Two-Stream Convolutional Networks for Dynamic Texture Synthesis
Supplemental Material

Matthew Tesfaldet   Marcus A. Brubaker
Department of Electrical Engineering and Computer Science
York University, Toronto
{mtesfald,mab}@eecs.yorku.ca

Konstantinos G. Derpanis
Department of Computer Science
Ryerson University, Toronto
kosta@scs.ryerson.ca

A. Experimental procedure

Here we provide further experimental details of our user study using Amazon Mechanical Turk (AMT). Experimental trials were grouped into batches of Human Intelligence Tasks (HITs) for users to complete. Each HIT consisted of 59 pairwise comparisons between a synthesized dynamic texture and its target. Users were asked to choose which texture appeared more realistic after viewing each texture independently for an exposure time (in seconds) sampled randomly from the set {0.3, 0.4, 0.6, 1.2, 2.4, 3.6, 4.8}. Note that 12 frames of the dynamic texture corresponds to 1.2 seconds, *i.e.*, 10 frames per second. Before viewing a dynamic texture, a centred dot is flashed twice to indicate to the user where to look (left or right). To prepare users for the task, the first three comparisons were used for warm-up, exposing them to the shortest (0.3s), median (1.2s), and longest (4.8s) durations. To prevent spamming and bias, we constrained the experiment as follows: users could make a choice only after both dynamic textures were shown; the next texture comparison could only be made after a decision was made for the current comparison; a choice could not be changed after the next pair of dynamic textures were shown; and users were each restricted to a single HIT. Obvious unrealistic dynamic textures were synthesized by terminating synthesis early (100 iterations) and were used as sentinel tests. Three of the 59 pairwise comparisons were sentinels and results from users which gave incorrect answers on any of the sentinel comparisons were not used. The left-right order of textures within a pair, display order within a pair, and order of pairs within a HIT, were randomized. An example of a HIT is shown in a video included with the supplemental on the project page: HIT_example.mp4.

Users were paid $2 USD per HIT, and were required to have at least a 98% HIT approval rating, greater than or equal to 5000 HITs approved, and to be residing in the US. We collected results from 200 unique users to evaluate our final model and another 200 to evaluate our baseline model.

B. Qualitative results

We provide videos showcasing the qualitative results of our two-stream model, including the experiments mentioned in the main manuscript, on our project page: ryersonvisionlab.github.io/two-stream-projpage. The videos are in MP4 format (H.264 codec) and are best viewed in a loop. They are enclosed in the following folders:

- target_textures: This folder contains the 59 dynamic textures used as targets for synthesis.

- dynamic_texture_synthesis: This folder contains synthesized dynamic textures where the appearance and dynamics targets are the same.

- using_concatenation_layer: This folder contains synthesized dynamic textures where the concatenation layer was used for computing the Gramian on the dynamics stream. These are the results from our final model.

- using_flow_decode_layer: This folder contains synthesized dynamic textures where the predicted flow output is used for computing the Gramian on the dynamics stream. These are the results from our baseline.

- full_synthesis: This folder contains regularly-synthesized dynamic textures, *i.e.*, not incrementally-generated, nor temporally-endless, etc.

- appearance_stream_only: This folder contains dynamic textures synthesized using only the appearance stream of our two-stream model. The dynamics stream is not used.

- incrementally_generated: This folder contains dynamic textures synthesized using the incremental process outlined in Section 3.3 in the main manuscript.

- `temporally_endless`: This folder contains a synthesized dynamic texture (`smoke_plume_1`) where there is no discernible temporal seam between the last and first frames. Played as a loop, it appears to be temporally endless, thus, it is presented in animated GIF format.

- `dynamics_style_transfer`: This folder contains synthesized dynamic textures where the appearance and dynamics targets are different. Also included are videos where the synthesized dynamic texture is "pasted" back onto the original image it was cropped from, showing a proof-of-concept of dynamics style transfer as an artistic tool.

- `comparisons/funke`: This folder contains four dynamic texture synthesis comparisons between our model and a recent (unpublished) approach [1]. The dynamic textures chosen are those reported by Funke et al. [1] which exhibit spatiotemporal homogeneity. For ease of comparison, we have concatenated the results from both models with their corresponding targets.

- `comparisons/xie_and_funke`: This folder contains nine dynamic texture synthesis comparisons between our model, Funke et al.'s [1], and Xie et al.'s [2]. The dynamic textures chosen cover the full range of our appearance and dynamics groupings. For ease of comparison, we have concatenated the results from all models with their corresponding targets.

C. Full user study results

Figures 1a and 1b show histograms of the average user accuracy on each texture, averaged over a range of exposure times. The histogram bars are ordered from lowest to highest accuracy, based on the results when using our final model.

Tables 1 and 2 show the average user accuracy on each texture when using our final model. The results are averaged over exposure times. Similarly, Tables 3 and 4 show the results when using our baseline.

Tables 5 and 6 show the average user accuracy on texture appearance groups when using our final model. The results are averaged over exposure times. Similarly, Tables 7 and 8 show the results when using our baseline.

Tables 9 and 10 show the average user accuracy on texture dynamics groups when using our final model. The results are averaged over exposure times. Similarly, Tables 11 and 12 show the results when using our baseline.

