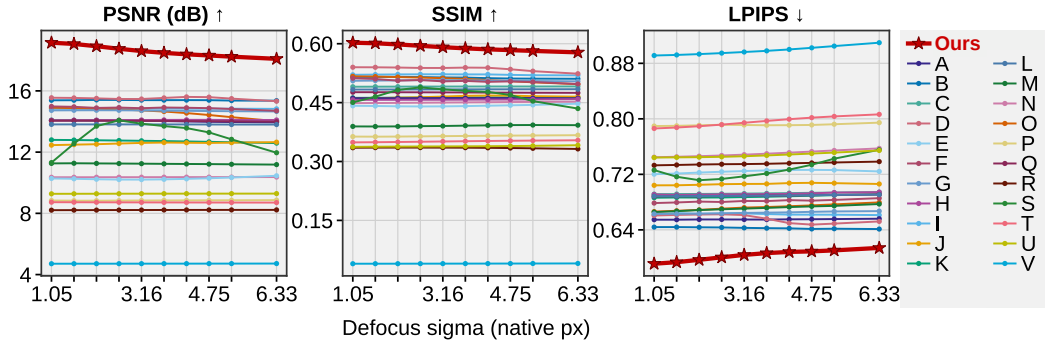


Figure A56: Game Focus-Blur Variation curves, generated from the same values as Appendix Table A42. Higher PSNR and SSIM and lower LPIPS indicate better restoration. The plotted native-pixel sigma equals the tabulated 256-reference-pixel sigma multiplied by $1080/256$. Method letters follow Section D.

Table A42: Full Game Focus-Blur Variation results, with 23 methods and 10 conditions. Headers give Gaussian σ in pixels at the 256-px reference scale; native-pixel σ equals the table value multiplied by $1080/256$.

Method	(0.25 px)			(0.375 px)			(0.5 px)			(0.625 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	15.39	0.5156	**0.6440**	15.39	0.5155	**0.6440**	15.41	0.5157	**0.6437**	15.41	0.5150	**0.6434**
UniProcessor	12.80	0.4621	0.6863	12.79	0.4623	0.6866	12.77	0.4625	0.6866	12.76	0.4628	0.6867
AST	12.46	0.4600	0.7042	12.49	0.4613	0.7042	12.52	0.4626	0.7049	12.56	0.4637	0.7058
OneRestore	10.36	0.4486	0.7447	10.36	0.4489	0.7453	10.36	0.4493	0.7461	10.36	0.4497	0.7472
General restoration backbones												
Restormer	14.84	0.5209	0.6615	14.83	0.5214	0.6640	14.84	0.5219	0.6631	14.84	0.5221	0.6636
X-Restormer	14.90	0.5169	0.6663	14.87	0.5163	0.6675	14.84	0.5151	0.6688	14.79	0.5138	0.6705
NAFNet	14.08	0.4612	0.6546	14.07	0.4614	0.6546	14.07	0.4614	0.6550	14.06	0.4615	0.6550
Pixel2Pixel	11.26	0.3894	0.6655	11.27	0.3892	0.6669	11.26	0.3894	0.6685	11.25	0.3901	0.6696
ConvIR	14.09	0.4905	0.6915	14.08	0.4906	0.6916	14.08	0.4907	0.6917	14.07	0.4909	0.6920
Uformer	10.28	0.4419	0.7202	10.26	0.4414	0.7212	10.23	0.4406	0.7226	10.21	0.4402	0.7237
U-Net	8.84	0.3635	0.7896	8.83	0.3632	0.7899	8.83	0.3635	0.7907	8.83	0.3640	0.7914
Degradation-specific restoration												
Ada-Deblur	**15.55**	**0.5401**	0.6607	**15.54**	**0.5399**	0.6615	**15.51**	**0.5394**	0.6621	**15.47**	**0.5383**	0.6624
DehazeFormer	14.08	0.4570	0.6909	14.09	0.4571	0.6903	14.09	0.4571	0.6907	14.09	0.4572	0.6912
OKNet	14.05	0.4765	0.6883	14.05	0.4765	0.6884	14.05	0.4764	0.6883	14.05	0.4762	0.6887
DnCNN	8.21	0.3351	0.7330	8.21	0.3353	0.7335	8.21	0.3355	0.7342	8.22	0.3354	0.7346
Enhancement-oriented restoration												
Retinexformer	14.73	0.5056	0.6630	14.73	0.5060	0.6631	14.73	0.5067	0.6633	14.73	0.5073	0.6637
HVI-CIDNet	14.98	0.5121	0.6786	14.96	0.5102	0.6795	14.89	0.5059	0.6807	14.91	0.5075	0.6801
IRNeXt	13.81	0.4832	0.6886	13.81	0.4832	0.6885	13.81	0.4834	0.6887	13.81	0.4835	0.6889
DEA-Net	11.31	0.4504	0.7261	12.55	0.4651	0.7165	13.70	0.4823	0.7115	14.08	0.4887	0.7134
SFHformer	8.73	0.3487	0.7861	8.73	0.3491	0.7875	8.72	0.3497	0.7893	8.72	0.3503	0.7917
DeepSN-Net	9.28	0.3373	0.7442	9.28	0.3377	0.7445	9.28	0.3380	0.7447	9.28	0.3382	0.7452
DarkIR	4.71	0.0396	0.8913	4.71	0.0397	0.8921	4.71	0.0397	0.8933	4.71	0.0398	0.8947
Proposed method												
Recall(Ours)	**19.15**	**0.6026**	**0.5912**	**19.07**	**0.6012**	**0.5934**	**18.92**	**0.5982**	**0.5968**	**18.75**	**0.5947**	**0.6004**

Table A42 (continued).

Method	(0.75 px)			(0.875 px)			(1 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.40	0.5141	**0.6429**	15.39	0.5137	**0.6424**	15.40	0.5123	**0.6421**
UniProcessor	12.74	0.4629	0.6872	12.72	0.4632	0.6877	12.70	0.4633	0.6884
AST	12.60	0.4654	0.7062	12.63	0.4673	0.7062	12.61	0.4680	0.7074
OneRestore	10.36	0.4502	0.7484	10.36	0.4506	0.7497	10.37	0.4510	0.7513
General restoration backbones									
Restormer	14.84	0.5222	0.6636	14.85	0.5218	0.6628	14.84	0.5218	0.6620
X-Restormer	14.72	0.5123	0.6721	14.65	0.5106	0.6729	14.55	0.5074	0.6740
NAFNet	14.05	0.4616	0.6549	14.03	0.4615	0.6548	14.00	0.4615	0.6552
Pixel2Pixel	11.24	0.3904	0.6706	11.23	0.3913	0.6716	11.23	0.3920	0.6728
ConvIR	14.07	0.4909	0.6923	14.07	0.4910	0.6925	14.07	0.4911	0.6930
Uformer	10.20	0.4405	0.7247	10.22	0.4411	0.7257	10.25	0.4421	0.7263
U-Net	8.84	0.3646	0.7911	8.84	0.3651	0.7907	8.85	0.3656	0.7908
Degradation-specific restoration									
Ada-Deblur	**15.47**	**0.5382**	0.6613	**15.54**	**0.5392**	0.6560	**15.61**	**0.5388**	0.6497
DehazeFormer	14.10	0.4573	0.6913	14.10	0.4575	0.6915	14.11	0.4577	0.6919
OKNet	14.04	0.4760	0.6891	14.04	0.4758	0.6893	14.03	0.4755	0.6896
DnCNN	8.22	0.3354	0.7348	8.22	0.3352	0.7352	8.22	0.3348	0.7359
Enhancement-oriented restoration									
Retinexformer	14.72	0.5071	0.6644	14.71	0.5068	0.6648	14.70	0.5062	0.6652
HVI-CIDNet	14.87	0.5041	0.6816	14.91	0.5053	0.6815	14.90	0.5029	0.6828
IRNeXt	13.81	0.4836	0.6891	13.81	0.4837	0.6893	13.81	0.4838	0.6896
DEA-Net	13.86	0.4838	0.7171	13.70	0.4799	0.7212	13.57	0.4772	0.7268
SFHformer	8.72	0.3510	0.7943	8.71	0.3517	0.7970	8.71	0.3523	0.7995
DeepSN-Net	9.28	0.3384	0.7461	9.29	0.3386	0.7473	9.29	0.3389	0.7486
DarkIR	4.71	0.0398	0.8963	4.71	0.0399	0.8980	4.71	0.0400	0.9000
Proposed method									
Recall(Ours)	**18.60**	**0.5911**	**0.6039**	**18.48**	**0.5882**	**0.6065**	**18.39**	**0.5857**	**0.6082**

Table A42 (continued).

Method	(1.125 px)			(1.25 px)			(1.5 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.39	0.5114	**0.6413**	15.37	0.5111	**0.6416**	**15.36**	0.5107	**0.6411**
UniProcessor	12.67	0.4633	0.6891	12.64	0.4633	0.6900	12.59	0.4631	0.6914
AST	12.60	0.4678	0.7078	12.62	0.4664	0.7073	12.65	0.4652	0.7061
OneRestore	10.37	0.4514	0.7528	10.37	0.4518	0.7544	10.37	0.4525	0.7574
General restoration backbones									
Restormer	14.84	0.5207	0.6619	14.84	0.5198	0.6618	14.83	0.5194	0.6613
X-Restormer	14.42	0.5046	0.6753	14.28	0.5017	0.6767	14.02	0.4970	0.6796
NAFNet	13.98	0.4615	0.6553	13.97	0.4614	0.6555	13.94	0.4610	0.6560
Pixel2Pixel	11.22	0.3927	0.6738	11.21	0.3929	0.6745	11.18	0.3925	0.6772
ConvIR	14.07	0.4911	0.6934	14.06	0.4911	0.6937	14.06	0.4912	0.6944
Uformer	10.29	0.4431	0.7264	10.34	0.4442	0.7262	10.45	0.4472	0.7242
U-Net	8.85	0.3660	0.7912	8.85	0.3663	0.7922	8.86	0.3670	0.7945
Degradation-specific restoration									
Ada-Deblur	**15.59**	**0.5349**	0.6475	**15.50**	**0.5301**	0.6490	15.33	**0.5236**	0.6521
DehazeFormer	14.11	0.4578	0.6926	14.10	0.4581	0.6937	14.10	0.4589	0.6943
OKNet	14.02	0.4754	0.6899	14.01	0.4751	0.6903	13.99	0.4749	0.6910
DnCNN	8.22	0.3343	0.7365	8.23	0.3336	0.7371	8.23	0.3320	0.7383
Enhancement-oriented restoration									
Retinexformer	14.68	0.5057	0.6660	14.67	0.5050	0.6665	14.66	0.5041	0.6670
HVI-CIDNet	14.87	0.5041	0.6821	14.82	0.5026	0.6831	14.70	0.4973	0.6857
IRNeXt	13.80	0.4839	0.6900	13.80	0.4840	0.6903	13.80	0.4841	0.6907
DEA-Net	13.29	0.4694	0.7338	12.84	0.4538	0.7426	11.96	0.4348	0.7554
SFHformer	8.71	0.3528	0.8017	8.71	0.3533	0.8035	8.70	0.3540	0.8064
DeepSN-Net	9.29	0.3393	0.7499	9.29	0.3399	0.7513	9.29	0.3414	0.7544
DarkIR	4.72	0.0401	0.9023	4.72	0.0402	0.9048	4.72	0.0404	0.9097

Table A42 (continued).

