Supplementary Materials

A Theoretical Relations Between Data-Augmentation, Generalization, and a Model's Bias and Robustness

A.1   Data-Augmentation, Regularization and Structural Risk Minimization

Bias-Variance Decomposition. The expected error of a trained model can *always* be decomposed into two terms that can be tune by altering the considered model class and regularization, and a third term which is the inherent measurement noise, that can not be reduced. In fact, the true labels are obtained from $\boldsymbol{y} = f(\boldsymbol{x}) + \epsilon$ with f the true, unknown, data model, and ϵ some irreducible error i.e. coming from measurements or data compression. For the Mean-Squared Error (MSE) we obtain this decomposition as

$$\mathbb{E}_{\epsilon,\boldsymbol{X},\mathbb{D}}\left[\left(\boldsymbol{y} - \hat{f}(\boldsymbol{x};\boldsymbol{D})\right)^2\right] = \mathbb{E}_{\epsilon,\boldsymbol{X},\mathbb{D}}\left[\epsilon^2 + \epsilon\left(f(\boldsymbol{x}) - \hat{f}(\boldsymbol{x};\boldsymbol{D})\right) + \left(f(\boldsymbol{x}) - \hat{f}(\boldsymbol{x};\boldsymbol{D})\right)^2\right]$$

$$= \mathrm{Var}(\epsilon)^2 + \mathbb{E}_{\boldsymbol{X}}\left[\left(f(\boldsymbol{x}) - \mathbb{E}_{\mathbb{D}}\left[\hat{f}(\boldsymbol{x};\boldsymbol{D})\right]\right)^2 - \mathbb{E}_{\mathbb{D}}\left[\hat{f}(\boldsymbol{x};\boldsymbol{D})\right]^2 + \mathbb{E}_{\mathbb{D}}\left[\hat{f}(\boldsymbol{x};\boldsymbol{D})^2\right]\right]$$

$$= \mathrm{Var}(\epsilon)^2 + \mathbb{E}_{\boldsymbol{X}}\left[\underbrace{\left(f(\boldsymbol{x}) - \mathbb{E}_{\mathbb{D}}\left[\hat{f}(\boldsymbol{x};\boldsymbol{D})\right]\right)^2}_{\text{bias}} + \underbrace{\mathrm{Var}_{\mathbb{D}}\left(\hat{f}(\boldsymbol{x};\boldsymbol{D})\right)}_{\text{variance}}\right].$$

Although we only derive here the MSE case, the same can be obtained in the multivariate case and in classification settings [Valentini and Dietterich, 2004, Hastie et al., 2009]. When the model is with low complexity e.g. the model is under-parametrized, or the regularization is applied aggressively, the variance term becomes small and the bias term increases. Conversely, when the model is not regularized and is overparametrized, the variance term increases and the bias term reduces. One strategy to find the best model is offered by structural risk minimization.

Structural Risk Minimization (SRM). As introduced by Vapnik and Chervonenkis [1974], SRM proposes a search strategy to obtain the best model. One first chooses a class of function that $\hat{f}$ must live in, hopefully informed from a priori knowledge e.g. polynomials of degree k, resnet50 DN architecture. Then, one finds a hierarchical construction of nested functional spaces that relate to the function complexity. For example, it could be considering polynomials of increasing degree, up to k, or considering resnet50s with weights being bounded by an increasing constant. Finally, one minimizes the empirical risk (training error) for each model and picks the one with best valid set performances. The valid set performance can be estimated empirically from a subset of the training set that has been set apart before fitting, or from other measures such as the VC-dimension of the trained model [Vapnik and Chervonenkis, 2015]. For example, cross-validating the weight decay parameter of a model corresponds to SRM. We make this connection precise below.

From Data-Augmentation and Weight Decay to Nested Functional Spaces. Regularization is commonly employed during training to prevent overfitting i.e. reduce the model complexity. One might argue that regularization does not *strictly* restrict the model functional space, it simply *favors* simpler models to be used. Yet, it turns out that regularization can be cast as explicitly restricting the parameter space of the model i.e. restricting the functional space of the model.

To see this, let's consider the following loss function to be minimized $\ell(\theta,\gamma)$ that depends of the parameters θ and the dataset $\boldsymbol{D}$. We define the following two optimization problems, one with Tikhonov regularization with amplitude γ and one with a constraint on the space of θ

$$\min_{\theta \in \mathbb{R}^K} \ell(\theta, \boldsymbol{D}) + \gamma\|\theta\|_2^2, \qquad\qquad (P1)$$

$$\min_{\theta \in \mathbb{R}^K : \|\theta\|_2^2 \leq \beta} \ell(\theta, \boldsymbol{D}). \qquad\qquad (P2)$$

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Let's also denote by $\hat{\theta}(\gamma)$ the parameter value that is a global minimum of (P1); if multiple global minimum exist, pick the one with greatest ℓ_2 norm. We now have to solve for θ, λ the following system that results from the Lagrangian, with λ the Lagrange multiplier [Bertsekas, 2014] and s^2 the slack variable of the inequality

$$\nabla_\theta \ell(\theta, \boldsymbol{D}) + 2\lambda\theta = 0 \text{ and } \|\theta\|_2^2 - \beta - s^2 = 0 \text{ and } 2\lambda s = 0,$$

setting $\lambda \leftarrow \gamma$, $\theta \leftarrow \hat{\theta}(\gamma)$, and $\beta \leftarrow \|\hat{\theta}(\gamma)\|_2^2, s \leftarrow 0$ solves the system. As a result, solving the constrained optimization problem with $\beta = \|\hat{\theta}(\gamma)\|_2^2$ and solving the Tikhonov regularized problem with γ coefficient is equivalent. Since we also have that $\|\hat{\theta}(\gamma_1)\|_2^2 \leq \|\hat{\theta}(\gamma_2)\|_2^2$, we obtain that starting from a high value of Tikhonov regularization and gradually reducing it produces nested functional spaces where the model live in. More general results can be obtained in different regularization settings in Kloft et al. [2009], Hastie et al. [2009]. Moving to the case of DA, the same procedure applies. In fact, one can use the results of Phaisangittisagul [2016], LeJeune et al. [2019], Balestriero et al. [2022] to cast DAs such as dropout, and image perturbations as explicit regularizers à la Tikhonov and repeat the above procedure. In fact, DA can be seen as producing a model with lower variance and a bias towards the augmented dataset. Hence, **if the augmented dataset is not aligned with the true underlying data distribution, DA will increase the model's bias**. For results studying DA in the context of structural risk minimization, we refer the reader to Chapelle et al. [2000], Arjovsky et al. [2019], Chen et al. [2020a], Ilse et al. [2021]. In short, it is clear from the above that DA is yet another form of regularization that can be applied for structural risk minimization. Yet, even if DA effectively restrict the functional space of the model, it can be at the cost of producing strong biases, as we empirically observed in Section 3.

A.2 Statistical Test

To further convey our claim, we now propose a formal statistical test [Neyman and Pearson, 1933, Fisher, 1955] on the hypothesis that the per-class accuracy is significantly lower when DA is applied for those classes. A test of significance is a formal procedure for comparing observed data with a claim or hypothesis. In our case we aim to test if the mean accuracy on class y of a model trained without DA is greater than the one obtained with DA. Due to the stochastic optimization process, this accuracy is a random variable even when the dataset is not changed. Hence we define that random variable by $\text{Accu}_y(\mathbb{X})$ and our null hypothesis by $H_0 = \mathbb{E}[\text{Accu}_y(\mathbb{X})] < \mathbb{E}[\text{Accu}_y(\mathbb{X}_{\text{DA}})]$ with $\mathbb{X}$ the original dataset and $\mathbb{X}_{\text{DA}}$ the DA dataset using random crop with $\alpha \in [100, 8]$. A one-sided t-test is used and the form that does not assume equal variances is known as Welch's t-test [Welch, 1947] with statistic $t = \frac{\hat{\mu}(\mathbb{X}_1) - \hat{\mu}(\mathbb{X}_2)}{\sqrt{\hat{\sigma}^2(\mathbb{X}_1) - \hat{\sigma}^2(\mathbb{X}_2)}}$, and with degrees of freedom $\nu = \left(\frac{\hat{\sigma}^2(\mathbb{X}_1)}{N_1} + \frac{\hat{\sigma}^2(\mathbb{X}_2)}{N_2}\right)^2 \left(\frac{\hat{\sigma}^4(\mathbb{X}_1)}{N_1^2(N_2-1)} + \frac{\hat{\sigma}^4(\mathbb{X}_2)}{N_2^2(N_1-1)}\right)^{-1}$. Note that one could formulate this problem in term of average treatment effect, where the treatment is the application of DA and the outcome is the accuracy on class y of the trained model. Doing so, one could measure the per-sample bias from the Conditional Treatment Effect, however we limit ourselves to a per-class study and leave such fine-grained analysis for future work.

B   Proof of Theorem 1

Proof. To streamline our derivations and without loss of generality, we first impose that $\mathcal{T}_{-\alpha}$ inverts the action of $\mathcal{T}_\alpha$, that $\mathcal{T}_0$ acts as the identity mapping and that $\mathcal{T}_\alpha \circ \mathcal{T}_\beta = \mathcal{T}_{\alpha+\beta}$. In short, we have a *group* structure that allows us to define the following equivalence class $\sim$ that is positive iff two images are related by a transformation, formally defined as

$$\boldsymbol{u} \sim \boldsymbol{v} \iff \exists \alpha : T_\alpha(\boldsymbol{u}) = \boldsymbol{v}, \tag{2}$$

which is *reflexive* ($\boldsymbol{u} \sim \boldsymbol{u}$ with $\alpha = 0$), *symmetric* ($\boldsymbol{u} \sim \boldsymbol{v}$ with α implies that $\boldsymbol{v} \sim \boldsymbol{u}$ with $-\alpha$), and *transitive* ($\boldsymbol{u} \sim \boldsymbol{v}$ with α and $\boldsymbol{v} \sim \boldsymbol{w}$ with β implies that $\boldsymbol{u} \sim \boldsymbol{w}$ with $\alpha + \beta$).