Tables 13 and 14 show the average user accuracy over all textures when using our final model. The results are averaged over exposure times. Similarly, Tables 15 and 16 show the results when using our baseline.

D. Qualitative comparisons

We qualitatively compare our results to those of Funke et al. [1] and Xie et al. [2]. Note that Funke et al. [1] provided results on only five textures and of those only four are dynamic textures in the sense that their appearance and dynamics are spatiotemporally coherent. Their results on these sequences (`cranberries`, `flames`, `leaves`, and `water_5`) are included in the folder `funke` under `dynamic_texture_synthesis/comparisons`. Our results are included as well.

We also compare our results to [1, 2] on nine dynamic textures chosen to cover the full range of our dynamics and appearance groupings. We use their publicly available code and follow the parameters used in their experiments. For Funke et al.'s model [1], the parameters used are $\Delta t = 4$ and $T = 12$ (recall that target dynamic textures consist of 12 frames). For the spatiotemporal and temporal models from Xie et al. [2], the parameters used are $T = 1200$ and $\tilde{M} = 3$. A comparison between our results, Funke et al.'s [1], and Xie et al's [2] on the nine dynamic textures are included in the folder `xie_and_funke` under `dynamic_texture_synthesis/comparisons`. Note for Xie et al. [2], we compare with their spatiotemporal model (labeled "Xie et al. (ST)") designed for dynamic textures with both spatial and temporal homogeneity, and their temporal model (labeled "Xie et al. (FC)") designed for dynamic textures with only temporal homogeneity.

Overall, we demonstrate that our results appear qualitatively better, showing more temporal coherence and similarity in dynamics and fewer artifacts, *e.g.*, blur and flicker. This may be a natural consequence of their limited representation of dynamics. Although the spatiotemporal model of Xie et al. [2] is able to synthesize dynamic textures that lack spatial homogeneity (*e.g.*, `bamboo` and `escalator`), we note that their method can not synthesize novel dynamic textures, *i.e.*, it appears to faithfully reproduce the target texture, reducing the applicability of their approach.

As a consequence of jointly modelling appearance and dynamics, the methods of [1, 2] are not capable of the novel form of style transfer we demonstrated. This was enabled by the factored representation of dynamics and appearance. Furthermore, the spatiotemporal extent of the output sequence generated by Xie et al.'s [2] method is limited to being equal to the input. The proposed approach does not share this limitation.

References

[1] C. M. Funke, L. A. Gatys, A. S. Ecker, and M. Bethge. Synthesising dynamic textures using convolutional neural networks. *arXiv:1702.07006*, 2017. 2

[2] J. Xie, S.-C. Zhu, and Y. N. Wu. Synthesizing dynamic patterns by spatial-temporal generative convnet. In *CVPR*, 2017. 2

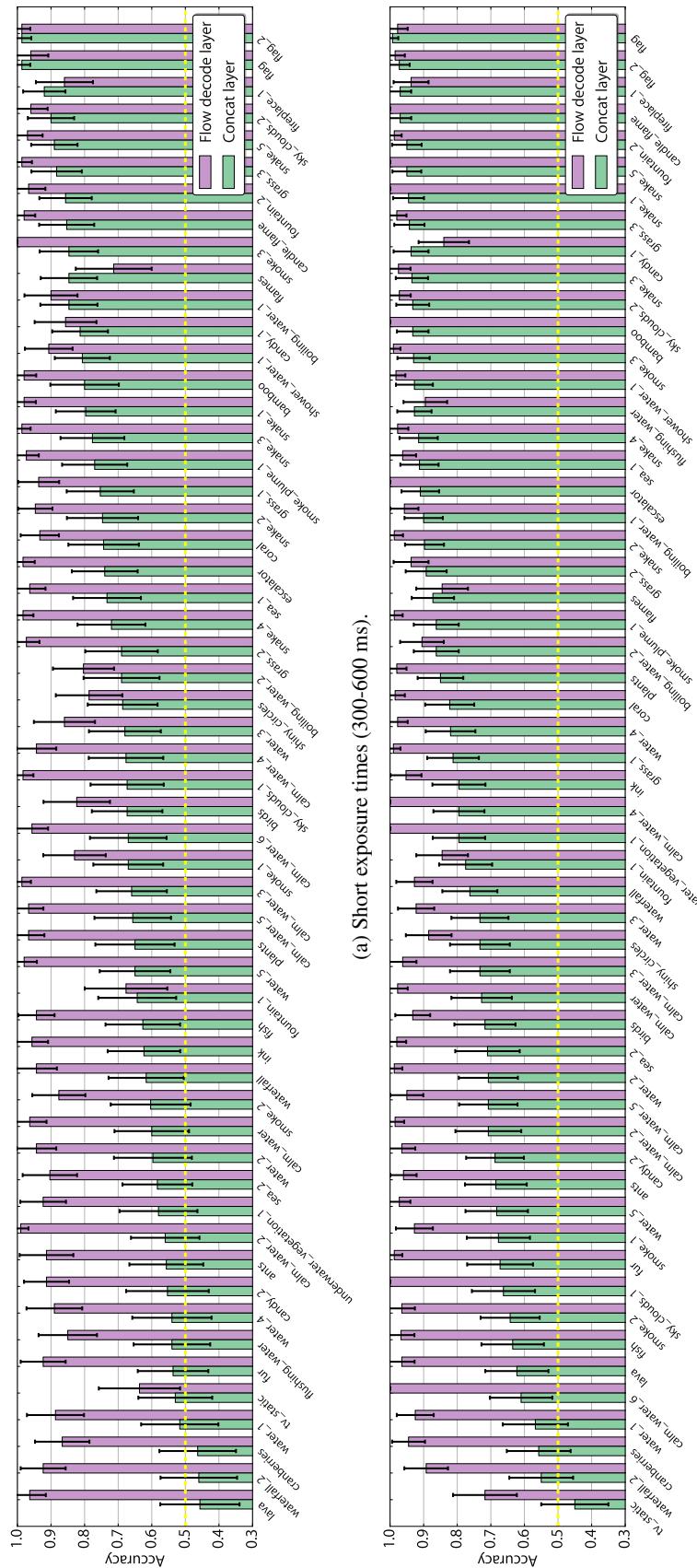(a) Short exposure times (300-600 ms).