Method	(1.125 px)			(1.25 px)			(1.5 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Proposed method									
Recall(Ours)	**18.31**	**0.5837**	**0.6090**	**18.23**	**0.5817**	**0.6104**	**18.09**	**0.5780**	**0.6140**

D.6.3 Software Focus-Blur Variation

Appendix Table A43 and Figure A57 report the Software sweep.

Software PSNR decreases from 21.600 to 19.365 dB as focus blur increases, while RECALL leads all three metrics at the 10 recorded conditions.

Increasing focus blur progressively weakens cues from the fine boundaries separating adjacent tools and panels, while RECALL retains the leading trajectory. Broad page hierarchy therefore continues to support the recovery of principal interface contours as local edges soften.

The complete model sustains the strongest coarse interface reconstruction across the blur range.

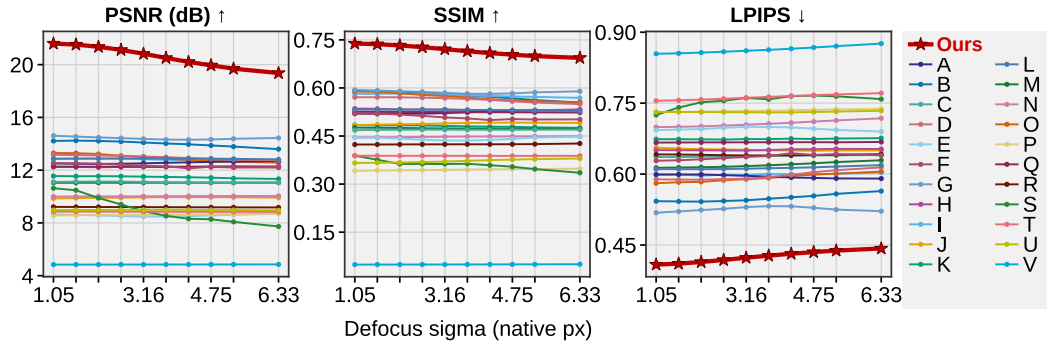


Figure A57: Software Focus-Blur Variation curves, generated from the same values as Appendix Table A43. Higher PSNR and SSIM and lower LPIPS indicate better restoration. The plotted native-pixel sigma equals the tabulated 256-reference-pixel sigma multiplied by $1080/256$. Method letters follow Section D.

Table A43: Full Software Focus-Blur Variation results, with 23 methods and 10 conditions. Headers give Gaussian σ in pixels at the 256-px reference scale; native-pixel σ equals the table value multiplied by $1080/256$.

Method	(0.25 px)			(0.375 px)			(0.5 px)			(0.625 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	14.22	0.5901	0.5426	14.24	0.5899	0.5421	14.22	0.5877	0.5417	14.17	0.5841	0.5430
UniProcessor	11.55	0.4843	0.6738	11.54	0.4832	0.6737	11.54	0.4834	0.6735	11.54	0.4830	0.6730
AST	9.85	0.4838	0.6561	9.88	0.4855	0.6539	9.90	0.4867	0.6527	9.91	0.4876	0.6521
OneRestore	10.00	0.4458	0.6993	10.00	0.4461	0.6999	10.01	0.4466	0.7009	10.01	0.4472	0.7024
General restoration backbones												
Restormer	12.84	0.5815	0.5982	12.87	0.5816	0.5993	12.88	0.5823	0.5965	12.87	0.5808	0.5987
X-Restormer	13.30	0.5890	0.5807	13.29	0.5879	0.5827	13.22	0.5835	0.5835	13.09	0.5780	0.5870
NAFNet	12.51	0.5197	0.5992	12.48	0.5192	0.5991	12.47	0.5190	0.5992	12.49	0.5200	0.5977
Pixel2Pixel	11.04	0.4763	0.6132	11.04	0.4758	0.6138	11.05	0.4751	0.6145	11.05	0.4743	0.6153
ConvIR	11.11	0.4682	0.6361	11.13	0.4691	0.6360	11.14	0.4697	0.6365	11.13	0.4699	0.6370
Uformer	8.65	0.4451	0.6929	8.61	0.4441	0.6942	8.57	0.4421	0.6952	8.52	0.4385	0.6978
U-Net	8.56	0.3416	0.7312	8.59	0.3425	0.7313	8.60	0.3432	0.7320	8.61	0.3437	0.7328
Degradation-specific restoration												
Ada-Deblur	13.17	0.5709	0.5889	13.15	0.5710	0.5883	13.12	0.5708	0.5881	13.07	0.5697	0.5892
DehazeFormer	12.25	0.5356	0.6507	12.24	0.5350	0.6504	12.22	0.5332	0.6502	12.24	0.5329	0.6500
OKNet	12.27	0.5252	0.6666	12.27	0.5252	0.6668	12.26	0.5249	0.6670	12.26	0.5248	0.6671
DnCNN	9.22	0.4235	0.6416	9.21	0.4235	0.6413	9.21	0.4238	0.6408	9.20	0.4239	0.6399

Table A43 (continued).

Method	(0.25 px)			(0.375 px)			(0.5 px)			(0.625 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Enhancement-oriented restoration												
Retinexformer	**14.61**	**0.5939**	**0.5183**	**14.55**	**0.5919**	**0.5210**	**14.48**	**0.5898**	**0.5239**	**14.43**	**0.5879**	**0.5266**
HVI-CIDNet	12.53	0.5207	0.6282	12.53	0.5199	0.6292	12.50	0.5168	0.6312	12.41	0.5128	0.6337
IRNeXt	12.88	0.5322	0.6105	12.88	0.5322	0.6103	12.88	0.5321	0.6103	12.89	0.5321	0.6107
DEA-Net	10.63	0.3886	0.7250	10.48	0.3760	0.7407	9.89	0.3628	0.7518	9.40	0.3628	0.7551
SFHformer	8.86	0.3884	0.7551	8.85	0.3883	0.7560	8.85	0.3883	0.7575	8.85	0.3882	0.7593
DeepSN-Net	8.97	0.3660	0.7313	8.98	0.3666	0.7314	8.98	0.3674	0.7313	8.99	0.3686	0.7309
DarkIR	4.84	0.0489	0.8544	4.84	0.0489	0.8554	4.84	0.0490	0.8568	4.84	0.0491	0.8587
Proposed method												
Recall(Ours)	**21.60**	**0.7385**	**0.4086**	**21.52**	**0.7365**	**0.4106**	**21.35**	**0.7326**	**0.4141**	**21.12**	**0.7272**	**0.4184**

Table A43 (continued).

Method	(0.75 px)			(0.875 px)			(1 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	14.10	0.5807	0.5445	14.02	0.5768	0.5478	13.96	0.5725	0.5509
UniProcessor	11.51	0.4816	0.6740	11.48	0.4801	0.6740	11.46	0.4793	0.6749
AST	9.93	0.4893	0.6514	9.96	0.4907	0.6503	9.95	0.4914	0.6497
OneRestore	10.02	0.4478	0.7043	10.02	0.4482	0.7064	10.03	0.4486	0.7086
General restoration backbones									
Restormer	12.82	0.5798	0.5982	12.78	0.5765	0.6002	12.76	0.5750	0.5998
X-Restormer	12.99	0.5746	0.5892	12.87	0.5706	0.5917	12.78	0.5652	0.5958
NAFNet	12.51	0.5214	0.5963	12.56	0.5240	0.5945	12.59	0.5264	0.5928
Pixel2Pixel	11.05	0.4736	0.6168	11.05	0.4734	0.6185	11.05	0.4731	0.6207
ConvIR	11.11	0.4697	0.6377	11.08	0.4693	0.6387	11.08	0.4694	0.6392
Uformer	8.48	0.4360	0.6998	8.48	0.4360	0.6997	8.51	0.4376	0.6987
U-Net	8.62	0.3444	0.7334	8.62	0.3451	0.7339	8.63	0.3459	0.7349
Degradation-specific restoration									
Ada-Deblur	13.04	0.5681	0.5903	12.99	0.5657	0.5936	12.92	0.5627	0.5983
DehazeFormer	12.27	0.5329	0.6497	12.26	0.5312	0.6508	12.27	0.5307	0.6525
OKNet	12.25	0.5248	0.6672	12.25	0.5243	0.6674	12.24	0.5241	0.6674
DnCNN	9.20	0.4241	0.6393	9.19	0.4241	0.6393	9.19	0.4242	0.6397
Enhancement-oriented restoration									
Retinexformer	**14.37**	**0.5847**	**0.5301**	**14.32**	**0.5819**	**0.5323**	**14.31**	**0.5816**	**0.5319**
HVI-CIDNet	12.33	0.5079	0.6363	12.30	0.5049	0.6382	12.14	0.4998	0.6441
IRNeXt	12.89	0.5319	0.6114	12.88	0.5315	0.6124	12.88	0.5310	0.6131
DEA-Net	8.89	0.3627	0.7609	8.54	0.3633	0.7582	8.32	0.3589	0.7648
SFHformer	8.85	0.3882	0.7613	8.84	0.3881	0.7632	8.84	0.3881	0.7652
DeepSN-Net	8.99	0.3703	0.7307	8.99	0.3725	0.7305	8.99	0.3747	0.7306
DarkIR	4.84	0.0492	0.8607	4.85	0.0493	0.8627	4.85	0.0494	0.8651
Proposed method									
Recall(Ours)	**20.83**	**0.7209**	**0.4231**	**20.51**	**0.7146**	**0.4275**	**20.21**	**0.7086**	**0.4316**

Table A43 (continued).