Lastly, given a set of samples $\mathbb{X}$, we define the following g mapping that will decompose $\mathbb{X}$ into a set of generators/prototypes $\mu_1, \mu_2, \dots$ and corresponding DA parameters sets $\mathbb{A}_1, \mathbb{A}_2, \dots$ so that when applying all the DA parameters from $\mathbb{A}_i$ to μ_i, and going that for all i recover exactly $\mathbb{X}$. We define those formally as

$$g(\mathbb{X}) \mapsto \{(\mu_1, \mathbb{A}_1), (\mu_2, \mathbb{A}_2), \dots\} \text{ s.t. } \cup_{(\mu, \mathbb{A}) \in g(\mathbb{X})} \{T_\alpha(\mu), \forall \alpha \in \mathbb{A}\} = \mathbb{X}. \tag{3}$$

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Note that there is a bijection between the pairs given by $g(\mathbb{X})$ and the set of equivalent samples defined by $\mathbb{X}/\sim$. Using this, we obtain the following decomposition of the empirical error

$$\mathcal{L} = \mathbb{E}_{\boldsymbol{X}}\left[\|f^*(\boldsymbol{x}) - f_\theta(\boldsymbol{x})\|\right] = \sum_{(\mu,\mathbb{A})\in g(\mathbb{X})} \sum_{\alpha\in\mathbb{A}} \|f^*(\mathcal{T}_\alpha(\mu)) - f_\theta(\mathcal{T}_\alpha(\mu))\| p(\mathcal{T}_\alpha(\mu)).$$

Given the above, we now simply split a dataset $\mathbb{X}$ into two, one that contains training samples, and one that contains everything else. Without loss of generality we assume that $p(\mathcal{T}_\alpha(\mu))$ is a constant κ i.e. that the distribution of samples is uniform on the data manifold. If not, the below result still holds as long as the incorrect DA occurs for samples with nonzero probability of occurring. Using the fact that the model has 0 training error, we obtain that the approximation error between f^* and f_θ can not be 0 unless the DA is perfectly aligned with the level-sets of f^* as in

$$\frac{\mathcal{L}}{\kappa} = \sum_{(\mu,\mathbb{A})\in g(\mathbb{X}\setminus\mathbb{X}_{\text{train}})}\sum_{\alpha\in\mathbb{A}} \|f^*(\mathcal{T}_\alpha(\mu)) - f_\theta(\mathcal{T}_\alpha(\mu))\|_2^2 + \sum_{(\mu,\mathbb{A})\in g(\mathbb{X}_{\text{train}})}\sum_{\alpha\in\mathbb{A}} \|f^*(\mathcal{T}_\alpha(\mu)) - f_\theta(\mathcal{T}_\alpha(\mu))\|_2^2$$

$$\geq \sum_{(\mu,\mathbb{A})\in g(\mathbb{X}_{\text{train}})}\sum_{\alpha\in\mathbb{A}} \|f^*(\mathcal{T}_\alpha(\mu)) - f_\theta(\mathcal{T}_\alpha(\mu))\|_2^2$$

$$\geq \sum_{(\mu,\mathbb{A})\in g(\mathbb{X}_{\text{train}})}\sum_{\alpha\in\mathbb{A}} \|f^*(\mathcal{T}_\alpha(\mu)) - \text{const}\|_2^2 \quad \text{(since zero training error for } f_\theta),$$

$$>0$$

where the second to last equality assumes that the model has 0 training error, and will thus predict the same constant for all DA version of the same sample. The last step follows if the DA does not respect the true level-sets of the true function f^*. □

C Additional Figures

D Resnet50 Per-Class Accuracy Difference (with - without random crop)

class	top1 diff.	class	top1 diff.	class	top1 diff.	class	top1 diff.	class	top1 diff.
academic gown	-19.88	barn spider	-19.57	sunglass	-10.97	Windsor tie	-10.22	overskirt	-10.17
tailed frog	-9.9	assault rifle	-9.73	chain	-8.23	velvet	-8.12	tobacco shop	-7.31
consomme	-7.26	seashore	-6.88	screen	-6.71	monastery	-6.58	strawberry	-6.54
quilt	-6.53	wool	-6.24	green mamba	-5.39	bulletproof vest	-5.3	lemon	-5.25
English foxhound	-5.15	French loaf	-5.15	vault	-5.05	chain mail	-4.97	redbone	-4.86
polecat	-4.83	terrapin	-4.8	pomegranate	-4.73	maillot	-4.53	black-and-tan co	-4.34
sidewinder	-4.2	titi	-3.56	bighorn	-3.52	suit	-3.51	breastplate	-3.42
beaker	-3.37	rock python	-3.33	Siberian husky	-3.31	standard schnauz	-3.23	rock beauty	-3.18
cliff	-2.99	Walker hound	-2.81	spaghetti squash	-2.75	collie	-2.6	frying pan	-2.55
pier	-2.52	slide rule	-2.46	theater curtain	-2.4	rule	-2.29	cassette player	-2.27
komondor	-2.26	acoustic guitar	-2.17	prairie chicken	-2.14	plate rack	-2.07	ear	-2.06
shoji	-2.05	wire-haired fox	-1.9	maillot	-1.89	long-horned beet	-1.83	Sussex spaniel	-1.81
Sealyham terrier	-1.64	sax	-1.62	honeycomb	-1.58	Japanese spaniel	-1.51	grey whale	-1.49
cucumber	-1.47	alp	-1.46	envelope	-1.28	whiptail	-1.27	otterhound	-1.24
tiger cat	-1.23	affenpinscher	-1.15	fox squirrel	-1.13	barrel	-1.05	gazelle	-1.01
zebra	-0.95	red-breasted mer	-0.9	indri	-0.9	hen-of-the-woods	-0.88	lipstick	-0.86
tile roof	-0.84	lorikeet	-0.63	viaduct	-0.52	chocolate sauce	-0.47	prayer rug	-0.38
passenger car	-0.37	Weimaraner	-0.35	daisy	-0.32	potpie	-0.31	loudspeaker	-0.31
horned viper	-0.29	peacock	-0.29	red fox	-0.27	porcupine	-0.22	red wine	-0.21
monarch	-0.21	window shade	-0.21	patas	-0.2	golf ball	-0.16	trench coat	-0.15
valley	-0.11	hand-held comput	-0.11	chiffonier	-0.01	yellow lady's sl	0	Norwich terrier	0.02
chow	0.04	palace	0.1	sea anemone	0.1	lakeside	0.12	jay	0.12
eggnog	0.12	freight car	0.14	great grey owl	0.16	trombone	0.18	redshank	0.19
ox	0.2	sloth bear	0.21	mink	0.21	vine snake	0.23	pelican	0.24
Appenzeller	0.24	little blue hero	0.29	jackfruit	0.31	leatherback turt	0.32	eft	0.34
Dandie Dinmont	0.38	damselfly	0.41	yawl	0.53	thresher	0.57	ground beetle	0.57
black stork	0.63	magpie	0.65	notebook	0.66	spatula	0.68	Loafer	0.7
hartebeest	0.71	white wolf	0.71	king penguin	0.72	steel arch bridg	0.76	jacamar	0.8
stopwatch	0.82	Band Aid	0.86	car wheel	0.87	stone wall	0.94	black grouse	1.03
spider web	1.06	Saluki	1.06	school bus	1.1	hog	1.1	dugong	1.11
container ship	1.12	lumbermill	1.14	bannister	1.15	kuvasz	1.15	giant panda	1.16
broccoli	1.17	Bouvier des Flan	1.18	Norwegian elkhou	1.25	lifeboat	1.28	spiny lobster	1.28
water ouzel	1.31	pajama	1.33	abacus	1.34	typewriter keybo	1.37	indigo bunting	1.4
tabby	1.42	sleeping bag	1.42	groenendael	1.43	digital clock	1.44	beaver	1.48
quill	1.49	isopod	1.51	papillon	1.51	snowmobile	1.51	American lobster	1.52
pick	1.54	sunscreen	1.6	window screen	1.6	armadillo	1.6	Blenheim spaniel	1.61
bittern	1.64	gar	1.65	drumstick	1.65	bald eagle	1.65	night snake	1.7
European gallinu	1.7	agaric	1.74	comic book	1.75	revolver	1.86	brambling	1.87
rapeseed	1.87	Tibetan mastiff	1.9	scoreboard	1.9	nematode	1.91	cauliflower	1.91
flamingo	1.92	cocktail shaker	1.92	proboscis monkey	1.94	wood rabbit	1.94	grille	1.95
Afghan hound	1.98	muzzle	1.98	Samoyed	1.98	ostrich	2	abaya	2.03