(b) Long exposure times (1200-4800 ms).

Figure 1: Per-texture accuracies averaged over exposure times. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Dynamic texture	300 ms.	400 ms.	600 ms.	1200 ms.	2400 ms.	3600 ms.	4800 ms.
ants	0.625±0.194	0.333±0.161	0.714±0.193	0.536±0.185	0.636±0.201	0.857±0.15	0.704±0.172
bamboo	0.769±0.162	0.786±0.215	0.842±0.164	0.906±0.101	0.95±0.096	0.938±0.084	0.926±0.099
birds	0.609±0.199	0.786±0.152	0.615±0.187	0.542±0.199	0.867±0.122	0.682±0.195	0.778±0.192
boiling_water_1	0.806±0.139	0.88±0.127	0.846±0.196	0.714±0.193	0.97±0.058	0.96±0.077	0.963±0.071
boiling_water_2	0.533±0.252	0.842±0.164	0.7±0.164	0.87±0.138	0.731±0.17	0.852±0.134	1.0±0.0
calm_water	0.607±0.181	0.571±0.212	0.615±0.187	0.636±0.164	0.75±0.19	0.762±0.182	0.762±0.182
calm_water_2	0.44±0.195	0.621±0.177	0.622±0.156	0.7±0.201	0.652±0.195	0.773±0.175	0.706±0.217
calm_water_3	0.813±0.135	0.5±0.245	0.667±0.169	0.7±0.201	0.824±0.181	0.63±0.182	0.781±0.143
calm_water_4	0.727±0.186	0.654±0.183	0.65±0.209	0.767±0.151	0.875±0.132	0.848±0.122	0.682±0.195
calm_water_5	0.609±0.199	0.773±0.175	0.591±0.205	0.609±0.199	0.708±0.182	0.724±0.163	0.786±0.152
calm_water_6	0.6±0.248	0.773±0.175	0.643±0.177	0.5±0.2	0.519±0.188	0.765±0.202	0.658±0.151
candle_flame	0.806±0.139	0.75±0.212	1.0±0.0	0.909±0.12	1.0±0.0	1.0±0.0	0.968±0.062
candy_1	0.81±0.168	0.839±0.129	0.788±0.139	0.9±0.131	0.938±0.119	0.963±0.071	0.952±0.091
candy_2	0.5±0.219	0.429±0.212	0.727±0.186	0.636±0.164	0.652±0.195	0.724±0.163	0.741±0.165
coral	0.591±0.205	0.81±0.168	0.826±0.155	0.815±0.147	0.773±0.175	0.885±0.123	0.828±0.137
cranberries	0.48±0.196	0.318±0.195	0.593±0.185	0.64±0.188	0.548±0.175	0.519±0.188	0.524±0.214
escalator	0.792±0.162	0.733±0.158	0.696±0.188	0.967±0.064	0.933±0.126	0.926±0.099	0.815±0.147
fireplace_1	0.909±0.12	0.952±0.091	0.897±0.111	0.917±0.111	1.0±0.0	0.962±0.074	1.0±0.0
fish	0.571±0.212	0.65±0.209	0.656±0.165	0.652±0.195	0.696±0.188	0.692±0.177	0.5±0.179
flag	1.0±0.0	1.0±0.0	0.964±0.069	0.968±0.062	1.0±0.0	1.0±0.0	1.0±0.0
flag_2	0.964±0.069	1.0±0.0	1.0±0.0	0.923±0.102	1.0±0.0	1.0±0.0	0.966±0.066
flames	0.72±0.176	0.909±0.12	0.913±0.115	0.889±0.119	0.889±0.119	0.875±0.132	0.833±0.133
flushing_water	0.5±0.209	0.565±0.203	0.552±0.181	0.871±0.118	0.92±0.106	0.917±0.111	1.0±0.0
fountain_1	0.435±0.203	0.688±0.227	0.808±0.151	0.833±0.149	0.788±0.139	0.667±0.189	0.808±0.151
fountain_2	0.929±0.095	0.826±0.155	0.815±0.147	1.0±0.0	0.905±0.126	0.967±0.064	0.933±0.089
fur	0.452±0.175	0.538±0.192	0.621±0.177	0.75±0.15	0.737±0.198	0.526±0.225	0.667±0.218
grass_1	0.813±0.135	0.778±0.192	0.667±0.202	0.792±0.162	0.735±0.148	0.895±0.138	0.826±0.155