Method	(1.125 px)			(1.25 px)			(1.5 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	13.87	0.5675	0.5538	13.79	0.5623	0.5581	13.59	0.5541	0.5641
UniProcessor	11.43	0.4787	0.6742	11.38	0.4772	0.6751	11.33	0.4755	0.6759
AST	9.95	0.4920	0.6493	9.94	0.4916	0.6497	9.91	0.4908	0.6500
OneRestore	10.03	0.4488	0.7110	10.04	0.4490	0.7134	10.04	0.4491	0.7179
General restoration backbones									
Restormer	12.72	0.5734	0.5992	12.66	0.5720	0.6007	12.62	0.5691	0.6030
X-Restormer	12.70	0.5607	0.5992	12.64	0.5585	0.6009	12.57	0.5561	0.6053
NAFNet	12.63	0.5284	0.5918	12.65	0.5299	0.5908	12.69	0.5320	0.5905
Pixel2Pixel	11.05	0.4727	0.6228	11.05	0.4725	0.6254	11.05	0.4723	0.6292
ConvIR	11.07	0.4695	0.6395	11.07	0.4697	0.6397	11.06	0.4698	0.6405
Uformer	8.56	0.4414	0.6961	8.62	0.4450	0.6933	8.70	0.4478	0.6900
U-Net	8.64	0.3465	0.7358	8.66	0.3470	0.7367	8.71	0.3481	0.7379

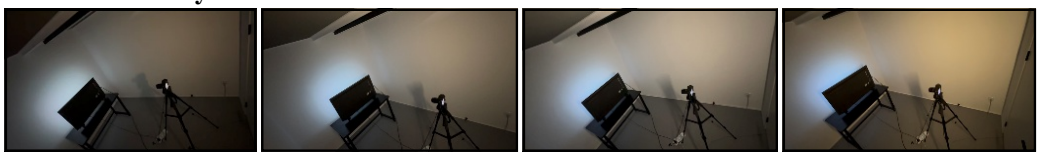
Table A43 (continued).

Method	(1.125 px)			(1.25 px)			(1.5 px)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Degradation-specific restoration									
Ada-Deblur	12.85	0.5584	0.6040	12.80	0.5543	0.6082	12.75	0.5495	0.6141
DehazeFormer	12.29	0.5306	0.6525	12.30	0.5308	0.6533	12.29	0.5325	0.6531
OKNet	12.24	0.5239	0.6674	12.23	0.5238	0.6672	12.22	0.5232	0.6678
DnCNN	9.18	0.4244	0.6401	9.18	0.4247	0.6408	9.17	0.4266	0.6421
Enhancement-oriented restoration									
Retinexformer	**14.33**	**0.5830**	**0.5287**	**14.38**	**0.5862**	**0.5249**	**14.44**	**0.5895**	**0.5215**
HVI-CIDNet	12.26	0.5028	0.6404	12.20	0.5016	0.6422	12.21	0.5018	0.6397
IRNeXt	12.87	0.5303	0.6143	12.86	0.5293	0.6159	12.82	0.5272	0.6189
DEA-Net	8.28	0.3542	0.7660	8.08	0.3467	0.7645	7.73	0.3354	0.7586
SFHformer	8.84	0.3880	0.7669	8.84	0.3880	0.7684	8.83	0.3882	0.7711
DeepSN-Net	8.98	0.3764	0.7312	8.97	0.3778	0.7322	8.95	0.3799	0.7339
DarkIR	4.85	0.0495	0.8677	4.85	0.0496	0.8705	4.85	0.0499	0.8760
Proposed method									
Recall(Ours)	**19.95**	**0.7038**	**0.4350**	**19.70**	**0.6993**	**0.4382**	**19.36**	**0.6938**	**0.4426**

D.7 Ambient-Light Variation

Ambient-light variation tests whether webpage-region relationships remain recoverable as a larger recorded background-light level reduces content contrast. The Browser sweep spans ten conditions labeled by per-channel linear RGB offsets from 0.0008 to 0.0080 while screen content and the remaining imaging conditions stay fixed.

Ambient intensity



Ambient color temperature

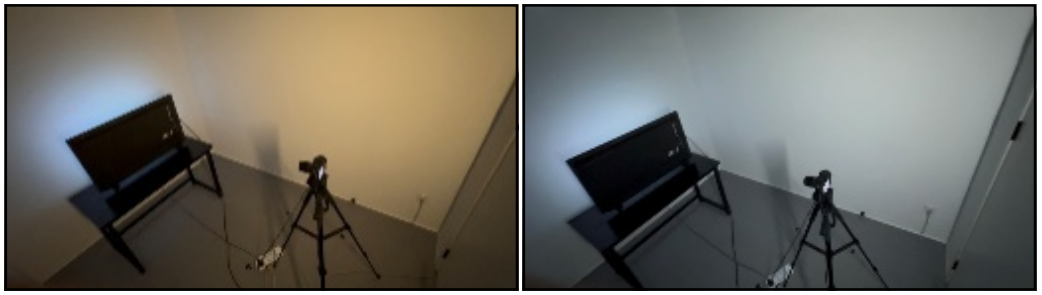


Figure A58: Real captures of the physical acquisition scene under the ambient-light configurations used for the robustness study. The upper row varies ambient intensity, and the lower row varies ambient color temperature.

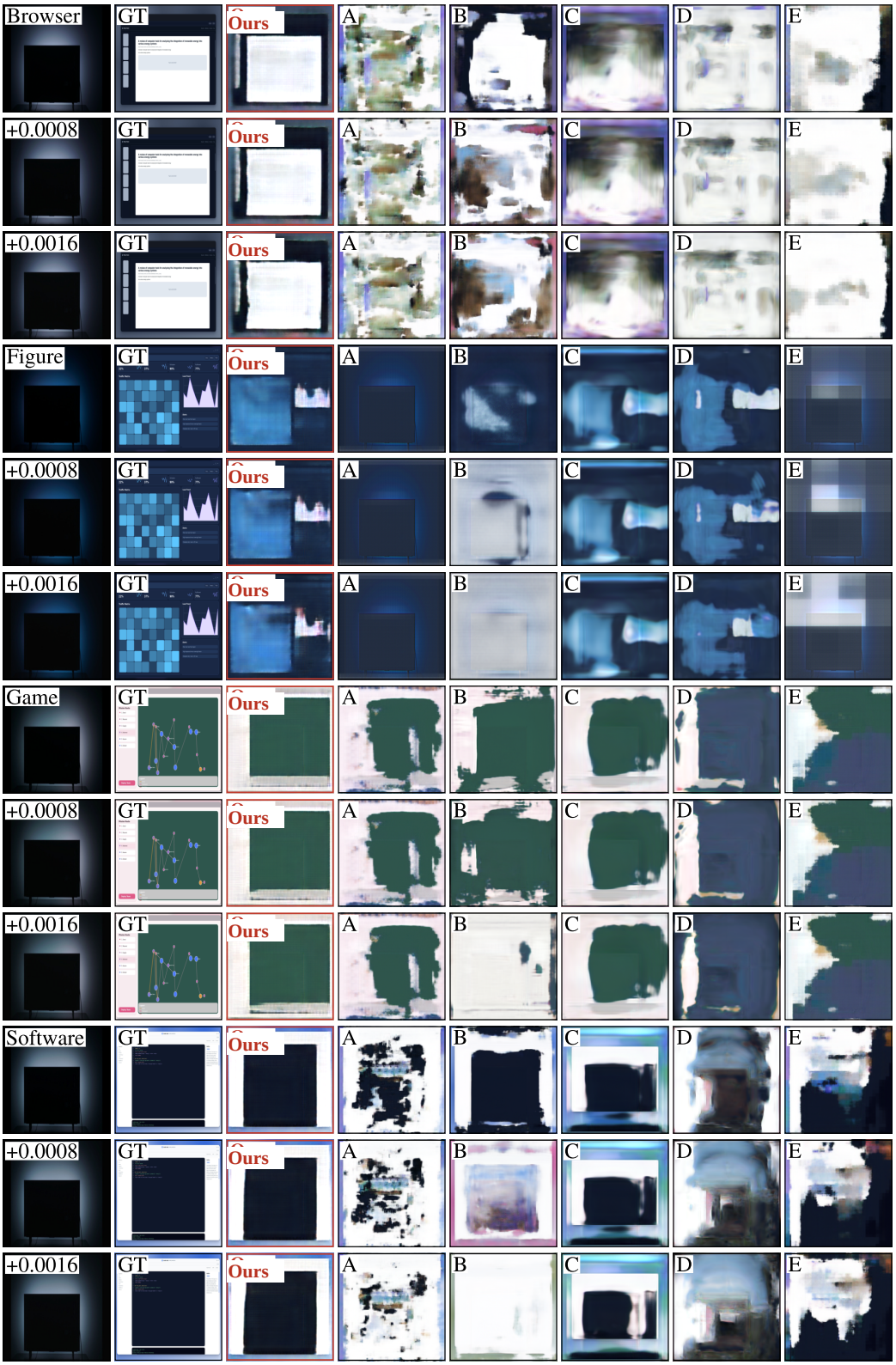


Figure A59: Ambient-light robustness on Browser, Figure, Game, and Software. Each three-row block shows the reference acquisition and the additive levels $+0.0008$ and $+0.0016$.

D.7.1 Browser Ambient-Light Variation

Appendix Table A44 and Figure A60 report the Browser sweep.

Increasing the recorded background-light level lowers Browser PSNR from 18.964 to 14.220 dB, while RECALL retains the strongest endpoint and leads all three metrics across the 10 recorded conditions.