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class	top1 diff.	class	top1 diff.	class	top1 diff.	class	top1 diff.	class	top1 diff.	class	top1 diff.
earthstar	2.04	bee eater	2.05	frilled lizard	2.07	pole	2.07	slot	2.09
barometer	2.1	harp	2.11	butternut squash	2.12	siamang	2.14	screwdriver	2.15
flat-coated retr	2.15	goldfish	2.17	tape player	2.23	lampshade	2.23	jaguar	2.25
flatworm	2.27	meat loaf	2.29	Model T	2.3	harvestman	2.3	electric ray	2.31
dial telephone	2.32	Pomeranian	2.33	solar dish	2.36	cassette	2.36	cardoon	2.37
neck brace	2.37	Komodo dragon	2.41	orange	2.44	weasel	2.44	oxygen mask	2.45
black swan	2.45	cabbage butterfl	2.45	albatross	2.46	trailer truck	2.55	crane	2.55
Irish setter	2.57	Leonberg	2.6	sports car	2.62	worm fence	2.63	paddle	2.63
bell pepper	2.64	studio couch	2.65	mountain bike	2.67	running shoe	2.69	brassiere	2.7
coucal	2.7	parachute	2.71	grey fox	2.73	streetcar	2.77	toy terrier	2.77
guenon	2.8	space heater	2.81	limpkin	2.82	platypus	2.83	ballplayer	2.83
tiger shark	2.83	sulphur butterfl	2.86	gyromitra	2.88	American egret	2.9	Scotch terrier	2.94
Ibizan hound	2.94	Persian cat	2.96	Irish water span	2.99	Yorkshire terrie	3.02	Mexican hairless	3.02
bee	3.04	mixing bowl	3.06	ant	3.07	white stork	3.1	bell cote	3.11
jack-o'-lantern	3.12	swimming trunks	3.14	odometer	3.16	broom	3.17	brain coral	3.17
speedboat	3.22	lacewing	3.24	limousine	3.26	king crab	3.28	head cabbage	3.28
Tibetan terrier	3.29	wild boar	3.29	walking stick	3.3	grasshopper	3.3	French horn	3.3
lesser panda	3.31	clumber	3.34	dough	3.37	African grey	3.39	partridge	3.43
Newfoundland	3.43	bath towel	3.44	plane	3.44	whiskey jug	3.45	vulture	3.45
American coot	3.46	radiator	3.48	goldfinch	3.49	bloodhound	3.5	dalmatian	3.5
robin	3.52	ping-pong ball	3.53	liner	3.57	combination lock	3.57	barbell	3.63
hay	3.63	Rottweiler	3.65	water tower	3.67	dingo	3.68	centipede	3.68
Irish terrier	3.68	bullet train	3.68	Norfolk terrier	3.68	remote control	3.7	drilling platfor	3.7
green lizard	3.73	ballpoint	3.73	letter opener	3.74	macaw	3.74	totem pole	3.76
sombrero	3.79	dhole	3.79	barracouta	3.8	Arctic fox	3.82	Airedale	3.83
junco	3.83	Saint Bernard	3.85	vestment	3.86	keeshond	3.87	paper towel	3.87
axolotl	3.88	Old English shee	3.89	potter's wheel	3.9	curly-coated ret	3.9	scabbard	3.94
bassoon	3.96	hook	3.98	Boston bull	4	borzoi	4	African elephant	4.01
African hunting	4.03	skunk	4.04	three-toed sloth	4.06	Shih-Tzu	4.07	Gila monster	4.08
crossword puzzle	4.1	coral fungus	4.1	cliff dwelling	4.12	African crocodil	4.13	organ	4.14
bustard	4.15	projectile	4.17	fire screen	4.18	Pekinese	4.19	hippopotamus	4.19
mousetrap	4.22	EntleBucher	4.26	rock crab	4.27	Bernese mountain	4.28	corn	4.3
sock	4.32	pineapple	4.32	lionfish	4.34	volcano	4.37	stinkhorn	4.39
German shepherd	4.39	sorrel	4.4	echidna	4.4	folding chair	4.4	snow leopard	4.41
brown bear	4.45	orangutan	4.46	racer	4.47	Kerry blue terri	4.48	Indian elephant	4.53
West Highland wh	4.56	cougar	4.6	Bedlington terri	4.62	carbonara	4.62	spoonbill	4.62
Eskimo dog	4.64	zucchini	4.65	balloon	4.65	Welsh springer s	4.67	hummingbird	4.72
Indian cobra	4.72	photocopier	4.73	cloak	4.76	apiary	4.76	trolleybus	4.77
artichoke	4.78	library	4.78	hourglass	4.79	airliner	4.82	megalith	4.83
spotlight	4.84	minibus	4.85	laptop	4.88	Petri dish	4.93	puck	4.95
common newt	4.95	house finch	4.97	ringlet	4.97	coffee mug	4.98	sundial	5.01
gondola	5.02	Chihuahua	5.04	moving van	5.06	shopping cart	5.09	sulphur-crested	5.09
knot	5.09	trifle	5.11	trimaran	5.13	dishrag	5.17	Australian terri	5.17
malamute	5.19	Chesapeake Bay r	5.22	drake	5.23	whippet	5.24	missile	5.24
leopard	5.24	European fire sa	5.26	screw	5.27	miniskirt	5.3	leaf beetle	5.31
briard	5.33	computer keyboar	5.36	tiger	5.36	miniskirt	5.37	Maltese dog	5.38
cuirass	5.39	sturgeon	5.41	tub	5.42	loupe	5.42	ibex	5.43
trilobite	5.45	kelpie	5.46	bathing cap	5.46	bottlecap	5.47	toy poodle	5.5
ambulance	5.5	Great Dane	5.51	rifle	5.52	panpipe	5.54	crate	5.55
stole	5.62	red-backed sandp	5.62	Brittany spaniel	5.64	scorpion	5.65	chickadee	5.71
holster	5.71	mobile home	5.73	promontory	5.74	toucan	5.76	half track	5.77
vending machine	5.81	tench	5.81	boxer	5.82	wing	5.83	oystercatcher	5.84
ruddy turnstone	5.84	park bench	5.84	water jug	5.85	Gordon setter	5.89	magnetic compass	5.89
English setter	5.96	banjo	5.99	cradle	5.99	steel drum	5.99	analog clock	5.99
sandbar	6	coil	6	pickelhaube	6	gong	6.03	triumphal arch	6.05
Great Pyrenees	6.06	ski mask	6.11	plunger	6.11	sliding door	6.12	Arabian camel	6.12
basketball	6.16	ocarina	6.16	jigsaw puzzle	6.16	amphibian	6.16	red wolf	6.18
schipperke	6.18	lynx	6.2	pedestal	6.2	maze	6.21	mask	6.21
gorilla	6.23	alligator lizard	6.23	milk can	6.23	wall clock	6.23	barber chair	6.27
weevil	6.29	malinois	6.3	steam locomotive	6.32	buckeye	6.36	French bulldog	6.36
beacon	6.37	black and gold g	6.37	wardrobe	6.37	bicycle-built-fo	6.37	cowboy boot	6.42
sea lion	6.45	fire engine	6.47	fiddler crab	6.51	beagle	6.52	teddy	6.54
slug	6.54	cock	6.55	geyser	6.55	water snake	6.59	Granny Smith	6.6
fig	6.61	warthog	6.63	Egyptian cat	6.63	hair spray	6.64	carpenter's kit	6.65
kit fox	6.66	ice bear	6.69	catamaran	6.69	maypole	6.71	ruffed grouse	6.74
crane	6.74	snowplow	6.75	American Staffor	6.78	triceratops	6.81	bib	6.82
hair slide	6.82	hamster	6.9	German short-hai	6.9	paddlewheel	6.91	pool table	6.92
miniature poodle	6.93	thunder snake	6.95	knee pad	6.97	file	6.97	Dungeness crab	6.97
tarantula	6.98	parallel bars	6.99	aircraft carrier	7	mosquito net	7.01	face powder	7.03
racket	7.04	snorkel	7.06	cleaver	7.07	tusker	7.11	packet	7.11
football helmet	7.16	handkerchief	7.16	bearskin	7.17	nipple	7.17	hoopskirt	7.18
monitor	7.2	washer	7.2	quail	7.2	Italian greyhoun	7.21	rugby ball	7.25
hornbill	7.27	nail	7.28	dam	7.28	guillotine	7.3	lens cap	7.33
rotisserie	7.36	chain saw	7.4	street sign	7.4	military uniform	7.45	silky terrier	7.48
spotted salaman	7.48	disk brake	7.49	kite	7.49	soccer ball	7.53	suspension bridg	7.55
lotion	7.56	goblet	7.57	kimono	7.63	fireboat	7.64	hognose snake	7.65
sea slug	7.65	hip	7.65	violin	7.66	cheetah	7.66	mosque	7.68
forklift	7.7	book jacket	7.71	entertainment ce	7.72	marmot	7.73	mashed potato	7.74
fountain	7.75	bison	7.77	tank	7.77	radio telescope	7.78	admiral	7.78
hatchet	7.79	fly	7.81	stretcher	7.81	colobus	7.81	jean	7.83
ski	7.83	electric fan	7.87	Angora	7.87	pirate	7.88	stupa	7.9
prison	7.91	tennis ball	7.98	langur	7.98	capuchin	7.98	dogsled	8.01
baseball	8.03	torch	8.03	feather boa	8.06	horizontal bar	8.08	banana	8.09
thimble	8.09	lion	8.1	safety pin	8.11	jinrikisha	8.13	bathtub	8.16
throne	8.18	pretzel	8.18	grocery store	8.2	jellyfish	8.22	common iguana	8.22
Border terrier	8.26	tripod	8.3	hotdog	8.31	thatch	8.32	boa constrictor	8.33
dock	8.33	bobsled	8.36	rhinoceros beetl	8.37	cello	8.4	bluetick	8.42
African chameleo	8.43	gibbon	8.43	Cardigan	8.43	dowitcher	8.44	Siamese cat	8.45
Brabancon griffo	8.45	bull mastiff	8.49	goose	8.5	starfish	8.5	shower curtain	8.55
matchstick	8.55	bow	8.56	carousel	8.57	cardigan	8.57	pug	8.58
dragonfly	8.61	banded gecko	8.62	wombat	8.63	diaper	8.65	great white shar	8.65