grass_2	0.632±0.217	0.667±0.202	0.767±0.151	0.88±0.127	1.0±0.0	0.88±0.127	0.813±0.135
grass_3	0.8±0.175	0.903±0.104	0.95±0.096	0.958±0.08	1.0±0.0	0.92±0.106	0.889±0.119
ink	0.476±0.214	0.714±0.167	0.679±0.173	0.724±0.163	0.808±0.151	0.783±0.169	0.87±0.138
lava	0.458±0.199	0.346±0.183	0.556±0.23	0.733±0.158	0.593±0.185	0.522±0.204	0.652±0.195
plants	0.632±0.217	0.667±0.202	0.652±0.195	0.767±0.151	0.806±0.139	0.857±0.15	0.96±0.077
sea_1	0.6±0.192	0.769±0.162	0.826±0.155	0.955±0.087	0.857±0.15	0.964±0.069	0.88±0.127
sea_2	0.542±0.199	0.625±0.168	0.581±0.174	0.75±0.173	0.75±0.19	0.533±0.252	0.808±0.151
shiny_circles	0.517±0.182	0.741±0.165	0.8±0.175	0.609±0.199	0.9±0.131	0.767±0.151	0.652±0.195
shower_water_1	0.767±0.151	0.903±0.104	0.75±0.16	1.0±0.0	0.952±0.091	0.87±0.138	0.889±0.145
sky_clouds_1	0.667±0.202	0.737±0.198	0.613±0.171	0.72±0.176	0.652±0.195	0.571±0.259	0.714±0.15
sky_clouds_2	0.792±0.162	0.938±0.119	0.97±0.058	0.957±0.083	0.92±0.106	0.889±0.119	0.962±0.074
smoke_1	0.538±0.192	0.731±0.17	0.741±0.165	0.471±0.237	0.895±0.138	0.76±0.167	0.588±0.165
smoke_2	0.478±0.204	0.727±0.186	0.6±0.215	0.72±0.176	0.5±0.173	0.724±0.163	0.63±0.182
smoke_3	0.769±0.162	0.833±0.149	0.938±0.119	0.821±0.142	0.931±0.092	0.968±0.062	1.0±0.0
smoke_plume_1	0.724±0.163	0.783±0.169	0.81±0.168	0.963±0.071	0.84±0.144	0.778±0.157	0.87±0.138
snake_1	0.862±0.126	0.704±0.172	0.826±0.155	0.88±0.127	0.905±0.126	1.0±0.0	1.0±0.0
snake_2	0.72±0.176	0.708±0.182	0.813±0.191	0.958±0.08	0.852±0.134	0.9±0.107	0.88±0.127
snake_3	0.643±0.177	0.773±0.175	0.917±0.111	0.87±0.138	0.913±0.115	1.0±0.0	0.964±0.069
snake_4	0.643±0.177	0.815±0.147	0.714±0.193	1.0±0.0	0.917±0.111	0.889±0.119	0.852±0.134
snake_5	0.826±0.155	0.947±0.1	0.889±0.103	0.875±0.132	0.923±0.102	1.0±0.0	1.0±0.0
tv_static	0.538±0.192	0.63±0.182	0.423±0.19	0.615±0.187	0.227±0.175	0.619±0.208	0.333±0.178
underwater_vegetation_1	0.656±0.165	0.5±0.231	0.579±0.222	0.821±0.142	0.813±0.191	0.733±0.158	0.821±0.142
water_1	0.556±0.23	0.32±0.183	0.667±0.169	0.727±0.186	0.571±0.212	0.583±0.197	0.394±0.167
water_4	0.375±0.237	0.586±0.179	0.652±0.195	0.826±0.155	0.706±0.153	0.818±0.161	0.917±0.111
water_2	0.632±0.217	0.64±0.188	0.52±0.196	0.739±0.179	0.667±0.202	0.724±0.163	0.7±0.164
water_3	0.545±0.208	0.741±0.165	0.75±0.173	0.833±0.149	0.771±0.139	0.652±0.195	0.682±0.195
water_5	0.688±0.161	0.667±0.218	0.586±0.179	0.759±0.156	0.65±0.209	0.652±0.195	0.667±0.189
waterfall	0.571±0.183	0.586±0.179	0.688±0.227	0.792±0.162	0.696±0.188	0.731±0.17	0.833±0.133
waterfall_2	0.444±0.187	0.364±0.201	0.583±0.197	0.75±0.16	0.37±0.182	0.632±0.217	0.452±0.175