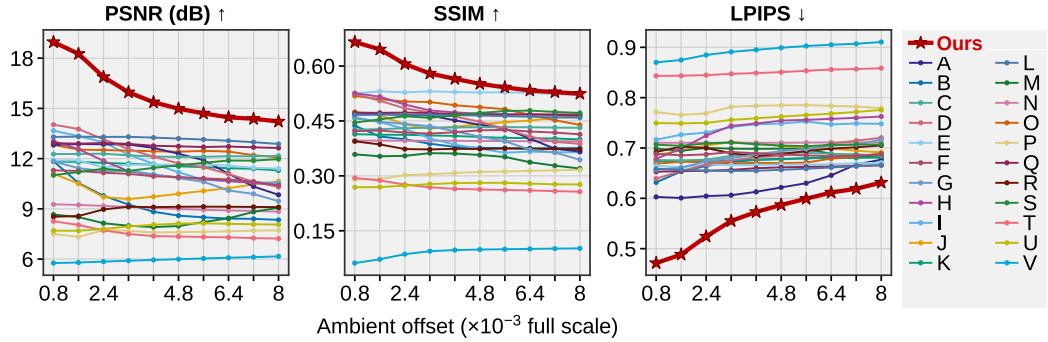


Figure A60: Browser Ambient-Light Variation curves, generated from the same values as Appendix Table A44. Higher PSNR and SSIM and lower LPIPS indicate better restoration. The axis expresses the tabulated dimensionless per-channel linear RGB offset in 10^{-3} full-scale units. Method letters follow Section D.

Table A44: Full Browser Ambient-Light Variation results, with 23 methods and 10 conditions. Headers give the dimensionless per-channel additive offset in linear RGB, with full scale 1.

Method	(0.0008 linear)			(0.0016 linear)			(0.0024 linear)			(0.0032 linear)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	11.85	0.4369	0.6317	10.55	0.4076	0.6534	9.78	0.4000	0.6643	9.26	0.3878	0.6716
UniProcessor	11.83	0.4138	0.6734	11.80	0.4123	0.6742	11.75	0.4122	0.6739	11.70	0.4104	0.6752
AST	11.10	0.4749	0.6861	10.51	0.4653	0.6949	9.70	0.4404	0.7049	9.58	0.4293	0.7118
OneRestore	9.27	0.3963	0.7105	9.23	0.3962	0.7103	9.17	0.3958	0.7105	9.12	0.3960	0.7102
General restoration backbones												
Restormer	13.67	0.4599	0.7165	13.35	0.4469	0.7264	12.98	0.4283	0.7306	12.23	0.4024	0.7416
X-Restormer	12.82	0.5184	0.6687	12.54	0.5094	0.6727	12.51	0.5030	0.6719	12.48	0.5016	0.6691
NAFNet	12.82	0.4675	**0.6028**	12.87	0.4696	**0.6007**	12.86	0.4665	**0.6044**	12.84	0.4648	**0.6062**
Pixel2Pixel	8.65	0.3587	0.6988	8.51	0.3535	0.6943	8.14	0.3546	0.7002	7.99	0.3621	0.6986
ConvIR	12.27	0.4262	0.6762	12.28	0.4277	0.6754	12.29	0.4299	0.6767	12.20	0.4317	0.6844
Uformer	11.89	0.5255	0.6645	11.89	**0.5307**	0.6616	11.48	**0.5281**	0.6670	11.63	**0.5308**	0.6660
U-Net	7.50	0.2904	0.7712	7.32	0.2911	0.7657	7.72	0.3020	0.7687	7.68	0.3044	0.7816
Degradation-specific restoration												
Ada-Deblur	**14.03**	0.5239	0.6391	**13.77**	0.5052	0.6542	13.15	0.4844	0.6672	12.58	0.4731	0.6757
DehazeFormer	13.04	**0.5261**	0.6785	12.57	0.5162	0.6988	11.87	0.4948	0.7247	11.25	0.4787	0.7439
OKNet	12.92	0.4727	0.6528	12.89	0.4721	0.6541	12.93	0.4728	0.6547	12.88	0.4718	0.6564
DnCNN	8.53	0.3944	0.6921	8.57	0.3859	0.7027	8.96	0.3732	0.6999	9.12	0.3722	0.6894
Enhancement-oriented restoration												
Retinexformer	11.83	0.4572	0.6565	11.43	0.4474	0.6611	11.26	0.4419	0.6733	11.28	0.4357	0.6803
HVI-CIDNet	11.30	0.4220	0.6884	11.26	0.4239	0.6854	11.16	0.4184	0.6873	11.09	0.4155	0.6921
IRNeXt	13.30	0.4663	0.6585	13.31	0.4671	0.6568	**13.30**	0.4670	0.6551	**13.30**	0.4664	0.6543
DEA-Net	11.01	0.4454	0.7066	11.20	0.4543	0.7044	11.40	0.4630	0.7090	11.27	0.4582	0.7111
SFHformer	8.26	0.2944	0.8433	8.04	0.2874	0.8436	7.71	0.2762	0.8447	7.50	0.2689	0.8473
DeepSN-Net	7.70	0.2687	0.7495	7.69	0.2695	0.7489	7.80	0.2734	0.7499	7.94	0.2776	0.7557
DarkIR	5.76	0.0618	0.8701	5.79	0.0722	0.8749	5.85	0.0861	0.8847	5.90	0.0942	0.8910
Proposed method												
Recall(Ours)	**18.96**	**0.6656**	**0.4714**	**18.26**	**0.6455**	**0.4883**	**16.88**	**0.6055**	**0.5242**	**15.97**	**0.5797**	**0.5550**

Table A44 (continued).

Method	(0.0040 linear)			(0.0048 linear)			(0.0056 linear)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	8.83	0.3791	0.6765	8.59	0.3766	0.6785	8.49	0.3760	0.6794
UniProcessor	11.63	0.4091	0.6767	11.54	0.4062	0.6775	11.49	0.4037	0.6800
AST	9.73	0.4341	0.7092	9.90	0.4409	0.7037	10.07	0.4467	0.7000
OneRestore	9.05	0.3956	0.7103	8.99	0.3953	0.7104	8.94	0.3949	0.7107
General restoration backbones									
Restormer	11.69	0.3852	0.7473	11.18	0.3742	0.7485	10.74	0.3634	0.7526
X-Restormer	12.44	0.4930	0.6705	12.41	0.4876	0.6699	12.46	0.4822	0.6710
NAFNet	12.64	0.4517	**0.6129**	12.29	0.4394	**0.6216**	11.91	0.4292	**0.6300**
Pixel2Pixel	7.91	0.3610	0.6983	7.97	0.3571	0.6986	8.21	0.3517	0.6979
ConvIR	12.12	0.4323	0.6891	12.10	0.4329	0.6904	12.11	0.4330	0.6905
Uformer	11.64	**0.5290**	0.6662	11.63	**0.5277**	0.6670	11.66	**0.5285**	0.6668
U-Net	7.59	0.3079	0.7839	7.60	0.3108	0.7847	7.63	0.3118	0.7852
Degradation-specific restoration									
Ada-Deblur	12.11	0.4619	0.6816	11.72	0.4480	0.6839	11.49	0.4287	0.6952
DehazeFormer	11.03	0.4732	0.7486	10.88	0.4700	0.7544	10.78	0.4685	0.7559
OKNet	12.76	0.4685	0.6598	12.74	0.4678	0.6616	12.69	0.4666	0.6624
DnCNN	9.10	0.3738	0.6840	9.12	0.3735	0.6883	9.13	0.3746	0.6937
Enhancement-oriented restoration									
Retinexformer	11.07	0.4219	0.6870	10.83	0.4070	0.6939	10.62	0.3947	0.6979
HVI-CIDNet	10.95	0.4192	0.6894	10.89	0.4244	0.6870	10.82	0.4255	0.6854
IRNeXt	**13.26**	0.4657	0.6547	**13.20**	0.4647	0.6566	**13.14**	0.4633	0.6587
DEA-Net	11.45	0.4653	0.7072	11.60	0.4718	0.7050	11.75	0.4771	0.7035
SFHformer	7.37	0.2645	0.8489	7.35	0.2629	0.8507	7.32	0.2615	0.8534
DeepSN-Net	8.05	0.2802	0.7590	8.12	0.2810	0.7623	8.13	0.2809	0.7653
DarkIR	5.95	0.0974	0.8951	5.99	0.0988	0.8991	6.04	0.0997	0.9026
Proposed method									
Recall(Ours)	**15.37**	**0.5651**	**0.5729**	**14.98**	**0.5515**	**0.5868**	**14.70**	**0.5417**	**0.5992**

Table A44 (continued).

Method	(0.0064 linear)			(0.0072 linear)			(0.0080 linear)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	8.42	0.3752	0.6809	8.40	0.3758	0.6820	8.34	0.3759	0.6830
UniProcessor	11.42	0.4032	0.6799	11.39	0.4020	0.6803	11.29	0.3997	0.6809
AST	10.23	0.4509	0.6989	10.46	0.4590	0.6945	10.64	0.4630	0.6913
OneRestore	8.90	0.3947	0.7111	8.87	0.3946	0.7111	8.83	0.3946	0.7113
General restoration backbones									
Restormer	10.65	0.3664	0.7469	10.58	0.3645	0.7486	10.55	0.3644	0.7480
X-Restormer	12.42	0.4667	0.6789	12.20	0.4519	0.6831	12.08	0.4392	0.6894
NAFNet	11.10	0.4020	**0.6457**	10.33	0.3741	0.6673	9.84	0.3664	0.6767
Pixel2Pixel	8.43	0.3374	0.6883	8.82	0.3278	0.6847	9.07	0.3202	0.6838
ConvIR	12.14	0.4328	0.6882	12.14	0.4319	0.6874	12.16	0.4313	0.6845
Uformer	11.58	**0.5265**	0.6676	11.45	**0.5232**	0.6694	11.40	**0.5203**	0.6707
U-Net	7.66	0.3136	0.7837	7.70	0.3151	0.7822	7.72	0.3163	0.7793
Degradation-specific restoration									
Ada-Deblur	11.09	0.4076	0.7089	10.62	0.3929	0.7145	10.30	0.3874	0.7204
DehazeFormer	10.66	0.4681	0.7579	10.55	0.4680	0.7600	10.42	0.4683	0.7626
OKNet	12.72	0.4681	0.6629	12.67	0.4664	0.6645	12.63	0.4648	**0.6657**
DnCNN	9.12	0.3742	0.6988	9.11	0.3734	0.7013	9.10	0.3726	0.7051
Enhancement-oriented restoration									
Retinexformer	10.10	0.3715	0.7048	9.89	0.3640	0.7062	9.46	0.3440	0.7170
HVI-CIDNet	10.75	0.4211	0.6835	10.62	0.4183	0.6848	10.41	0.4134	0.6871
IRNeXt	**13.07**	0.4615	0.6612	**12.98**	0.4598	**0.6637**	**12.88**	0.4590	0.6659
DEA-Net	11.89	0.4784	0.7062	11.88	0.4747	0.7070	11.97	0.4717	0.7068
SFHformer	7.30	0.2602	0.8559	7.25	0.2583	0.8568	7.22	0.2568	0.8584
DeepSN-Net	8.11	0.2788	0.7683	8.08	0.2770	0.7715	8.06	0.2766	0.7756
DarkIR	6.08	0.1006	0.9052	6.12	0.1013	0.9070	6.16	0.1019	0.9105

Table A44 (continued).