18

class	top1 diff.	class	top1 diff.	class	top1 diff.	class	top1 diff.	class	top1 diff.
space shuttle	8.7	snail	8.74	bulbul	8.75	corkscrew	8.75	basenji	8.81
umbrella	8.83	ptarmigan	8.84	marimba	8.92	dung beetle	8.93	oscilloscope	8.94
pot	8.99	modem	9.03	electric guitar	9.03	pinwheel	9.04	gown	9.04
cockroach	9.05	mushroom	9.08	CD player	9.1	brass	9.11	waffle iron	9.13
bolete	9.13	Lhasa	9.13	golden retriever	9.14	barn	9.17	Staffordshire bu	9.18
leafhopper	9.18	hen	9.2	llama	9.22	beach wagon	9.23	standard poodle	9.24
wine bottle	9.28	gasmask	9.31	swing	9.32	horse cart	9.32	electric locomot	9.35
recreational veh	9.35	eel	9.35	dome	9.41	tiger beetle	9.44	oboe	9.45
American chamele	9.46	plastic bag	9.47	beer bottle	9.52	king snake	9.54	bubble	9.59
dining table	9.6	tick	9.64	flagpole	9.65	toilet tissue	9.7	black widow	9.72
sea snake	9.78	projector	9.8	hammerhead	9.82	mailbox	9.83	soft-coated whea	9.95
Pembroke	10.02	hare	10.03	chambered nautil	10.03	boathouse	10.04	Polaroid camera	10.05
mouse	10.07	cornet	10.08	butcher shop	10.11	tow truck	10.11	miniature schnau	10.12
coho	10.19	switch	10.23	car mirror	10.23	manhole cover	10.23	hard disc	10.26
guacamole	10.26	espresso	10.31	Scottish deerhou	10.34	web site	10.44	greenhouse	10.46
chimpanzee	10.5	beer glass	10.5	grand piano	10.57	flute	10.58	cocker spaniel	10.59
desk	10.59	lawn mower	10.61	bagel	10.62	vizsla	10.69	croquet ball	10.7
water buffalo	10.73	mongoose	10.74	pop bottle	10.74	Irish wolfhound	10.77	strainer	10.77
accordion	10.78	warplane	10.78	upright	10.81	Rhodesian ridgeb	10.81	wallaby	10.82
cicada	10.83	digital watch	10.89	planetarium	10.97	bolo tie	10.99	cannon	11
obelisk	11.02	menu	11.02	Greater Swiss Mo	11.03	coral reef	11.06	koala	11.07
go-kart	11.11	anemone fish	11.12	chainlink fence	11.13	bullfrog	11.16	bookcase	11.17
basset	11.21	marmoset	11.24	cellular telepho	11.31	china cabinet	11.37	ashcan	11.46
sweatshirt	11.48	space bar	11.49	table lamp	11.53	paintbrush	11.53	wreck	11.53
refrigerator	11.55	dishwasher	11.55	microwave	11.56	American black b	11.57	hot pot	11.57
pill bottle	11.58	loggerhead	11.63	seat belt	11.63	spider monkey	11.66	mud turtle	11.66
soap dispenser	11.67	bakery	11.68	doormat	11.68	Doberman	11.75	hamper	11.77
guinea pig	11.77	punching bag	11.8	police van	11.9	killer whale	11.91	miniature pinsch	11.94
reflex camera	11.95	rubber eraser	11.96	candle	11.99	howler monkey	12.05	traffic light	12.07
cup	12.17	pizza	12.22	mountain tent	12.25	stove	12.32	vase	12.33
ladybug	12.35	balance beam	12.39	whistle	12.39	caldron	12.42	garter snake	12.51
motor scooter	12.66	Shetland sheepdo	12.73	binder	12.75	padlock	12.77	hyena	12.81
toyshop	12.86	impala	12.87	Madagascar cat	12.87	microphone	12.87	Border collie	12.88
mailbag	12.97	cab	13	sea urchin	13.02	acorn	13.08	Lakeland terrier	13.1
crash helmet	13.11	stingray	13.12	canoe	13.2	carton	13.21	rain barrel	13.28
tree frog	13.28	pencil box	13.29	American alligat	13.3	can opener	13.36	coyote	13.37
hand blower	13.47	fountain pen	13.63	bucket	13.65	golfcart	13.66	picket fence	13.69
shovel	13.72	chiton	13.77	cricket	13.81	pencil sharpener	13.83	cairn	13.91
custard apple	13.92	Christmas stocki	13.94	yurt	13.96	ringneck snake	13.96	maraca	14.02
garbage truck	14.06	lycaenid	14.12	drum	14.13	rocking chair	14.13	dumbbell	14.19
barrow	14.2	crutch	14.21	saltshaker	14.24	fur coat	14.32	moped	14.41
shower cap	14.46	wok	14.5	syringe	14.51	sarong	14.53	parking meter	14.55
English springer	14.67	badger	14.85	iPod	14.88	altar	14.9	iron	14.92
wig	14.94	Crock Pot	14.97	washbasin	15.03	necklace	15.08	clog	15.08
scuba diver	15.16	stethoscope	15.16	chest	15.16	harmonica	15.21	minivan	15.26
ram	15.43	wallet	15.47	gas pump	15.48	four-poster	15.5	plow	15.5
diamondback	15.51	meerkat	15.52	wooden spoon	15.57	confectionery	15.63	sandal	15.65
water bottle	15.65	submarine	15.7	crayfish	15.77	pay-phone	15.81	bassinet	15.83
black-footed fer	15.91	puffer	16.05	sewing machine	16.1	ladle	16.12	binoculars	16.18
patio	16.3	burrito	16.38	oil filter	16.38	reel	16.53	sea cucumber	16.64
television	16.65	plate	16.68	toaster	16.7	lab coat	16.81	baboon	16.87
green snake	16.95	power drill	16.97	joystick	16.98	timber wolf	16.98	measuring cup	17.03
volleyball	17.03	backpack	17.05	conch	17.07	shoe shop	17.08	buckle	17.1
jeep	17.2	cash machine	17.22	box turtle	17.25	giant schnauzer	17.29	Labrador retriev	17.38
acorn squash	17.4	squirrel monkey	17.49	teapot	17.5	turnstile	17.56	cheeseburger	17.65
breakwater	17.7	church	17.74	mortar	17.89	spindle	18.29	printer	18.3
bikini	18.32	lighter	18.44	cinema	18.46	chime	18.63	pitcher	18.7
mantis	18.73	tractor	18.76	crib	18.8	barbershop	18.8	tricycle	18.96
unicycle	19.07	home theater	19.13	hermit crab	19.2	radio	19.29	piggy bank	19.37
castle	19.46	restaurant	19.52	shopping basket	19.82	sunglasses	19.84	soup bowl	19.96
agama	20.49	vacuum	20.53	harvester	20.57	birdhouse	20.69	perfume	20.97
bow tie	21.03	ice cream	21.16	shield	21.39	medicine chest	21.98	cowboy hat	22.56
coffeepot	22.57	ice lolly	22.69	Dutch oven	22.75	bookshop	22.9	apron	22.98
poncho	23.41	mitten	23.6	groom	23.63	swab	23.72	otter	23.91
bonnet	24.37	schooner	24.54	stage	24.56	tray	25.09	garden spider	25.15
toilet seat	25.8	desktop computer	25.83	espresso maker	26.21	purse	26.84	scale	26.87
convertible	26.98	oxcart	27.62	macaque	27.77	wolf spider	28.4	mortarboard	29.46
hammer	29.5	pillow	29.56	jersey	29.87	safe	30.35	pickup	33.25

E Resnet50 Per-Class Accuracy Difference (with - without weight decay)

class	top1 diff.	class	top1 diff.	class	top1 diff.	class	top1 diff.	class	top1 diff.
gong	-26.41	black and gold g	-18.7	partridge	-18	projectile	-17.31	microphone	-16.79
desktop computer	-14.99	American chamele	-13.9	rifle	-12.6	chime	-12.5	mailbag	-12.42
syringe	-11.52	CD player	-11.33	rubber eraser	-11.19	can opener	-11.11	pencil sharpener	-10.9
cornet	-10.73	motor scooter	-10.65	strainer	-10.63	garden spider	-10.6	shovel	-10.55
plunger	-10.55	mousetrap	-10.09	ice lolly	-9.7	vacuum	-9.65	doormat	-9.6
soap dispenser	-9.51	wine bottle	-9.4	breakwater	-9.38	spotlight	-9.15	modem	-9.12
radio	-8.98	sidewinder	-8.97	banana	-8.85	damselfly	-8.73	envelope	-8.69
television	-8.64	brassiere	-8.5	matchstick	-8.46	coffeepot	-8.43	water jug	-8.4
pitcher	-8.4	lighter	-8.34	tiger shark	-8.31	dining table	-8.26	Labrador retriev	-8.23
miniskirt	-8.2	bolete	-8.1	lakeside	-8.1	redbone	-8.07	grocery store	-8.03
pencil box	-8.01	African crocodil	-8	coffee mug	-7.93	ear	-7.91	wallet	-7.89
dome	-7.83	mouse	-7.79	vase	-7.79	toy poodle	-7.77	maillot	-7.76
hammer	-7.75	bow	-7.73	book jacket	-7.68	face powder	-7.67	tractor	-7.59
whippet	-7.58	ballpoint	-7.54	ruffed grouse	-7.5	English setter	-7.4	Eskimo dog	-7.4
spatula	-7.29	cannon	-7.22	birdhouse	-7.21	paintbrush	-7.18	Chihuahua	-7.18