Table 1: Per-texture accuracies averaged over exposure times, using the concatenation layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Dynamic texture	Short (300-600 ms.)	Long (1200-4800 ms.)	All (300-4800 ms.)
ants	0.526±0.111	0.673±0.093	0.608±0.072
bamboo	0.797±0.103	0.928±0.048	0.882±0.048
birds	0.675±0.105	0.723±0.09	0.702±0.069
boiling_water_1	0.841±0.086	0.915±0.053	0.886±0.047
boiling_water_2	0.703±0.112	0.864±0.066	0.802±0.06
calm_water	0.6±0.111	0.716±0.091	0.665±0.071
calm_water_2	0.571±0.102	0.707±0.098	0.636±0.072
calm_water_3	0.692±0.102	0.729±0.089	0.713±0.067
calm_water_4	0.676±0.111	0.798±0.075	0.751±0.064
calm_water_5	0.657±0.114	0.712±0.087	0.69±0.069
calm_water_6	0.677±0.114	0.604±0.093	0.632±0.072
candle_flame	0.861±0.08	0.97±0.033	0.924±0.04
candy_1	0.812±0.083	0.94±0.051	0.876±0.05
candy_2	0.556±0.123	0.688±0.086	0.64±0.071
coral	0.742±0.106	0.827±0.073	0.794±0.061
cranberries	0.473±0.114	0.558±0.095	0.522±0.073
escalator	0.74±0.098	0.909±0.057	0.835±0.055
fireplace_1	0.917±0.064	0.971±0.032	0.949±0.033
fish	0.63±0.111	0.627±0.094	0.629±0.072
flag	0.987±0.025	0.99±0.02	0.989±0.016
flag_2	0.985±0.03	0.971±0.032	0.976±0.023
flames	0.843±0.085	0.87±0.063	0.86±0.051
flushing_water	0.541±0.114	0.918±0.054	0.756±0.064
fountain_1	0.646±0.116	0.776±0.079	0.727±0.067
fountain_2	0.859±0.077	0.947±0.045	0.908±0.043
fur	0.535±0.105	0.682±0.097	0.609±0.073
grass_1	0.761±0.099	0.8±0.078	0.784±0.062
grass_2	0.7±0.107	0.88±0.064	0.806±0.059
grass_3	0.887±0.074	0.941±0.046	0.919±0.041
ink	0.636±0.107	0.792±0.079	0.725±0.066
lava	0.441±0.118	0.631±0.093	0.556±0.074
plants	0.651±0.118	0.841±0.069	0.771±0.063
sea_1	0.73±0.101	0.917±0.055	0.835±0.056
sea_2	0.586±0.103	0.729±0.094	0.657±0.071
shiny_circles	0.671±0.106	0.729±0.089	0.703±0.068
shower_water_1	0.809±0.082	0.93±0.054	0.869±0.05
sky_clouds_1	0.662±0.11	0.68±0.093	0.673±0.071
sky_clouds_2	0.904±0.068	0.931±0.05	0.92±0.04
smoke_1	0.671±0.104	0.674±0.094	0.672±0.07
smoke_2	0.6±0.119	0.637±0.089	0.624±0.071
smoke_3	0.833±0.09	0.927±0.049	0.892±0.046
smoke_plume_1	0.767±0.097	0.863±0.067	0.823±0.057
snake_1	0.797±0.089	0.947±0.045	0.879±0.049
snake_2	0.738±0.107	0.896±0.058	0.836±0.055
snake_3	0.77±0.096	0.94±0.047	0.868±0.05
snake_4	0.724±0.101	0.903±0.06	0.822±0.058
snake_5	0.885±0.071	0.95±0.043	0.921±0.04
tv_static	0.532±0.11	0.448±0.099	0.486±0.074
underwater_vegetation_1	0.594±0.116	0.794±0.078	0.713±0.068
water_1	0.521±0.115	0.55±0.098	0.538±0.074
water_4	0.559±0.118	0.806±0.076	0.708±0.068
water_2	0.594±0.116	0.709±0.088	0.663±0.071
water_3	0.685±0.107	0.74±0.084	0.718±0.066
water_5	0.646±0.105	0.688±0.093	0.669±0.07
waterfall	0.603±0.112	0.767±0.082	0.699±0.068
waterfall_2	0.466±0.114	0.543±0.095	0.511±0.073