Method	(0.0064 linear)			(0.0072 linear)			(0.0080 linear)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Proposed method									
Recall(Ours)	**14.47**	**0.5332**	**0.6116**	**14.38**	**0.5287**	**0.6190**	**14.22**	**0.5244**	**0.6313**

Background illumination raises wall brightness while reducing the relative contrast of screen-generated light. The ambient-light sweep therefore examines recovery as the screen contribution becomes less distinct within the observation. PromptIR adapts restoration through degradation-conditioned prompts Potlapalli et al. (2023), while IRNeXt combines content-aware local attention with high-pass filter modulation Cui et al. (2023). At the largest per-channel linear-RGB offset of 0.0080, RECALL achieves 14.22 dB, compared with 8.34 dB for PromptIR and 12.88 dB for the strongest baseline, IRNeXt, retaining a 1.34 dB advantage (Table A44).

D.8 White-Balance Variation

We examine whether dominant screen colors and regional organization remain recoverable as the relative channel responses of the wall observation change. Browser, Game, and Software each use ten conditions, with the levels and ranges listed in the corresponding results table. Browser uses the following warm/cool RGB gains. Before application in linear RGB, gains are divided by their luminance-weighted sum using weights $(0.2126, 0.7152, 0.0722)$. Each sweep preserves the screen content and the other stated conditions.

Level	Warm RGB gains	Cool RGB gains
1	$(1.04, 1.00, 0.96)$	$(0.96, 1.00, 1.04)$
1.25	$(1.055, 0.999375, 0.94125)$	$(0.945, 0.9975, 1.0575)$
1.5	$(1.07, 0.99875, 0.9225)$	$(0.93, 0.995, 1.075)$
2	$(1.08, 1.00, 0.91)$	$(0.92, 1.00, 1.09)$
2.5	$(1.13, 0.99625, 0.8475)$	$(0.87, 0.985, 1.145)$
3	$(1.14, 1.00, 0.84)$	$(0.86, 1.00, 1.16)$
3.5	$(1.19, 0.99375, 0.7725)$	$(0.81, 0.975, 1.215)$
4	$(1.20, 1.00, 0.76)$	$(0.80, 0.99, 1.23)$
4.5	$(1.25, 0.99125, 0.6975)$	$(0.75, 0.965, 1.285)$
5	$(1.28, 0.99, 0.66)$	$(0.72, 0.96, 1.32)$

D.8.1 Browser White-Balance Variation

Appendix Table A45 and Figure A62 report the Browser sweep.

Increasing white-balance shift lowers Browser PSNR from 19.170 to 14.930 dB, while RECALL leads all three metrics at the 10 recorded conditions.

The white-balance curves move the Browser evaluation from spatial relocation and screen-to-background contrast to changing channel relationships. RECALL remains strongest across all three metrics while the shift grows, preserving the best available recovery of dominant webpage colors and structure throughout the recorded range.

This final Browser sweep extends the reconstruction advantage from intensity, texture, noise, and geometry to dominant webpage colors and regional layout under changing color relationships.



Figure A61: White-balance robustness on Browser, Figure, Game, and Software. Each three-row block shows the reference acquisition and the shift levels 1.5 and 2.5.

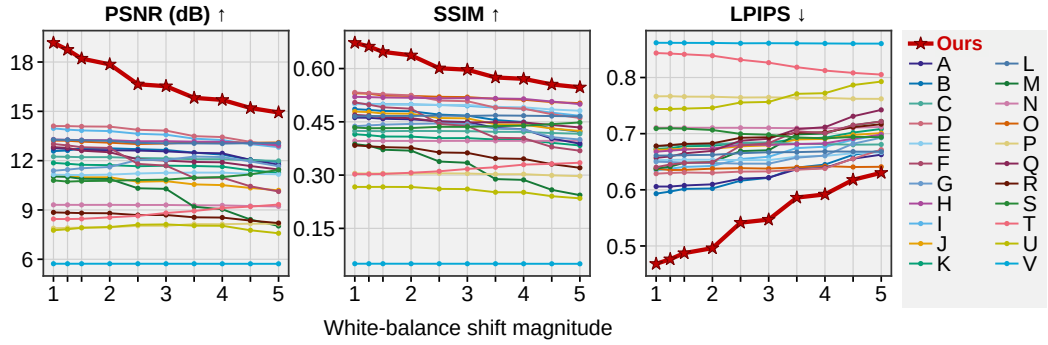


Figure A62: Browser White-Balance Variation curves, generated from the same values as Appendix Table A45. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

Table A45: Full Browser White-Balance Variation results, with 23 methods and 10 conditions. Headers give dimensionless shift levels, with RGB gains defined above.

Method	(1)			(1.25)			(1.5)			(2)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	12.58	0.4858	**0.5931**	12.62	0.4836	**0.5969**	12.76	0.4806	**0.6016**	12.75	0.4800	**0.6024**
UniProcessor	11.86	0.4151	0.6728	11.81	0.4124	0.6742	11.75	0.4086	0.6777	11.73	0.4084	0.6783
AST	11.05	0.4789	0.6712	11.07	0.4776	0.6720	10.98	0.4735	0.6731	10.99	0.4729	0.6730
OneRestore	9.31	0.3961	0.7106	9.31	0.3961	0.7107	9.31	0.3963	0.7106	9.31	0.3962	0.7105
General restoration backbones												
Restormer	13.96	0.5019	0.6346	13.89	0.5001	0.6377	13.84	0.4997	0.6407	13.80	0.4994	0.6425
X-Restormer	13.22	0.5305	0.6376	13.21	0.5292	0.6352	13.16	0.5239	0.6355	13.09	0.5231	0.6377
NAFNet	12.76	0.4619	0.6058	12.72	0.4614	0.6058	12.65	0.4586	0.6077	12.64	0.4571	0.6098
Pixel2Pixel	11.04	0.3872	0.6377	11.01	0.3828	0.6413	10.90	0.3715	0.6482	10.88	0.3689	0.6492
ConvIR	12.24	0.4244	0.6774	12.23	0.4241	0.6787	12.21	0.4237	0.6809	12.21	0.4243	0.6812
Uformer	11.15	0.4999	0.6526	11.13	0.4992	0.6533	11.12	0.4983	0.6537	11.15	0.4983	0.6535
U-Net	7.89	0.3050	0.7665	7.91	0.3043	0.7667	7.93	0.3045	0.7659	7.94	0.3047	0.7658
Degradation-specific restoration												
Ada-Deblur	**14.11**	**0.5327**	0.6287	**14.10**	**0.5304**	0.6300	**14.08**	**0.5275**	0.6308	**14.07**	**0.5247**	0.6302
DehazeFormer	13.29	0.5204	0.6679	13.26	0.5195	0.6698	13.25	0.5185	0.6714	13.25	0.5178	0.6734
OKNet	12.82	0.4694	0.6570	12.78	0.4674	0.6594	12.61	0.4630	0.6649	12.51	0.4603	0.6694
DnCNN	8.85	0.3837	0.6780	8.83	0.3813	0.6797	8.81	0.3787	0.6817	8.80	0.3770	0.6828
Enhancement-oriented restoration												
Retinexformer	11.39	0.4377	0.6500	11.45	0.4400	0.6494	11.54	0.4420	0.6484	11.62	0.4441	0.6477
HVI-CIDNet	13.01	0.5046	0.6403	12.93	0.4983	0.6451	12.82	0.4910	0.6478	12.77	0.4870	0.6491
IRNeXt	13.27	0.4656	0.6609	13.27	0.4659	0.6612	13.24	0.4666	0.6616	13.20	0.4665	0.6623
DEA-Net	10.80	0.4341	0.7092	10.73	0.4319	0.7095	10.76	0.4322	0.7089	10.78	0.4326	0.7065
SFHformer	8.45	0.3027	0.8436	8.45	0.3027	0.8427	8.46	0.3032	0.8414	8.55	0.3066	0.8389
DeepSN-Net	7.76	0.2668	0.7438	7.83	0.2667	0.7440	7.91	0.2668	0.7447	7.96	0.2666	0.7460
DarkIR	5.73	0.0505	0.8619	5.73	0.0505	0.8618	5.73	0.0505	0.8617	5.73	0.0505	0.8616
Proposed method												
Recall(Ours)	**19.17**	**0.6726**	**0.4682**	**18.75**	**0.6622**	**0.4764**	**18.21**	**0.6469**	**0.4873**	**17.86**	**0.6374**	**0.4961**

Table A45 (continued).

Method	(2.5)			(3)			(3.5)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.70	0.4704	**0.6162**	12.65	0.4676	**0.6213**	12.49	0.4550	0.6396
UniProcessor	11.66	0.4040	0.6838	11.69	0.4041	0.6835	11.67	0.4003	0.6908
AST	10.72	0.4607	0.6775	10.75	0.4598	0.6791	10.56	0.4432	0.6897
OneRestore	9.30	0.3962	0.7104	9.30	0.3964	0.7102	9.28	0.3964	0.7098

Table A45 (continued).