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class	top1 diff.	class	top1 diff.	class	top1 diff.	class	top1 diff.	class	top1 diff.
Band Aid	-7.17	cuirass	-7.17	mortar	-7.13	paper towel	-7.13	cassette player	-7.1
violin	-7.01	rugby ball	-6.99	maillot	-6.98	slug	-6.97	long-horned beet	-6.97
sunglasses	-6.97	shield	-6.96	basset	-6.93	muzzle	-6.91	harvester	-6.9
wolf spider	-6.9	apron	-6.81	meerkat	-6.72	hand blower	-6.67	seat belt	-6.61
accordion	-6.6	mink	-6.55	flute	-6.55	gown	-6.47	mashed potato	-6.47
hammerhead	-6.46	packet	-6.4	barber chair	-6.4	restaurant	-6.33	red wolf	-6.32
reel	-6.22	badger	-6.2	cleaver	-6.2	pop bottle	-6.16	bluetick	-6.16
macaque	-6.15	Brabancon griffo	-6.13	swimming trunks	-6.11	nail	-6.11	bucket	-6.09
spindle	-6.06	bow tie	-6.03	quill	-5.98	plate	-5.97	breastplate	-5.95
otter	-5.94	eel	-5.94	common newt	-5.93	Dungeness crab	-5.92	safe	-5.89
drumstick	-5.83	dumbbell	-5.82	corkscrew	-5.82	hook	-5.74	rotisserie	-5.72
warplane	-5.66	clog	-5.64	coyote	-5.61	stretcher	-5.59	Staffordshire bu	-5.59
kit fox	-5.57	street sign	-5.55	Yorkshire terrie	-5.54	lotion	-5.53	agaric	-5.5
mixing bowl	-5.47	beaker	-5.39	racket	-5.38	safety pin	-5.37	basenji	-5.35
Irish terrier	-5.32	catamaran	-5.32	langur	-5.28	switch	-5.28	apiary	-5.25
custard apple	-5.21	plastic bag	-5.2	electric guitar	-5.19	wild boar	-5.17	eggnog	-5.16
stethoscope	-5.13	mud turtle	-5.12	fly	-5.12	diaper	-5.08	notebook	-5.04
dial telephone	-5.01	pajama	-4.95	solar dish	-4.95	ashcan	-4.87	ant	-4.85
soccer ball	-4.83	Lakeland terrier	-4.8	swab	-4.77	toyshop	-4.75	mitten	-4.74
joystick	-4.72	black-footed fer	-4.72	patio	-4.7	bonnet	-4.67	maraca	-4.65
home theater	-4.65	crane	-4.63	sandal	-4.6	cloak	-4.6	hen	-4.59
water buffalo	-4.59	tray	-4.58	cricket	-4.51	oboe	-4.47	teddy	-4.46
diamondback	-4.45	tile roof	-4.44	hand-held comput	-4.44	cowboy boot	-4.44	boxer	-4.43
wok	-4.42	fountain	-4.42	standard poodle	-4.4	Maltese dog	-4.4	pier	-4.35
trombone	-4.33	cockroach	-4.33	prison	-4.33	computer keyboar	-4.32	studio couch	-4.3
West Highland wh	-4.29	Tibetan terrier	-4.28	Saint Bernard	-4.27	French loaf	-4.27	printer	-4.27
cowboy hat	-4.13	scabbard	-4.13	typewriter keybo	-4.1	beagle	-4.08	tusker	-4.04
barrel	-4.03	centipede	-3.95	worm fence	-3.93	American black b	-3.92	crash helmet	-3.92
tiger cat	-3.92	timber wolf	-3.89	pot	-3.86	bulbul	-3.86	kite	-3.85
electric locomot	-3.85	wreck	-3.84	water bottle	-3.83	wardrobe	-3.83	thunder snake	-3.83
chocolate sauce	-3.8	Bernese mountain	-3.78	Angora	-3.78	stage	-3.77	soup bowl	-3.76
coho	-3.76	conch	-3.72	space heater	-3.71	Border collie	-3.71	pineapple	-3.7
squirrel monkey	-3.69	Pomeranian	-3.68	hyena	-3.67	cup	-3.67	neck brace	-3.65
tiger	-3.65	bloodhound	-3.64	mongoose	-3.61	leafhopper	-3.58	pool table	-3.58
hair slide	-3.57	crutch	-3.54	entertainment ce	-3.51	mask	-3.48	tick	-3.44
Pembroke	-3.42	vestment	-3.42	pill bottle	-3.4	bakery	-3.4	dishrag	-3.4
cocker spaniel	-3.36	window screen	-3.35	barbershop	-3.3	lumbermill	-3.3	espresso maker	-3.29
handkerchief	-3.27	Brittany spaniel	-3.26	acorn squash	-3.22	piggy bank	-3.22	loudspeaker	-3.21
dingo	-3.21	church	-3.19	spider web	-3.19	washbasin	-3.19	park bench	-3.17
bee	-3.17	tree frog	-3.15	goblet	-3.13	thresher	-3.09	stone wall	-3.07
puffer	-3.06	porcupine	-3.05	Italian greyhoun	-3.05	anemone fish	-3.04	brown bear	-3.04
crayfish	-3.03	loupe	-3	knee pad	-3	jinrikisha	-2.98	pick	-2.96
gasmask	-2.95	wallaby	-2.95	Siamese cat	-2.94	viaduct	-2.93	night snake	-2.93
leaf beetle	-2.92	necklace	-2.9	llama	-2.9	banded gecko	-2.88	echidna	-2.86
Scottish deerhou	-2.85	African hunting	-2.85	Greater Swiss Mo	-2.84	hare	-2.84	desk	-2.83
barrow	-2.82	wool	-2.81	mortarboard	-2.81	caldron	-2.8	banjo	-2.79
axolotl	-2.78	photocopier	-2.75	plate rack	-2.74	washer	-2.71	pillow	-2.71
walking stick	-2.7	Petri dish	-2.7	American lobster	-2.69	butternut squash	-2.67	red-backed sandp	-2.67
mosquito net	-2.67	liner	-2.66	cardigan	-2.63	wall clock	-2.62	vending machine	-2.62
screwdriver	-2.61	running shoe	-2.6	malinois	-2.6	rhinoceros beetl	-2.59	African chameleo	-2.58
hamper	-2.57	beach wagon	-2.54	bassoon	-2.51	garter snake	-2.51	Arctic fox	-2.48
nipple	-2.47	military uniform	-2.46	vulture	-2.45	triceratops	-2.45	dam	-2.44
jersey	-2.44	measuring cup	-2.4	sarong	-2.4	beaver	-2.39	paddle	-2.38
little blue hero	-2.38	ibex	-2.37	shower cap	-2.35	sea cucumber	-2.34	drilling platfor	-2.33
rule	-2.32	fire screen	-2.31	brambling	-2.3	vine snake	-2.27	African elephant	-2.27
Newfoundland	-2.25	football helmet	-2.24	recreational veh	-2.23	abacus	-2.23	knot	-2.21
Kerry blue terri	-2.18	broom	-2.18	Border terrier	-2.18	Appenzeller	-2.17	ski mask	-2.15
ram	-2.15	gas pump	-2.1	howler monkey	-2.08	platypus	-2.08	yurt	-2.02
purse	-2.02	bannister	-2.01	leopard	-2	guenon	-2	electric ray	-2
snail	-2	shopping basket	-1.99	pug	-1.96	ballplayer	-1.91	borzoi	-1.9
stole	-1.87	bison	-1.85	steel drum	-1.85	fireboat	-1.85	Blenheim spaniel	-1.85
turnstile	-1.8	harmonica	-1.8	bighorn	-1.8	skunk	-1.79	panpipe	-1.78
punching bag	-1.77	Mexican hairless	-1.77	tobacco shop	-1.77	tricycle	-1.77	guillotine	-1.75
parachute	-1.74	prairie chicken	-1.71	fountain pen	-1.69	rain barrel	-1.68	white stork	-1.68
coil	-1.67	albatross	-1.65	carton	-1.65	hog	-1.63	reflex camera	-1.61
hamster	-1.58	bubble	-1.58	water snake	-1.57	chest	-1.57	wooden spoon	-1.53
shoji	-1.53	burrito	-1.52	power drill	-1.51	swing	-1.5	corn	-1.49
volleyball	-1.48	potter's wheel	-1.47	electric fan	-1.44	gyromitra	-1.42	binder	-1.41
radiator	-1.4	ladle	-1.4	boa constrictor	-1.39	toucan	-1.38	guinea pig	-1.37
pole	-1.37	acoustic guitar	-1.36	rock crab	-1.32	combination lock	-1.3	shoe shop	-1.29
digital clock	-1.28	holster	-1.27	minivan	-1.26	Afghan hound	-1.23	buckle	-1.22
hard disc	-1.18	butcher shop	-1.18	barn spider	-1.18	bassinet	-1.17	marmot	-1.16
sweatshirt	-1.14	armadillo	-1.13	trilobite	-1.13	stopwatch	-1.12	rock python	-1.12
American coot	-1.12	ski	-1.1	gar	-1.07	warthog	-1.05	bustard	-1.05
American egret	-1.04	honeycomb	-1.04	grey fox	-1.04	bathtub	-1.02	European gallinu	-1
hourglass	-0.99	ping-pong ball	-0.96	microwave	-0.96	cabbage butterfl	-0.96	French bulldog	-0.93
schooner	-0.93	spiny lobster	-0.91	Japanese spaniel	-0.9	sulphur-crested	-0.88	gorilla	-0.88
frying pan	-0.88	sea snake	-0.87	grille	-0.85	hummingbird	-0.84	quilt	-0.84
snowplow	-0.83	red wine	-0.83	isopod	-0.8	whistle	-0.79	mushroom	-0.78
iron	-0.78	vault	-0.77	bee eater	-0.77	Indian elephant	-0.76	seashore	-0.75
Welsh springer s	-0.73	geyser	-0.72	canoe	-0.7	sea slug	-0.69	hartebeest	-0.68
coral reef	-0.67	curly-coated ret	-0.66	marmoset	-0.65	scorpion	-0.64	three-toed sloth	-0.63
mailbox	-0.63	brain coral	-0.63	jack-o'-lantern	-0.62	Leonberg	-0.6	ice cream	-0.59
Bedlington terri	-0.58	hay	-0.58	dalmatian	-0.57	broccoli	-0.57	sombrero	-0.53
dishwasher	-0.53	oscilloscope	-0.52	sax	-0.51	sloth bear	-0.5	hippopotamus	-0.5
schipperke	-0.5	minibus	-0.5	toilet seat	-0.44	trifle	-0.44	crate	-0.42
goose	-0.42	Rhodesian ridgeb	-0.42	dock	-0.41	starfish	-0.41	barbell	-0.41
Old English shee	-0.4	hot pot	-0.39	disk brake	-0.38	Norfolk terrier	-0.37	pirate	-0.35
Gordon setter	-0.34	carpenter's kit	-0.32	sandbar	-0.31	cairn	-0.31	stingray	-0.28
mountain tent	-0.27	promontory	-0.25	macaw	-0.25	Indian cobra	-0.24	cucumber	-0.24
steel arch bridg	-0.23	monitor	-0.2	missile	-0.19	vizsla	-0.19	limpkin	-0.17