Table 2: Per-texture accuracies averaged over a range of exposure times, using the concatenation layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Dynamic texture	300 ms.	400 ms.	600 ms.	1200 ms.	2400 ms.	3600 ms.	4800 ms.
ants	0.933±0.126	0.9±0.186	0.913±0.115	0.963±0.071	1.0±0.0	1.0±0.0	0.885±0.123
bamboo	1.0±0.0	0.944±0.106	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0
birds	0.895±0.138	0.652±0.195	0.933±0.126	0.947±0.1	0.9±0.131	0.913±0.115	0.966±0.066
boiling_water_1	0.846±0.196	0.895±0.138	0.957±0.083	0.96±0.077	0.92±0.106	0.952±0.091	1.0±0.0
boiling_water_2	0.808±0.151	0.889±0.119	0.714±0.193	0.95±0.096	0.857±0.183	0.889±0.145	0.92±0.106
calm_water	0.929±0.135	0.963±0.071	1.0±0.0	0.962±0.074	0.952±0.091	1.0±0.0	1.0±0.0
calm_water_2	1.0±0.0	1.0±0.0	0.966±0.066	1.0±0.0	1.0±0.0	1.0±0.0	0.941±0.112
calm_water_3	1.0±0.0	1.0±0.0	0.957±0.083	0.941±0.112	0.955±0.087	0.96±0.077	1.0±0.0
calm_water_4	0.875±0.162	0.947±0.1	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0
calm_water_5	1.0±0.0	0.897±0.111	1.0±0.0	0.857±0.15	1.0±0.0	0.944±0.106	1.0±0.0
calm_water_6	0.913±0.115	1.0±0.0	0.958±0.08	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0
candle_flame	0.944±0.106	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0
candy_1	0.765±0.202	0.87±0.138	0.938±0.119	0.905±0.126	0.846±0.139	0.81±0.168	0.8±0.157
candy_2	0.864±0.143	0.875±0.132	1.0±0.0	1.0±0.0	0.96±0.077	0.952±0.091	0.95±0.096
coral	0.84±0.144	0.957±0.083	1.0±0.0	1.0±0.0	0.941±0.112	1.0±0.0	1.0±0.0
cranberries	0.75±0.212	0.917±0.111	0.926±0.099	0.958±0.08	0.867±0.172	0.95±0.096	1.0±0.0
escalator	0.947±0.1	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0
fireplace_1	0.905±0.126	0.765±0.202	0.923±0.102	0.867±0.172	0.929±0.095	0.947±0.1	1.0±0.0
fish	0.933±0.089	0.957±0.083	0.944±0.106	0.87±0.138	1.0±0.0	1.0±0.0	1.0±0.0
flag	0.875±0.162	1.0±0.0	1.0±0.0	0.958±0.08	1.0±0.0	1.0±0.0	0.947±0.1
flag_2	0.958±0.08	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	0.938±0.119
flames	0.667±0.189	0.75±0.19	0.722±0.207	0.789±0.183	0.826±0.155	0.917±0.111	0.842±0.164
flushing_water	0.941±0.112	0.88±0.127	0.727±0.186	1.0±0.0	0.8±0.157	0.906±0.101	0.867±0.172
fountain_1	0.609±0.199	0.65±0.209	0.769±0.229	0.913±0.115	0.762±0.182	0.818±0.161	0.895±0.138
fountain_2	0.95±0.096	1.0±0.0	0.947±0.1	0.952±0.091	1.0±0.0	1.0±0.0	1.0±0.0
fur	0.818±0.161	0.95±0.096	1.0±0.0	0.955±0.087	1.0±0.0	1.0±0.0	1.0±0.0
grass_1	0.952±0.091	0.938±0.119	0.917±0.111	1.0±0.0	1.0±0.0	0.958±0.08	1.0±0.0
grass_2	1.0±0.0	0.92±0.106	1.0±0.0	0.913±0.115	0.95±0.096	1.0±0.0	0.895±0.138
grass_3	1.0±0.0	1.0±0.0	0.958±0.08	0.923±0.145	1.0±0.0	1.0±0.0	1.0±0.0
ink	0.947±0.1	0.962±0.074	0.96±0.077	1.0±0.0	1.0±0.0	1.0±0.0	0.813±0.191
lava	0.952±0.091	1.0±0.0	0.941±0.112	1.0±0.0	0.906±0.101	1.0±0.0	0.95±0.096
plants	0.9±0.131	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	0.958±0.08	0.958±0.08
sea_1	0.889±0.145	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	0.958±0.08	0.889±0.145
sea_2	0.85±0.156	0.857±0.183	1.0±0.0	0.955±0.087	1.0±0.0	0.968±0.062	1.0±0.0
shiny_circles	0.808±0.151	0.8±0.175	0.75±0.19	0.88±0.127	0.8±0.202	0.96±0.077	0.9±0.131
shower_water_1	0.941±0.112	0.857±0.15	0.923±0.102	0.929±0.135	1.0±0.0	1.0±0.0	1.0±0.0
sky_clouds_1	1.0±0.0	1.0±0.0	0.947±0.1	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0
sky_clouds_2	0.941±0.112	1.0±0.0	0.941±0.112	1.0±0.0	0.933±0.126	0.96±0.077	1.0±0.0
smoke_1	0.867±0.172	0.773±0.175	0.846±0.139	0.889±0.145	0.944±0.106	0.929±0.095	0.95±0.096
smoke_2	0.667±0.239	0.957±0.083	1.0±0.0	1.0±0.0	0.947±0.1	1.0±0.0	0.909±0.12
smoke_3	1.0±0.0	1.0±0.0	1.0±0.0	0.96±0.077	1.0±0.0	1.0±0.0	1.0±0.0
smoke_plume_1	1.0±0.0	0.958±0.08	0.964±0.069	1.0±0.0	0.955±0.087	1.0±0.0	1.0±0.0
snake_1	0.941±0.112	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0
snake_2	0.958±0.08	0.917±0.111	0.962±0.074	1.0±0.0	1.0±0.0	1.0±0.0	0.955±0.087
snake_3	0.957±0.083	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	0.905±0.126	1.0±0.0
snake_4	1.0±0.0	0.947±0.1	1.0±0.0	0.957±0.083	0.95±0.096	1.0±0.0	1.0±0.0
snake_5	0.909±0.12	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0
tv_static	0.684±0.209	0.588±0.234	0.64±0.188	0.778±0.192	0.55±0.218	0.76±0.167	0.783±0.169
underwater_vegetation_1	0.857±0.183	0.958±0.08	0.952±0.091	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0
water_1	0.929±0.135	0.778±0.192	0.952±0.091	0.929±0.095	0.889±0.145	1.0±0.0	0.88±0.127
water_4	0.778±0.272	1.0±0.0	0.889±0.119	1.0±0.0	1.0±0.0	0.909±0.12	1.0±0.0
water_2	0.867±0.172	1.0±0.0	0.962±0.074	1.0±0.0	1.0±0.0	0.955±0.087	1.0±0.0
water_3	0.737±0.198	0.905±0.126	0.938±0.119	0.897±0.111	1.0±0.0	0.875±0.132	0.909±0.12
water_5	1.0±0.0	0.944±0.106	1.0±0.0	1.0±0.0	1.0±0.0	0.933±0.089	0.962±0.074
waterfall	0.947±0.1	0.933±0.126	0.952±0.091	0.85±0.156	0.929±0.095	0.926±0.099	1.0±0.0
waterfall_2	0.941±0.112	0.88±0.127	0.947±0.1	1.0±0.0	0.773±0.175	0.905±0.126	0.9±0.131