Method	(2.5)			(3)			(3.5)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
General restoration backbones									
Restormer	13.63	0.4973	0.6549	13.58	0.4948	0.6589	13.34	0.4900	0.6744
X-Restormer	13.01	**0.5205**	0.6385	13.04	**0.5197**	0.6378	13.11	0.5147	0.6401
NAFNet	12.61	0.4516	0.6198	12.56	0.4494	0.6217	12.48	0.4329	0.6366
Pixel2Pixel	10.32	0.3383	0.6690	10.28	0.3346	0.6705	9.20	0.2888	0.6987
ConvIR	12.16	0.4241	0.6836	12.14	0.4237	0.6844	12.09	0.4219	0.6820
Uformer	11.22	0.4977	0.6530	11.26	0.4974	0.6528	11.27	0.4921	0.6591
U-Net	8.04	0.3050	0.7644	8.04	0.3044	0.7647	8.14	0.3025	0.7639
Degradation-specific restoration									
Ada-Deblur	**13.88**	0.5098	0.6324	**13.83**	0.5081	0.6328	**13.49**	0.4900	**0.6358**
DehazeFormer	13.18	0.5161	0.6803	13.18	0.5166	0.6801	13.16	**0.5158**	0.6814
OKNet	12.08	0.4504	0.6874	12.00	0.4482	0.6909	11.92	0.4489	0.7081
DnCNN	8.69	0.3638	0.6927	8.69	0.3626	0.6936	8.55	0.3470	0.7015
Enhancement-oriented restoration									
Retinexformer	12.05	0.4454	0.6467	12.04	0.4439	0.6466	12.25	0.4309	0.6573
HVI-CIDNet	11.80	0.4439	0.6787	11.70	0.4385	0.6830	10.95	0.4050	0.7044
IRNeXt	13.09	0.4676	0.6652	13.05	0.4667	0.6669	13.05	0.4679	0.6671
DEA-Net	10.82	0.4360	0.6996	10.84	0.4358	0.6980	10.96	0.4379	0.6932
SFHformer	8.64	0.3108	0.8316	8.82	0.3173	0.8265	8.94	0.3221	0.8184
DeepSN-Net	8.10	0.2612	0.7555	8.12	0.2607	0.7565	8.05	0.2518	0.7710
DarkIR	5.73	0.0504	0.8610	5.73	0.0504	0.8611	5.73	0.0504	0.8609
Proposed method									
Recall(Ours)	**16.65**	**0.6009**	**0.5415**	**16.53**	**0.5967**	**0.5470**	**15.82**	**0.5749**	**0.5862**

Table A45 (continued).

Method	(4)			(4.5)			(5)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.37	0.4495	0.6450	12.05	0.4312	0.6623	11.92	0.4222	0.6698
UniProcessor	11.64	0.3992	0.6928	11.41	0.3910	0.7020	11.26	0.3834	0.7084
AST	10.51	0.4420	0.6907	10.34	0.4314	0.6978	10.19	0.4242	0.7010
OneRestore	9.28	0.3963	0.7096	9.24	0.3965	0.7107	9.22	0.3967	0.7119
General restoration backbones									
Restormer	13.25	0.4867	0.6767	13.00	0.4758	0.6893	12.82	0.4670	0.6973
X-Restormer	13.12	0.5122	0.6421	13.09	0.5054	**0.6406**	**13.11**	**0.5028**	**0.6410**
NAFNet	12.45	0.4291	0.6389	12.05	0.4029	0.6554	11.75	0.3885	0.6626
Pixel2Pixel	9.04	0.2865	0.7001	8.42	0.2585	0.7148	8.02	0.2436	0.7218
ConvIR	12.09	0.4216	0.6815	12.03	0.4184	0.6803	11.99	0.4165	0.6808
Uformer	11.27	0.4909	0.6603	11.20	0.4848	0.6652	11.17	0.4812	0.6665
U-Net	8.13	0.3026	0.7637	8.16	0.2992	0.7621	8.16	0.2972	0.7620
Degradation-specific restoration									
Ada-Deblur	**13.43**	0.4871	**0.6381**	**13.14**	0.4714	0.6553	12.90	0.4609	0.6715
DehazeFormer	13.14	**0.5146**	0.6828	13.07	**0.5072**	0.6912	12.94	0.4997	0.6983
OKNet	11.90	0.4482	0.7116	11.67	0.4411	0.7309	11.46	0.4341	0.7423
DnCNN	8.54	0.3457	0.7025	8.35	0.3309	0.7115	8.20	0.3206	0.7169
Enhancement-oriented restoration									
Retinexformer	12.22	0.4286	0.6610	11.95	0.4068	0.6821	11.66	0.4002	0.6928
HVI-CIDNet	10.97	0.4039	0.7007	10.44	0.3793	0.7153	10.12	0.3686	0.7217
IRNeXt	13.04	0.4673	0.6683	13.06	0.4663	0.6680	13.07	0.4654	0.6678
DEA-Net	11.00	0.4392	0.6917	11.16	0.4436	0.6942	11.44	0.4482	0.6938
SFHformer	9.12	0.3295	0.8124	9.20	0.3317	0.8082	9.33	0.3349	0.8052
DeepSN-Net	8.04	0.2515	0.7721	7.76	0.2406	0.7866	7.58	0.2346	0.7928
DarkIR	5.73	0.0503	0.8607	5.72	0.0503	0.8604	5.72	0.0502	0.8604
Proposed method									
Recall(Ours)	**15.70**	**0.5711**	**0.5918**	**15.20**	**0.5553**	**0.6179**	**14.93**	**0.5471**	**0.6303**

D.8.2 Game White-Balance Variation

Appendix Table A46 and Figure A63 report the Game sweep.

Game PSNR decreases from 19.022 to 17.075 dB as white-balance shift increases, while RECALL leads all three metrics at the 10 recorded conditions.

The game white-balance curves test whether low-light object structure survives a change in channel relationships, and RECALL remains strongest throughout the recorded range. Dominant colors and the canvas-to-object arrangement therefore remain the clearest recovered properties as color evidence changes.

The final Game sweep complements the intensity, noise, and geometry results with recovery of the broad canvas and dominant object-color arrangement under color variation.

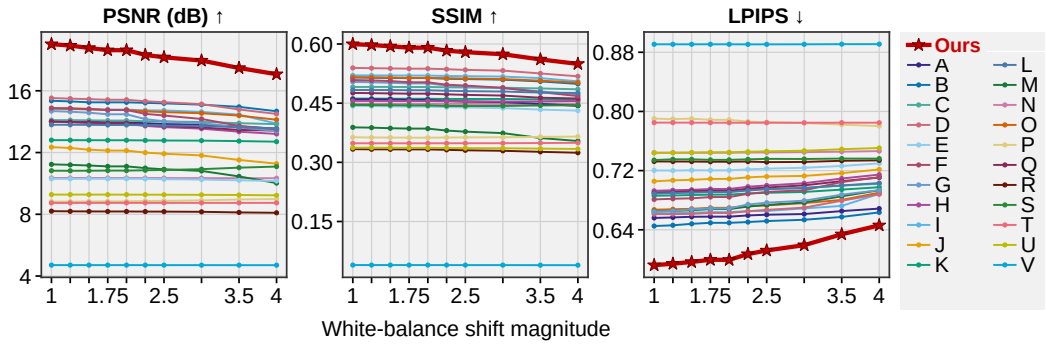


Figure A63: Game White-Balance Variation curves, generated from the same values as Appendix Table A46. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

Table A46: Full Game White-Balance Variation results, with 23 methods and 10 conditions. Headers give the listed dimensionless shift levels.

Method	(1)			(1.25)			(1.5)			(1.75)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	15.35	0.5153	**0.6451**	15.31	0.5146	**0.6461**	15.25	0.5137	**0.6481**	15.25	0.5137	**0.6494**
UniProcessor	12.80	0.4616	0.6860	12.80	0.4616	0.6864	12.80	0.4613	0.6870	12.80	0.4611	0.6875
AST	12.35	0.4582	0.7055	12.30	0.4577	0.7068	12.18	0.4570	0.7076	12.13	0.4563	0.7087
OneRestore	10.35	0.4483	0.7442	10.35	0.4483	0.7442	10.35	0.4482	0.7442	10.35	0.4482	0.7442
General restoration backbones												
Restormer	14.82	0.5206	0.6624	14.81	0.5204	0.6625	14.79	0.5202	0.6632	14.78	0.5201	0.6639
X-Restormer	14.86	0.5158	0.6671	14.83	0.5154	0.6677	14.80	0.5147	0.6684	14.75	0.5141	0.6697
NAFNet	14.03	0.4599	0.6560	14.01	0.4599	0.6567	13.99	0.4593	0.6576	13.96	0.4581	0.6578
Pixel2Pixel	11.23	0.3887	0.6650	11.20	0.3880	0.6655	11.16	0.3865	0.6664	11.10	0.3856	0.6680
ConvIR	14.10	0.4910	0.6910	14.10	0.4912	0.6915	14.09	0.4912	0.6920	14.07	0.4910	0.6926
Uformer	10.30	0.4427	0.7203	10.30	0.4427	0.7201	10.30	0.4419	0.7205	10.30	0.4413	0.7203
U-Net	8.82	0.3636	0.7902	8.82	0.3630	0.7897	8.83	0.3628	0.7902	8.83	0.3626	0.7887
Degradation-specific restoration												
Ada-Deblur	**15.53**	**0.5394**	0.6611	**15.49**	**0.5387**	0.6612	**15.46**	**0.5381**	0.6615	**15.42**	**0.5375**	0.6627
DehazeFormer	14.00	0.4557	0.6927	13.96	0.4557	0.6934	13.91	0.4555	0.6940	13.86	0.4554	0.6951
OKNet	14.00	0.4759	0.6898	13.98	0.4754	0.6908	13.95	0.4747	0.6923	13.91	0.4741	0.6926
DnCNN	8.20	0.3334	0.7324	8.19	0.3330	0.7323	8.19	0.3329	0.7322	8.18	0.3328	0.7320
Enhancement-oriented restoration												
Retinexformer	14.68	0.5040	0.6645	14.64	0.5030	0.6656	14.58	0.5017	0.6676	14.48	0.5001	0.6689
HVI-CIDNet	14.88	0.5087	0.6810	14.87	0.5077	0.6819	14.83	0.5061	0.6825	14.76	0.5031	0.6843
IRNeXt	13.80	0.4834	0.6888	13.80	0.4833	0.6895	13.79	0.4832	0.6902	13.78	0.4828	0.6909
DEA-Net	10.82	0.4458	0.7342	10.82	0.4451	0.7353	10.82	0.4448	0.7353	10.83	0.4443	0.7346
SFHformer	8.73	0.3483	0.7849	8.74	0.3483	0.7849	8.74	0.3483	0.7848	8.74	0.3483	0.7848
DeepSN-Net	9.28	0.3370	0.7439	9.28	0.3370	0.7441	9.28	0.3368	0.7444	9.27	0.3367	0.7448
DarkIR	4.71	0.0396	0.8908	4.71	0.0396	0.8908	4.71	0.0396	0.8908	4.71	0.0396	0.8908
Proposed method												
Recall(Ours)	**19.02**	**0.5996**	**0.5921**	**18.93**	**0.5975**	**0.5941**	**18.78**	**0.5941**	**0.5965**	**18.63**	**0.5906**	**0.5994**

Table A46 (continued).