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class	top1 diff.	class	top1 diff.	class	top1 diff.	class	top1 diff.	class	top1 diff.
admiral	-0.17	eft	-0.17	upright	-0.17	keeshond	-0.17	dowitcher	-0.17
throne	-0.16	Airedale	-0.16	lacewing	-0.14	Model T	-0.14	binoculars	-0.12
bib	-0.12	Rottweiler	-0.1	Scotch terrier	-0.1	marimba	-0.09	acorn	-0.09
fiddler crab	-0.09	sleeping bag	-0.08	black swan	-0.07	cliff	-0.06	siamang	-0.06
hip	-0.04	Chesapeake Bay r	-0.04	groenendael	-0.03	giant schnauzer	-0.02	lampshade	-0.01
umbrella	-0.01	yellow lady's sl	0	basketball	0	bell pepper	0	goldfish	0.01
velvet	0.04	flagpole	0.05	jacamar	0.06	jean	0.06	green mamba	0.09
red-breasted mer	0.1	freight car	0.1	pedestal	0.12	plane	0.12	confectionery	0.14
saltshaker	0.14	plow	0.14	African grey	0.16	harp	0.17	feather boa	0.17
zebra	0.2	orange	0.22	weasel	0.22	impala	0.23	peacock	0.23
shower curtain	0.23	buckeye	0.24	tub	0.24	puck	0.25	Persian cat	0.27
shopping cart	0.27	bittern	0.27	whiptail	0.28	scale	0.28	oxcart	0.28
cocktail shaker	0.29	lionfish	0.3	koala	0.31	revolver	0.32	drum	0.32
jeep	0.34	ringneck snake	0.34	letter opener	0.37	table lamp	0.37	spoonbill	0.37
sorrel	0.4	megalith	0.41	fox squirrel	0.43	lifeboat	0.43	waffle iron	0.45
grey whale	0.47	daisy	0.48	lesser panda	0.48	water tower	0.51	milk can	0.52
agama	0.52	totem pole	0.54	papillon	0.54	remote control	0.54	teapot	0.55
iPod	0.55	EntleBucher	0.56	chiton	0.58	hatchet	0.59	hornbill	0.59
cassette	0.59	refrigerator	0.6	kuvasz	0.6	earthstar	0.6	monarch	0.6
weevil	0.62	go-kart	0.62	greenhouse	0.63	flat-coated retr	0.64	Christmas stocki	0.65
leatherback turt	0.66	Crock Pot	0.67	traffic light	0.68	Loafer	0.69	space shuttle	0.71
scuba diver	0.71	cellular telepho	0.73	Bouvier des Flan	0.73	jaguar	0.74	ice bear	0.76
Windsor tie	0.77	racer	0.79	slot	0.82	jigsaw puzzle	0.83	tench	0.85
dough	0.86	picket fence	0.87	balance beam	0.89	stupa	0.89	Lhasa	0.91
ostrich	0.91	tripod	0.95	giant panda	0.97	organ	0.99	file	1
chambered nautil	1.02	chain saw	1.04	lorikeet	1.05	cock	1.06	box turtle	1.07
ptarmigan	1.08	jay	1.09	cicada	1.1	chiffonier	1.1	sea lion	1.12
spotted salamand	1.14	stove	1.15	cheetah	1.16	indigo bunting	1.18	limousine	1.19
Walker hound	1.19	stinkhorn	1.2	indri	1.2	triumphal arch	1.23	polecat	1.24
toilet tissue	1.26	strawberry	1.29	window shade	1.3	baboon	1.3	cauliflower	1.3
titi	1.31	sock	1.31	oxygen mask	1.31	bookcase	1.33	lion	1.33
sewing machine	1.34	Great Pyrenees	1.37	European fire sa	1.37	orangutan	1.38	water ouzel	1.39
Irish setter	1.42	rocking chair	1.42	head cabbage	1.43	junco	1.44	croquet ball	1.48
cinema	1.49	chimpanzee	1.5	tailed frog	1.51	forklift	1.53	ruddy turnstone	1.54
planetarium	1.54	wig	1.55	parking meter	1.55	airliner	1.56	valley	1.57
pickelhaube	1.61	clumber	1.63	robin	1.64	sturgeon	1.65	pelican	1.67
Sussex spaniel	1.69	thimble	1.7	mantis	1.72	coucal	1.73	palace	1.73
container ship	1.74	tabby	1.76	black stork	1.77	snow leopard	1.77	theater curtain	1.78
green snake	1.79	groom	1.79	web site	1.8	speedboat	1.8	great grey owl	1.84
sea urchin	1.86	wombat	1.86	chain mail	1.87	cardoon	1.88	carbonara	1.89
bobsled	1.89	barn	1.89	redshank	1.9	pretzel	1.92	affenpinscher	1.93
bottlecap	1.93	balloon	1.95	slide rule	1.96	trolleybus	1.96	otterhound	1.97
jackfruit	1.98	carousel	2	bath towel	2	cash machine	2	nematode	2.01
consomme	2.02	alligator lizard	2.03	tarantula	2.05	grand piano	2.07	steam locomotive	2.08
lemon	2.1	crib	2.1	snorkel	2.12	zucchini	2.13	toaster	2.15
Granny Smith	2.17	proboscis monkey	2.18	king snake	2.2	flamingo	2.2	chickadee	2.2
Sealyham terrier	2.21	cello	2.22	hen-of-the-woods	2.24	dogsled	2.24	horse cart	2.24
dhole	2.25	car mirror	2.26	manhole cover	2.28	overskirt	2.29	poncho	2.31
English springer	2.32	analog clock	2.32	mountain bike	2.33	flatworm	2.34	hermit crab	2.35
thatch	2.35	cab	2.38	tape player	2.39	Siberian husky	2.39	grasshopper	2.4
streetcar	2.44	English foxhound	2.45	sulphur butterfl	2.5	French horn	2.51	horned viper	2.51
barracouta	2.52	dugong	2.53	screw	2.53	tank	2.53	trench coat	2.55
quail	2.56	black-and-tan co	2.57	odometer	2.57	parallel bars	2.57	maypole	2.58
tiger beetle	2.58	Dandie Dinmont	2.59	bolo tie	2.6	Tibetan mastiff	2.61	ground beetle	2.61
yawl	2.61	airship	2.65	harvestman	2.66	king crab	2.67	Egyptian cat	2.68
house finch	2.68	hotdog	2.69	tennis ball	2.69	four-poster	2.69	cliff dwelling	2.7
pinwheel	2.72	bagel	2.76	malamute	2.81	medicine chest	2.81	school bus	2.81
oystercatcher	2.81	backpack	2.82	torch	2.84	red fox	2.86	convertible	2.87
Ibizan hound	2.97	terrapin	2.97	dung beetle	2.97	china cabinet	2.98	amphibian	2.99
golf ball	3	lawn mower	3.01	bicycle-built-fo	3.02	unicycle	3.03	German short-hai	3.04
cougar	3.04	crossword puzzle	3.05	coral fungus	3.06	common iguana	3.09	espresso	3.11
bulletproof vest	3.13	moving van	3.14	assault rifle	3.14	meat loaf	3.15	perfume	3.15
beer glass	3.16	snowmobile	3.16	drake	3.16	German shepherd	3.17	ocarina	3.18
folding chair	3.18	Gila monster	3.18	comic book	3.18	bullfrog	3.22	goldfinch	3.24
magpie	3.24	Madagascar cat	3.24	suit	3.25	padlock	3.25	cheeseburger	3.26
sea anemone	3.27	whiskey jug	3.28	miniature pinsch	3.29	baseball	3.29	black widow	3.31
guacamole	3.31	Arabian camel	3.32	hoopskirt	3.33	hair spray	3.37	prayer rug	3.4
artichoke	3.4	colobus	3.43	sundial	3.44	patas	3.45	maze	3.47
pickup	3.47	projector	3.52	fur coat	3.54	gondola	3.56	Samoyed	3.57
lynx	3.59	horizontal bar	3.65	lens cap	3.67	golfcart	3.67	bell cote	3.68
submarine	3.7	bullet train	3.71	frilled lizard	3.73	ringlet	3.74	Saluki	3.76
bald eagle	3.77	trailer truck	3.77	beer bottle	3.79	chow	3.8	black grouse	3.84
radio telescope	3.84	miniature schnau	3.84	Boston bull	3.85	komondor	3.88	Australian terri	3.88
lab coat	3.9	laptop	3.92	white wolf	3.93	king penguin	3.97	boathouse	4.08
gazelle	4.1	ambulance	4.17	garbage truck	4.19	fig	4.22	green lizard	4.24
barometer	4.24	Shetland sheepdo	4.25	ladybug	4.28	brass	4.35	library	4.35
rapeseed	4.4	chain	4.41	kelpie	4.41	mobile home	4.42	Polaroid camera	4.47
loggerhead	4.48	paddlewheel	4.49	police van	4.53	silky terrier	4.53	pomegranate	4.59
Pekinese	4.6	bikini	4.61	fire engine	4.66	spider monkey	4.69	ox	4.77
sports car	4.83	Weimaraner	4.84	Irish water span	4.86	briard	4.87	Great Dane	4.9
gibbon	4.92	menu	4.98	pay-phone	5.04	Komodo dragon	5.09	bearskin	5.1
sliding door	5.16	hognose snake	5.18	Irish wolfhound	5.2	kimono	5.22	scoreboard	5.22
oil filter	5.26	mosque	5.3	moped	5.35	dragonfly	5.4	soft-coated whea	5.44
golden retriever	5.52	volcano	5.58	Norwich terrier	5.58	passenger car	5.72	crane	5.89
monastery	5.9	chainlink fence	5.95	bathing cap	5.95	Norwegian elkhou	6.06	standard schnauz	6.14
jellyfish	6.15	digital watch	6.15	American Staffor	6.28	pizza	6.3	collie	6.32
capuchin	6.34	lycaenid	6.35	car wheel	6.36	obelisk	6.42	bull mastiff	6.45
bookshop	6.5	suspension bridg	6.62	sunscreen	6.7	spaghetti squash	6.76	tow truck	6.78
rock beauty	7.29	altar	7.32	wood rabbit	7.53	American alligat	7.57	alp	7.62
killer whale	7.66	half track	7.68	academic gown	7.93	beacon	7.94	sunglass	7.95
castle	8.19	candle	8.21	cradle	8.36	screen	8.52	magnetic compass	8.7

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class	top1 diff.	class	top1 diff.	class	top1 diff.	class	top1 diff.	class	top1 diff.
lipstick	8.86	toy terrier	9.08	Dutch oven	9.47	aircraft carrier	9.47	abaya	9.55
great white shar	10.03	Doberman	10.1	Shih-Tzu	10.17	potpie	10.35	Cardigan	10.35
space bar	10.92	wing	11.48	trimaran	11.87	wire-haired fox	17.64	miniature poodle	21.65

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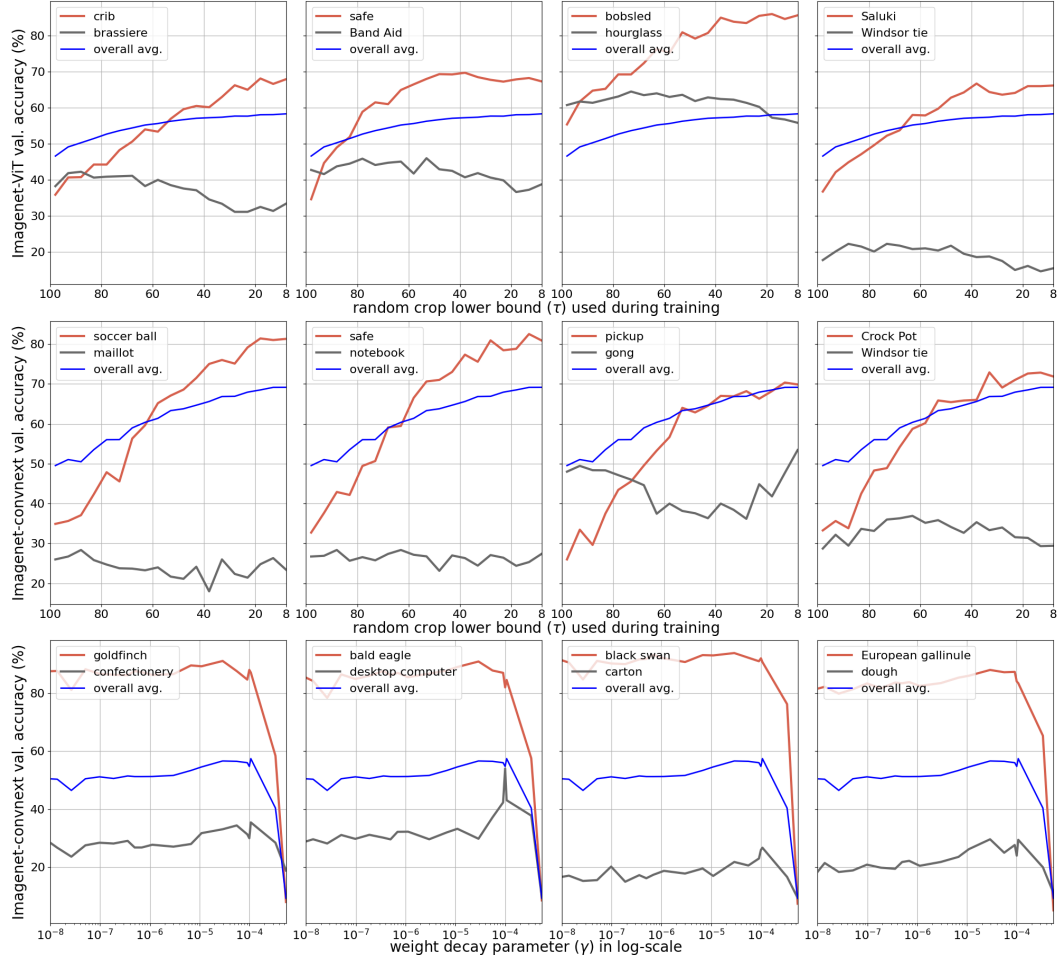
Figure 8: Reproduction of Figs. 12 and 13 but now with ViT small and random crop DA (top), Convnext-Tiny and random crop DA (middle) and Convnext-Tiny and weight decay (bottom).