Table 3: Per-texture accuracies averaged over exposure times, using the flow decode layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Dynamic texture	Short (300-600 ms.)	Long (1200-4800 ms.)	All (300-4800 ms.)
ants	0.917±0.078	0.959±0.039	0.945±0.037
bamboo	0.983±0.034	1.0±0.0	0.993±0.013
birds	0.807±0.102	0.934±0.051	0.885±0.051
boiling_water_1	0.909±0.076	0.955±0.044	0.937±0.04
boiling_water_2	0.811±0.089	0.909±0.064	0.861±0.055
calm_water	0.963±0.05	0.979±0.028	0.974±0.026
calm_water_2	0.986±0.027	0.988±0.024	0.987±0.018
calm_water_3	0.985±0.029	0.964±0.04	0.974±0.026
calm_water_4	0.95±0.055	1.0±0.0	0.979±0.023
calm_water_5	0.954±0.051	0.948±0.05	0.951±0.036
calm_water_6	0.956±0.049	1.0±0.0	0.98±0.023
candle_flame	0.986±0.028	1.0±0.0	0.993±0.014
candy_1	0.857±0.092	0.839±0.075	0.846±0.058
candy_2	0.912±0.067	0.963±0.042	0.939±0.039
coral	0.932±0.057	0.985±0.029	0.957±0.033
cranberries	0.881±0.078	0.952±0.046	0.92±0.043
escalator	0.98±0.038	1.0±0.0	0.993±0.014
fireplace_1	0.875±0.081	0.94±0.051	0.912±0.046
fish	0.944±0.054	0.961±0.043	0.953±0.034
flag	0.963±0.05	0.979±0.029	0.973±0.026
flag_2	0.987±0.025	0.985±0.029	0.986±0.019
flames	0.71±0.113	0.847±0.077	0.789±0.066
flushing_water	0.844±0.089	0.884±0.068	0.867±0.054
fountain_1	0.661±0.124	0.847±0.077	0.773±0.069
fountain_2	0.96±0.054	0.989±0.021	0.979±0.023
fur	0.917±0.07	0.988±0.023	0.958±0.033
grass_1	0.934±0.062	0.988±0.023	0.966±0.03
grass_2	0.969±0.042	0.939±0.052	0.952±0.034
grass_3	0.983±0.034	0.989±0.022	0.986±0.019
ink	0.957±0.047	0.963±0.041	0.96±0.031
lava	0.966±0.046	0.956±0.043	0.96±0.032
plants	0.964±0.049	0.978±0.03	0.972±0.027
sea_1	0.968±0.044	0.965±0.039	0.966±0.029
sea_2	0.902±0.082	0.979±0.029	0.952±0.035
shiny_circles	0.788±0.099	0.894±0.065	0.848±0.057
shower_water_1	0.906±0.071	0.988±0.023	0.952±0.034
sky_clouds_1	0.985±0.029	1.0±0.0	0.993±0.014
sky_clouds_2	0.966±0.046	0.978±0.031	0.973±0.026
smoke_1	0.825±0.094	0.929±0.055	0.884±0.052
smoke_2	0.91±0.068	0.964±0.04	0.94±0.038
smoke_3	1.0±0.0	0.989±0.022	0.993±0.013
smoke_plume_1	0.972±0.038	0.986±0.026	0.979±0.023
snake_1	0.983±0.032	1.0±0.0	0.993±0.013
snake_2	0.946±0.052	0.986±0.027	0.966±0.03
snake_3	0.986±0.026	0.973±0.037	0.98±0.023
snake_4	0.984±0.03	0.975±0.034	0.979±0.023
snake_5	0.964±0.049	1.0±0.0	0.986±0.019
tv_static	0.639±0.121	0.721±0.095	0.687±0.075
underwater_vegetation_1	0.932±0.064	1.0±0.0	0.972±0.027
water_1	0.887±0.085	0.921±0.056	0.908±0.047
water_4	0.907±0.077	0.978±0.03	0.952±0.035
water_2	0.95±0.055	0.988±0.023	0.972±0.027
water_3	0.857±0.092	0.914±0.057	0.893±0.05
water_5	0.981±0.037	0.969±0.035	0.973±0.026
waterfall	0.945±0.06	0.921±0.056	0.931±0.042
waterfall_2	0.918±0.069	0.897±0.064	0.905±0.047

Table 4: Per-texture accuracies averaged over a range of exposure times, using the flow decode layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Appearance group	300 ms.	400 ms.	600 ms.	1200 ms.	2400 ms.	3600 ms.	4800 ms.
Regular & Near-regular	0.702±0.098	0.74±0.101	0.838±0.088	0.84±0.083	0.954±0.051	0.878±0.074	0.827±0.082
Irregular	0.806±0.046	0.853±0.044	0.837±0.043	0.903±0.036	0.909±0.037	0.919±0.031	0.902±0.035
Stochastic & Near-stochastic	0.616±0.03	0.658±0.029	0.687±0.028	0.76±0.026	0.751±0.026	0.776±0.026	0.762±0.025