Method	(2)			(2.25)			(2.5)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.25	0.5137	**0.6494**	15.22	0.5119	**0.6505**	15.19	0.5112	**0.6518**
UniProcessor	12.80	0.4611	0.6875	12.79	0.4607	0.6891	12.78	0.4606	0.6900
AST	12.13	0.4563	0.7088	12.00	0.4551	0.7109	11.92	0.4539	0.7120
OneRestore	10.35	0.4482	0.7443	10.35	0.4481	0.7445	10.34	0.4481	0.7446
General restoration backbones									
Restormer	14.78	0.5200	0.6639	14.73	0.5190	0.6652	14.73	0.5184	0.6654
X-Restormer	14.75	0.5141	0.6697	14.67	0.5131	0.6722	14.62	0.5124	0.6730
NAFNet	13.96	0.4582	0.6577	13.91	0.4559	0.6594	13.84	0.4543	0.6604
Pixel2Pixel	11.11	0.3855	0.6679	10.99	0.3805	0.6714	10.91	0.3778	0.6736
ConvIR	14.07	0.4910	0.6926	14.03	0.4903	0.6942	14.01	0.4898	0.6952
Uformer	10.30	0.4414	0.7204	10.29	0.4399	0.7217	10.27	0.4392	0.7227
U-Net	8.83	0.3625	0.7886	8.86	0.3629	0.7863	8.87	0.3632	0.7855
Degradation-specific restoration									
Ada-Deblur	**15.42**	**0.5375**	0.6626	**15.32**	**0.5361**	0.6651	**15.26**	**0.5344**	0.6669
DehazeFormer	13.86	0.4553	0.6952	13.72	0.4548	0.6982	13.65	0.4545	0.6999
OKNet	13.91	0.4740	0.6926	13.79	0.4724	0.6956	13.72	0.4710	0.6972
DnCNN	8.18	0.3328	0.7320	8.18	0.3317	0.7323	8.17	0.3305	0.7315
Enhancement-oriented restoration									
Retinexformer	14.48	0.5002	0.6689	14.17	0.4947	0.6742	14.03	0.4916	0.6766
HVI-CIDNet	14.75	0.5030	0.6843	14.51	0.4969	0.6886	14.40	0.4946	0.6912
IRNeXt	13.78	0.4828	0.6909	13.77	0.4814	0.6930	13.75	0.4805	0.6949
DEA-Net	10.83	0.4443	0.7346	10.85	0.4430	0.7353	10.87	0.4427	0.7359
SFHformer	8.74	0.3483	0.7847	8.74	0.3484	0.7847	8.74	0.3484	0.7847
DeepSN-Net	9.27	0.3367	0.7447	9.27	0.3363	0.7455	9.27	0.3361	0.7460
DarkIR	4.71	0.0396	0.8908	4.71	0.0395	0.8907	4.71	0.0395	0.8907
Proposed method									
Recall(Ours)	**18.63**	**0.5907**	**0.5993**	**18.33**	**0.5832**	**0.6071**	**18.17**	**0.5793**	**0.6120**

Table A46 (continued).

Method	(3)			(3.5)			(4)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	15.10	0.5096	**0.6535**	**14.96**	0.5051	**0.6574**	**14.68**	0.4989	**0.6635**
UniProcessor	12.77	0.4607	0.6911	12.74	0.4594	0.6943	12.70	0.4579	0.6975
AST	11.81	0.4517	0.7128	11.52	0.4471	0.7165	11.28	0.4438	0.7216
OneRestore	10.34	0.4481	0.7450	10.34	0.4479	0.7455	10.34	0.4479	0.7464
General restoration backbones									
Restormer	14.63	0.5174	0.6689	14.46	0.5135	0.6723	13.88	0.5054	0.6886
X-Restormer	14.55	0.5109	0.6760	14.39	0.5071	0.6804	14.12	0.5020	0.6902
NAFNet	13.81	0.4528	0.6613	13.69	0.4482	0.6653	13.55	0.4434	0.6686
Pixel2Pixel	10.81	0.3741	0.6769	10.45	0.3617	0.6852	10.02	0.3541	0.6935
ConvIR	13.98	0.4892	0.6964	13.90	0.4873	0.6997	13.84	0.4852	0.7022
Uformer	10.25	0.4376	0.7238	10.20	0.4337	0.7262	10.16	0.4312	0.7298
U-Net	8.90	0.3637	0.7843	8.96	0.3644	0.7822	8.98	0.3653	0.7802
Degradation-specific restoration									
Ada-Deblur	**15.14**	**0.5326**	0.6699	14.79	**0.5253**	0.6793	14.50	**0.5181**	0.6881
DehazeFormer	13.55	0.4543	0.7029	13.35	0.4542	0.7093	13.20	0.4551	0.7146
OKNet	13.63	0.4693	0.7001	13.47	0.4638	0.7058	13.42	0.4619	0.7107
DnCNN	8.16	0.3293	0.7317	8.12	0.3266	0.7333	8.10	0.3244	0.7339
Enhancement-oriented restoration									
Retinexformer	13.90	0.4879	0.6794	13.63	0.4796	0.6875	13.40	0.4723	0.6935
HVI-CIDNet	14.17	0.4890	0.6934	13.73	0.4780	0.7045	13.51	0.4680	0.7110
IRNeXt	13.72	0.4795	0.6966	13.63	0.4768	0.7000	13.56	0.4759	0.7031
DEA-Net	10.92	0.4429	0.7357	11.02	0.4442	0.7363	11.09	0.4448	0.7363
SFHformer	8.74	0.3485	0.7848	8.74	0.3489	0.7848	8.74	0.3495	0.7848
DeepSN-Net	9.26	0.3356	0.7469	9.25	0.3348	0.7489	9.23	0.3339	0.7506
DarkIR	4.71	0.0395	0.8908	4.70	0.0393	0.8910	4.70	0.0393	0.8910

Table A46 (continued).

Method	(3)			(3.5)			(4)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Proposed method									
Recall(Ours)	**17.96**	**0.5741**	**0.6192**	**17.48**	**0.5609**	**0.6339**	**17.07**	**0.5496**	**0.6461**

D.8.3 Software White-Balance Variation

Appendix Table A47 and Figure A64 report the Software sweep.

Software PSNR decreases from 21.046 to 14.956 dB as white-balance shift increases, while RECALL leads all three metrics at the 10 recorded conditions.

The software white-balance curves close the one-factor study with changing channel relationships across a densely partitioned interface. RECALL leads throughout the range, preserving the strongest recovery of dominant panel colors and structural hierarchy as the shift increases.

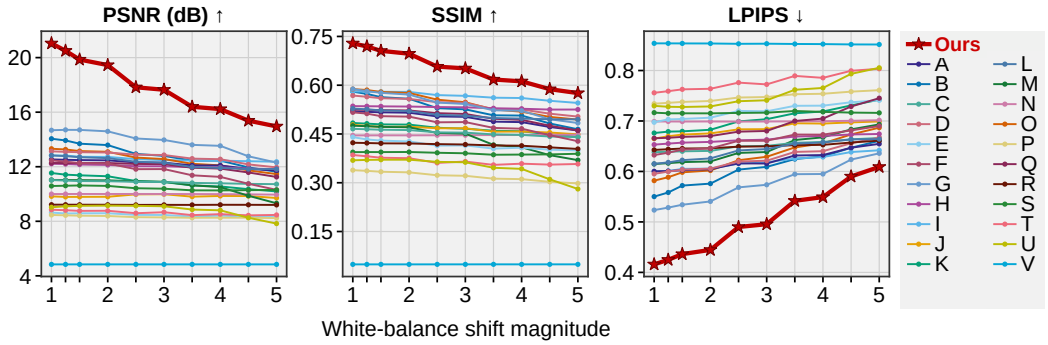


Figure A64: Software White-Balance Variation curves, generated from the same values as Appendix Table A47. Higher PSNR and SSIM and lower LPIPS indicate better restoration. Method letters follow Section D.

Table A47: Full Software White-Balance Variation results, with 23 methods and 10 conditions. Headers give the listed dimensionless shift levels.