23
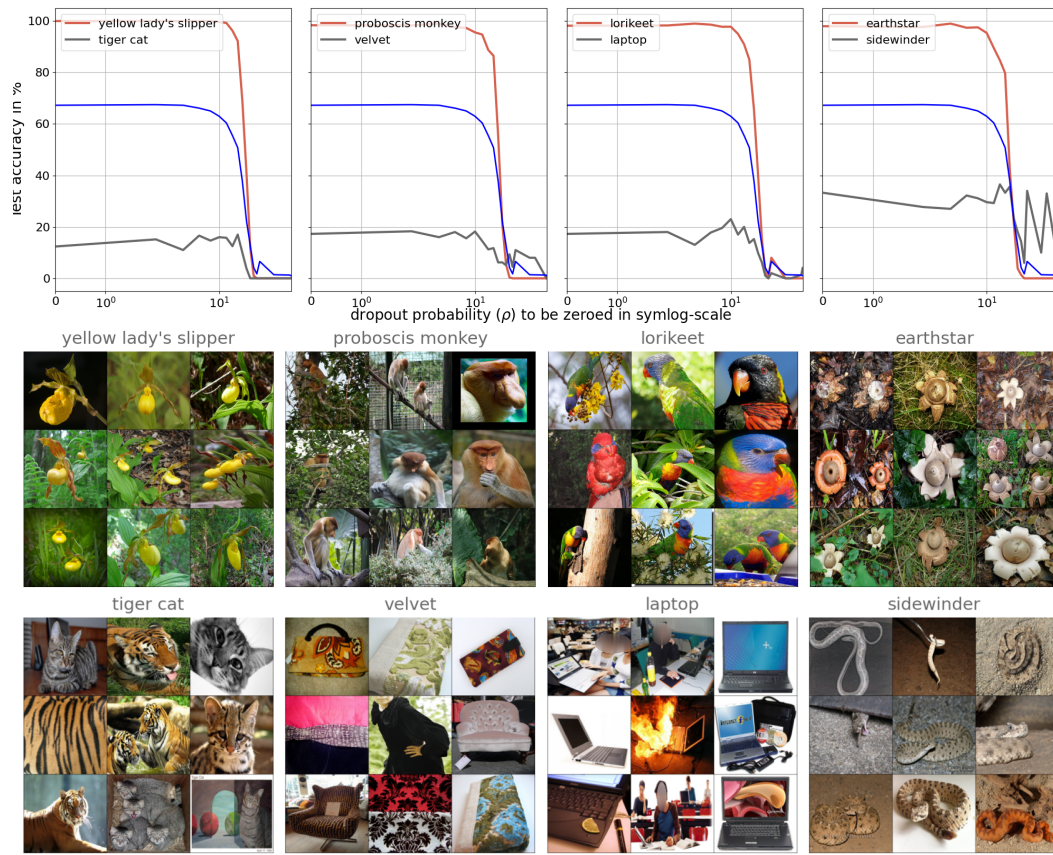
Figure 9: Reproduction of Figs. 12 and 13 but now with dropout (1d) with the best performing classes on the middle row and the worst performing classes one the bottom row.

24
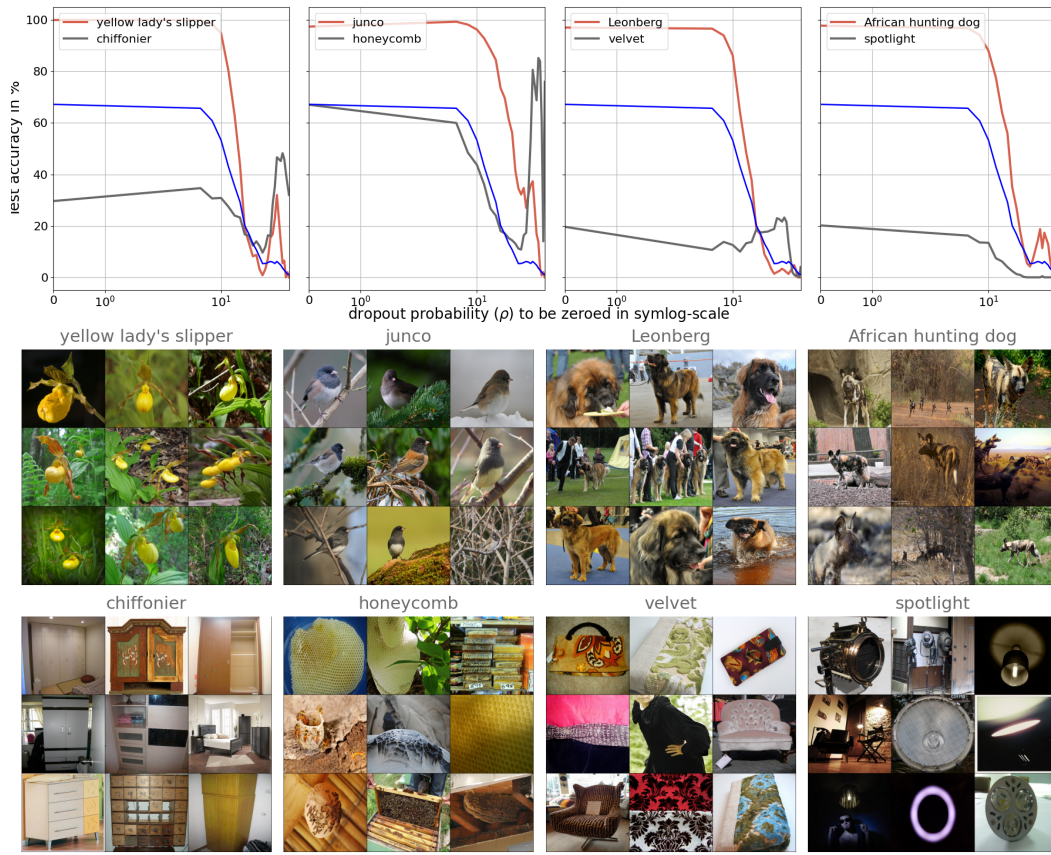
Figure 10: Reproduction of Figs. 12 and 13 but now with dropout (2d) with the best performing classes on the middle row and the worst performing classes one the bottom row.
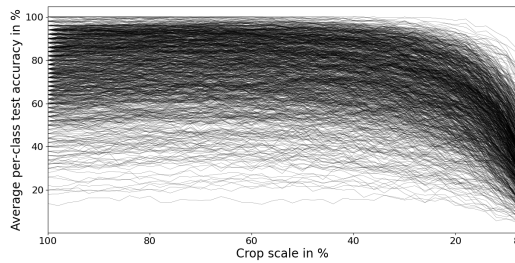
Figure 11: Per-class accuracy evolution when the proportion of the image being cropped (θ) is progressively increased from 8 to 100. While the overall trends mostly applies across classes, some extreme cases can present different sensitivity to aggressive cropping, leading to some classes being more successful as being label-preserved after application of the cropping. The weighted average of those lines (based on the proportion of samples coming from each class) gives back Fig. 5).

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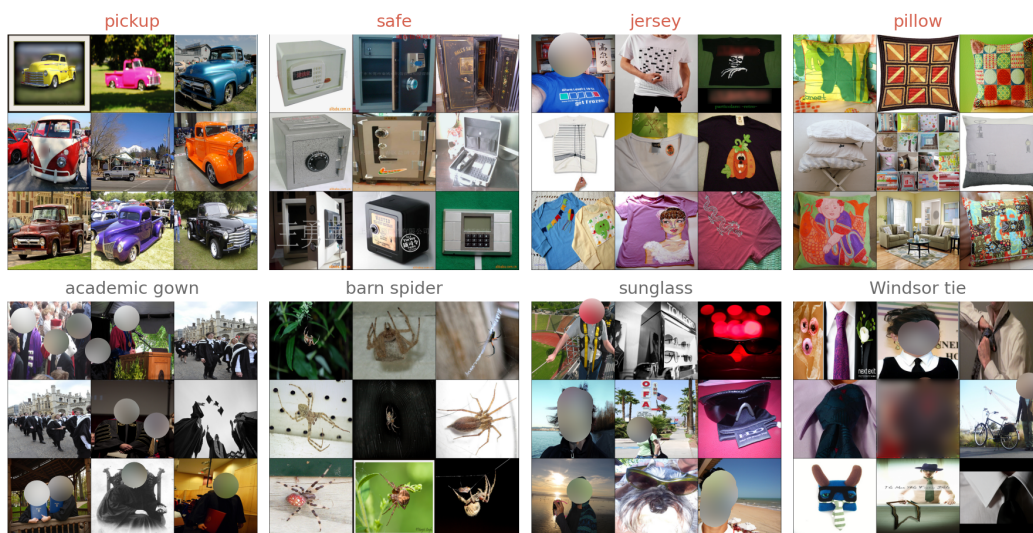
Figure 12: Random samples from the validation set of Imagenet that correspond to Fig. 2.
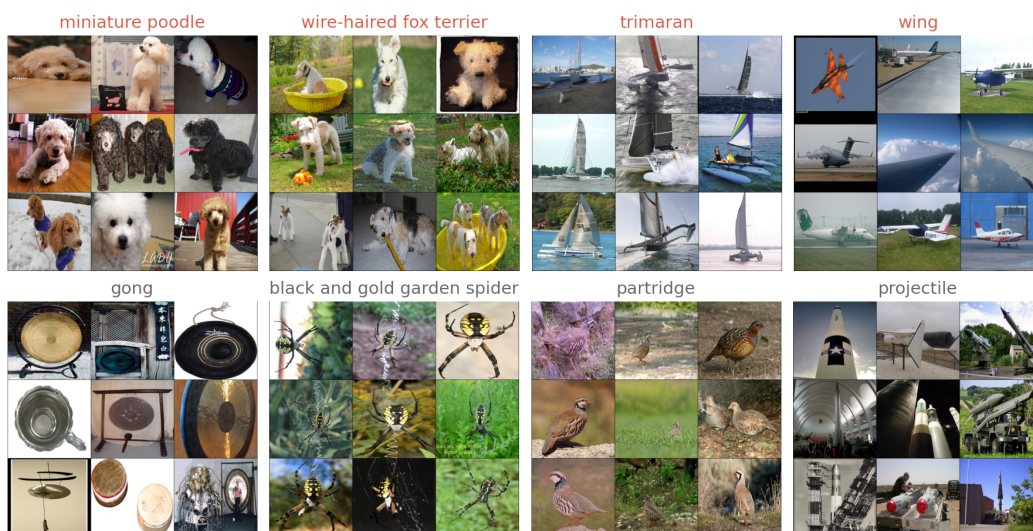
Figure 13: Random samples from the validation set of Imagenet that correspond to Fig. 3.