Table 5: Accuracies of textures grouped by appearances, averaged over exposure times, using the concatenation layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Appearance group	Short (300-600 ms.)	Long (1200-4800 ms.)	All (300-4800 ms.)
Regular & Near-regular	0.756±0.056	0.871±0.038	0.821±0.033
Irregular	0.831±0.026	0.908±0.017	0.875±0.015
Stochastic & Near-stochastic	0.654±0.017	0.762±0.013	0.717±0.01

Table 6: Accuracies of textures grouped by appearances, averaged over a range of exposure times, using the concatenation layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Appearance group	300 ms.	400 ms.	600 ms.	1200 ms.	2400 ms.	3600 ms.	4800 ms.
Regular & Near-regular	0.889±0.078	0.933±0.063	0.921±0.067	0.961±0.043	0.948±0.057	0.984±0.031	0.964±0.049
Irregular	0.89±0.041	0.942±0.031	0.957±0.026	0.953±0.028	0.96±0.025	0.968±0.022	0.947±0.029
Stochastic & Near-stochastic	0.901±0.021	0.916±0.018	0.937±0.016	0.957±0.014	0.945±0.015	0.955±0.013	0.96±0.013

Table 7: Accuracies of textures grouped by appearances, averaged over exposure times, using the flow decode layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Appearance group	Short (300-600 ms.)	Long (1200-4800 ms.)	All (300-4800 ms.)
Regular & Near-regular	0.914±0.04	0.964±0.023	0.943±0.022
Irregular	0.93±0.019	0.957±0.013	0.946±0.011
Stochastic & Near-stochastic	0.919±0.011	0.954±0.007	0.939±0.006

Table 8: Accuracies of textures grouped by appearances, averaged over a range of exposure times, using the flow decode layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Dynamics group	300 ms.	400 ms.	600 ms.	1200 ms.	2400 ms.	3600 ms.	4800 ms.
Spatially-consistent	0.625±0.032	0.664±0.032	0.698±0.03	0.741±0.028	0.753±0.028	0.762±0.028	0.755±0.028
Spatially-inconsistent	0.721±0.039	0.763±0.039	0.777±0.037	0.885±0.028	0.854±0.032	0.902±0.026	0.861±0.029

Table 9: Accuracies of textures grouped by dynamics, averaged over exposure times, using the concatenation layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Dynamics group	Short (300-600 ms.)	Long (1200-4800 ms.)	All (300-4800 ms.)
Spatially-consistent	0.663±0.018	0.753±0.014	0.715±0.011
Spatially-inconsistent	0.753±0.022	0.876±0.015	0.823±0.013

Table 10: Accuracies of textures grouped by dynamics, averaged over a range of exposure times, using the concatenation layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Dynamics group	300 ms.	400 ms.	600 ms.	1200 ms.	2400 ms.	3600 ms.	4800 ms.
Spatially-consistent	0.886±0.024	0.911±0.02	0.934±0.018	0.947±0.016	0.945±0.016	0.955±0.014	0.954±0.015
Spatially-inconsistent	0.92±0.027	0.942±0.023	0.949±0.021	0.974±0.016	0.954±0.02	0.966±0.017	0.964±0.018

Table 11: Accuracies of textures grouped by dynamics, averaged over exposure times, using the flow decode layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Dynamics group	Short (300-600 ms.)	Long (1200-4800 ms.)	All (300-4800 ms.)
Spatially-consistent	0.911±0.012	0.95±0.008	0.934±0.007
Spatially-inconsistent	0.937±0.013	0.964±0.009	0.953±0.008

Table 12: Accuracies of textures grouped by dynamics, averaged over a range of exposure times, using the flow decode layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Group	300 ms.	400 ms.	600 ms.	1200 ms.	2400 ms.	3600 ms.	4800 ms.
All textures	0.661±0.025	0.699±0.025	0.726±0.023	0.791±0.021	0.788±0.022	0.812±0.021	0.793±0.021

Table 13: Average accuracy over all textures, averaged over exposure times, using the concatenation layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Group	Short (300-600 ms.)	Long (1200-4800 ms.)	All (300-4800 ms.)
All textures	0.695±0.014	0.796±0.011	0.754±0.009

Table 14: Average accuracy over all textures, averaged over a range of exposure times, using the concatenation layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Group	300 ms.	400 ms.	600 ms.	1200 ms.	2400 ms.	3600 ms.	4800 ms.
All textures	0.898±0.018	0.922±0.015	0.94±0.013	0.956±0.012	0.948±0.013	0.959±0.011	0.957±0.012

Table 15: Average accuracy over all textures, averaged over exposure times, using the flow decode layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.

Group	Short (300-600 ms.)	Long (1200-4800 ms.)	All (300-4800 ms.)
All textures	0.921±0.009	0.955±0.006	0.941±0.005

Table 16: Average accuracy over all textures, averaged over a range of exposure times, using the flow decode layer. Each texture accuracy includes a margin of error with a 95% statistical confidence.