Method	(1)			(1.25)			(1.5)			(2)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines												
PromptIR	14.05	0.5802	0.5502	13.93	0.5732	0.5583	13.69	0.5633	0.5720	13.59	0.5583	0.5759
UniProcessor	11.54	0.4838	0.6761	11.42	0.4818	0.6789	11.37	0.4795	0.6795	11.30	0.4789	0.6826
AST	9.83	0.4784	0.6651	9.79	0.4745	0.6697	9.79	0.4719	0.6731	9.80	0.4723	0.6754
OneRestore	10.00	0.4455	0.6990	10.00	0.4456	0.6990	10.00	0.4457	0.6989	10.00	0.4457	0.6990
General restoration backbones												
Restormer	12.83	0.5812	0.5999	12.82	0.5803	0.6007	12.73	**0.5798**	0.6052	12.72	**0.5794**	0.6056
X-Restormer	13.32	0.5881	0.5818	13.27	**0.5852**	0.5885	13.15	0.5792	0.5983	13.10	0.5762	0.6019
NAFNet	12.54	0.5197	0.6003	12.51	0.5181	0.6008	12.49	0.5166	0.6025	12.47	0.5155	0.6045
Pixel2Pixel	11.03	0.4754	0.6147	11.03	0.4739	0.6164	11.02	0.4719	0.6185	11.00	0.4705	0.6198
ConvIR	11.02	0.4657	0.6381	10.98	0.4645	0.6391	10.95	0.4631	0.6399	10.94	0.4620	0.6407
Uformer	8.64	0.4403	0.6974	8.57	0.4332	0.7032	8.59	0.4296	0.7040	8.59	0.4270	0.7065
U-Net	8.46	0.3387	0.7343	8.44	0.3366	0.7359	8.41	0.3339	0.7378	8.39	0.3320	0.7396
Degradation-specific restoration												
Ada-Deblur	13.13	0.5682	0.5953	13.09	0.5644	0.5997	13.06	0.5600	0.6036	13.04	0.5578	0.6056
DehazeFormer	12.21	0.5357	0.6531	12.20	0.5353	0.6552	12.16	0.5350	0.6571	12.13	0.5344	0.6586
OKNet	12.27	0.5253	0.6657	12.27	0.5244	0.6667	12.27	0.5232	0.6685	12.27	0.5223	0.6701
DnCNN	9.22	0.4230	0.6427	9.22	0.4222	0.6440	9.21	0.4212	0.6454	9.21	0.4208	0.6459

Table A47 (continued).

Method	(1)			(1.25)			(1.5)			(2)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Enhancement-oriented restoration												
Retinexformer	**14.68**	**0.5883**	**0.5234**	**14.70**	0.5817	**0.5284**	**14.70**	0.5765	**0.5340**	**14.59**	0.5711	**0.5406**
HVI-CIDNet	12.47	0.5165	0.6325	12.37	0.5126	0.6371	12.27	0.5048	0.6433	12.24	0.5034	0.6456
IRNeXt	12.83	0.5282	0.6152	12.78	0.5258	0.6179	12.70	0.5227	0.6224	12.63	0.5204	0.6259
DEA-Net	10.59	0.3941	0.7165	10.61	0.3944	0.7152	10.63	0.3943	0.7152	10.59	0.3945	0.7151
SFHformer	8.85	0.3853	0.7558	8.81	0.3814	0.7591	8.76	0.3769	0.7627	8.77	0.3755	0.7638
DeepSN-Net	9.03	0.3690	0.7300	9.10	0.3703	0.7281	9.13	0.3708	0.7277	9.15	0.3709	0.7288
DarkIR	4.84	0.0489	0.8538	4.84	0.0489	0.8538	4.84	0.0489	0.8537	4.84	0.0489	0.8536
Proposed method												
Recall(Ours)	**21.05**	**0.7287**	**0.4159**	**20.50**	**0.7192**	**0.4250**	**19.86**	**0.7057**	**0.4362**	**19.45**	**0.6969**	**0.4446**

Table A47 (continued).

Method	(2.5)			(3)			(3.5)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.94	0.5294	0.6037	12.80	0.5257	0.6091	12.45	0.5075	0.6245
UniProcessor	10.95	0.4691	0.6991	10.88	0.4662	0.7036	10.63	0.4600	0.7152
AST	9.97	0.4676	0.6835	9.98	0.4676	0.6838	9.81	0.4571	0.6955
OneRestore	10.00	0.4460	0.6988	10.00	0.4462	0.6990	10.00	0.4467	0.6993
General restoration backbones									
Restormer	12.56	**0.5696**	0.6155	12.48	**0.5673**	0.6181	12.45	**0.5616**	0.6256
X-Restormer	12.67	0.5556	0.6222	12.56	0.5476	0.6291	12.21	0.5254	0.6476
NAFNet	12.32	0.5040	0.6161	12.30	0.5027	0.6157	12.10	0.4880	0.6316
Pixel2Pixel	10.93	0.4532	0.6367	10.90	0.4511	0.6385	10.64	0.4165	0.6623
ConvIR	10.89	0.4549	0.6498	10.88	0.4541	0.6507	10.81	0.4487	0.6568
Uformer	8.47	0.4142	0.7200	8.46	0.4149	0.7191	8.36	0.4050	0.7301
U-Net	8.30	0.3230	0.7465	8.28	0.3214	0.7475	8.26	0.3126	0.7530
Degradation-specific restoration									
Ada-Deblur	12.88	0.5479	0.6197	12.86	0.5455	0.6213	12.59	0.5268	0.6387
DehazeFormer	12.04	0.5328	0.6617	12.04	0.5320	0.6630	11.97	0.5292	0.6692
OKNet	12.21	0.5140	0.6789	12.19	0.5115	0.6802	11.93	0.4968	0.7000
DnCNN	9.20	0.4188	0.6491	9.21	0.4177	0.6498	9.20	0.4147	0.6521
Enhancement-oriented restoration									
Retinexformer	**14.07**	0.5466	**0.5684**	**13.96**	0.5422	**0.5736**	**13.60**	0.5228	**0.5946**
HVI-CIDNet	11.82	0.4859	0.6608	11.83	0.4866	0.6608	11.37	0.4687	0.6732
IRNeXt	12.37	0.5089	0.6417	12.30	0.5061	0.6443	11.97	0.4991	0.6552
DEA-Net	10.42	0.3922	0.7160	10.39	0.3906	0.7165	10.27	0.3861	0.7198
SFHformer	8.59	0.3610	0.7760	8.66	0.3652	0.7725	8.45	0.3549	0.7893
DeepSN-Net	9.13	0.3642	0.7392	9.10	0.3629	0.7410	8.86	0.3461	0.7618
DarkIR	4.84	0.0490	0.8529	4.84	0.0490	0.8531	4.84	0.0491	0.8526
Proposed method									
Recall(Ours)	**17.83**	**0.6572**	**0.4899**	**17.64**	**0.6518**	**0.4955**	**16.40**	**0.6175**	**0.5418**

Table A47 (continued).

Method	(4)			(4.5)			(5)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Unified restoration baselines									
PromptIR	12.45	0.5066	0.6297	11.95	0.4824	0.6469	11.63	0.4644	0.6607
UniProcessor	10.55	0.4584	0.7188	10.36	0.4488	0.7308	10.19	0.4412	0.7422
AST	9.86	0.4576	0.6949	9.85	0.4545	0.6972	9.71	0.4490	0.6991
OneRestore	9.99	0.4468	0.6996	9.97	0.4473	0.7004	9.95	0.4477	0.7015
General restoration backbones									
Restormer	12.45	**0.5606**	0.6286	12.40	**0.5521**	0.6385	**12.37**	**0.5454**	0.6419
X-Restormer	12.10	0.5185	0.6556	11.73	0.5025	0.6733	11.46	0.4943	0.6867
NAFNet	12.09	0.4864	0.6325	11.85	0.4715	0.6470	11.72	0.4607	0.6547
Pixel2Pixel	10.50	0.4090	0.6676	9.87	0.3848	0.6834	9.32	0.3695	0.6932
ConvIR	10.79	0.4470	0.6584	10.74	0.4422	0.6637	10.72	0.4403	0.6663
Uformer	8.41	0.4078	0.7304	8.35	0.4017	0.7371	8.35	0.3992	0.7409
U-Net	8.26	0.3111	0.7539	8.26	0.3029	0.7581	8.23	0.2979	0.7611

Table A47 (continued).

Method	(4)			(4.5)			(5)		
	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS	PSNR	SSIM	LPIPS
Degradation-specific restoration									
Ada-Deblur	12.55	0.5254	0.6401	12.17	0.5125	0.6558	11.95	0.5034	0.6672
DehazeFormer	11.95	0.5276	0.6704	11.86	0.5251	0.6733	11.82	0.5252	0.6742
OKNet	11.86	0.4933	0.7048	11.58	0.4754	0.7286	11.25	0.4607	0.7452
DnCNN	9.21	0.4139	0.6527	9.21	0.4089	0.6573	9.20	0.4040	0.6611
Enhancement-oriented restoration									
Retinexformer	**13.53**	0.5214	**0.5949**	**12.77**	0.4953	**0.6236**	12.30	0.4838	**0.6359**
HVI-CIDNet	11.26	0.4662	0.6730	10.75	0.4465	0.6813	10.30	0.4277	0.6901
IRNeXt	11.91	0.4973	0.6573	11.83	0.4952	0.6635	11.83	0.4950	0.6641
DEA-Net	10.26	0.3867	0.7180	10.28	0.3872	0.7166	10.30	0.3892	0.7161
SFHformer	8.52	0.3587	0.7855	8.43	0.3558	0.7994	8.47	0.3577	0.8035
DeepSN-Net	8.80	0.3427	0.7655	8.26	0.3105	0.7934	7.83	0.2808	0.8054
DarkIR	4.84	0.0490	0.8524	4.84	0.0490	0.8517	4.84	0.0490	0.8516
Proposed method									
Recall(Ours)	**16.23**	**0.6119**	**0.5492**	**15.38**	**0.5878**	**0.5900**	**14.96**	**0.5757**	**0.6090**

E Evidence Synthesis across Categories and Conditions

The supplementary experiments connect hidden-screen recovery to the organization and use of diffuse wall evidence. Tables A7–A47 and their paired curves extend the seven-category main comparison across observation conditions.

The mechanism studies link this recovery to the joint use of dispersed wall cues. Regional interventions show that wall locations contribute jointly to the reconstructed screen, and completion studies connect their combined use to larger PSNR gains. CASR comparisons examine the representation of these cues; RAL ablations and paired joint refinement connect restoration-based allocation to improved outputs.

The condition sweeps extend the reconstruction advantage across changes in wall return, texture, illumination, observation geometry, transport spread, blur, noise, and white balance. Material photographs additionally show wood, tiled, and frosted white wall configurations. These studies bring broad webpage regions, compact chart layouts, game canvases, and dense software interfaces into the same account of recoverable screen evidence.

Together, the results establish that diffuse wall light carries a recoverable view of hidden-screen organization. RECALL reconstructs coarse color and brightness distributions, regional layouts, and principal contours from this light, demonstrating the feasibility of recovering screen content with an ordinary camera behind a wall-facing display.