26
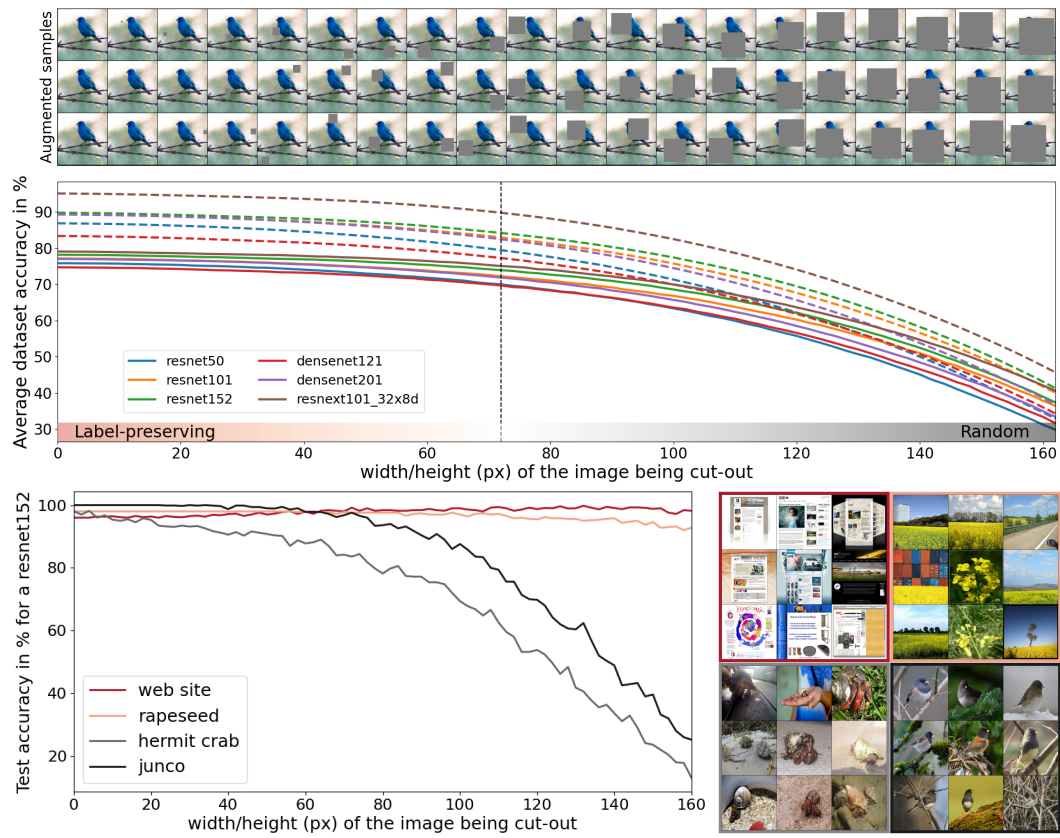
Figure 14: Reprise of Fig. 5 but using color jittering DA. The same conclusions are reached, different classes have different label-preserving regimes under this DA.

27
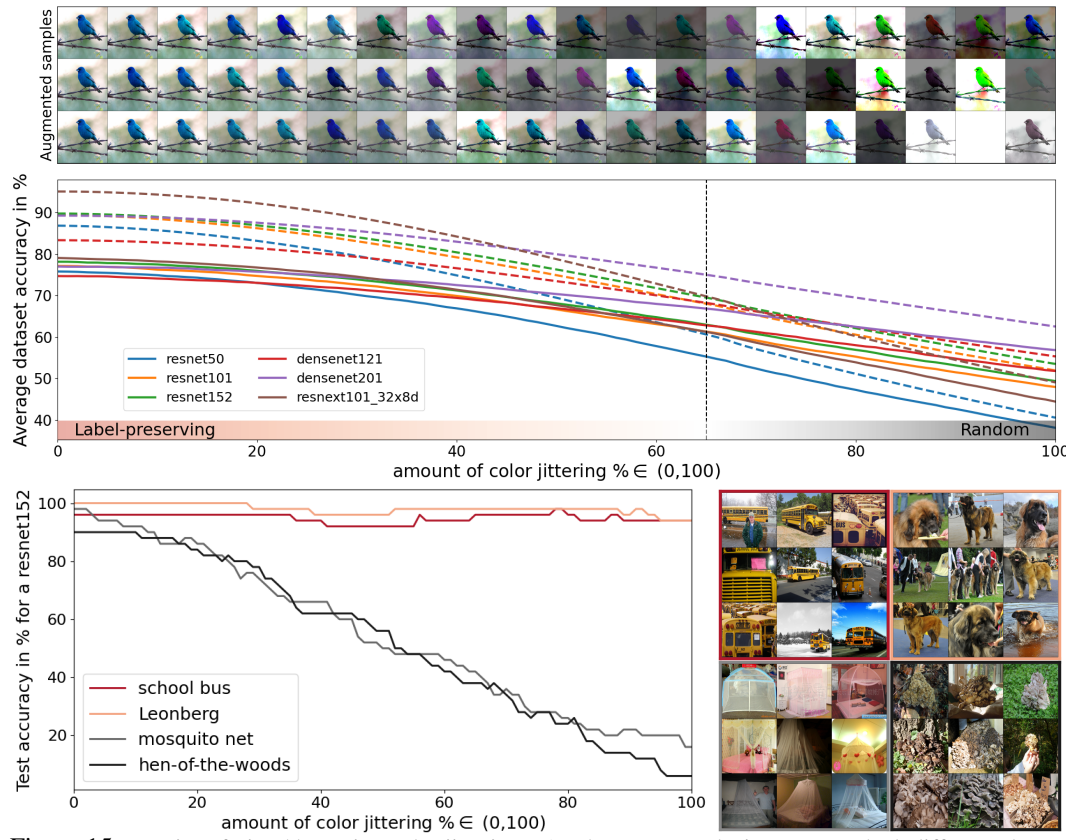
Figure 15: Reprise of Fig. 5 but using color jittering DA. The same conclusions are reached, different classes have different label-preserving regimes under this DA.

28
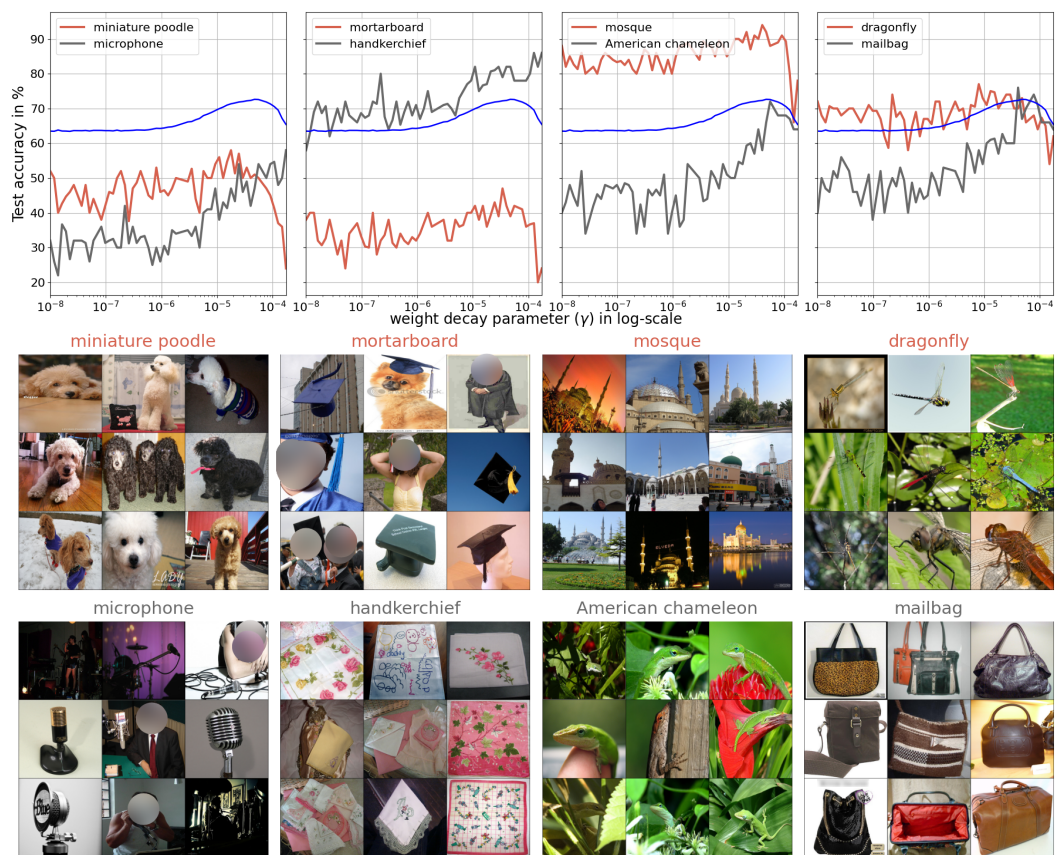
Figure 16: *All results in this figure employ official model implementations from PyTorch that we have trained on Imagenet with varying weight decay parameter.* Reprise of Fig. 3 but now with a different architecture (DenseNet121) instead of the ResNet50.
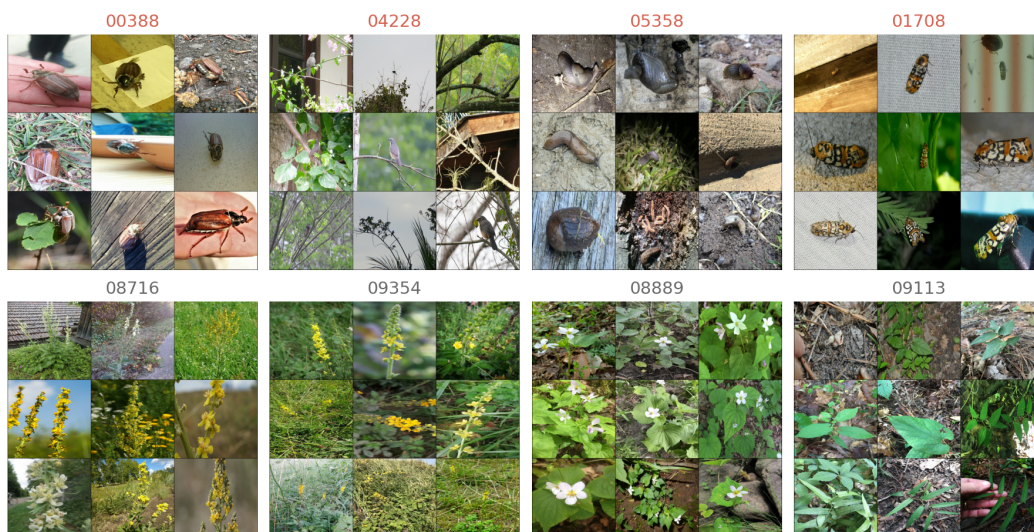
Figure 17: Random samples from the mini training set of INaturalist that correspond to Fig. 4

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