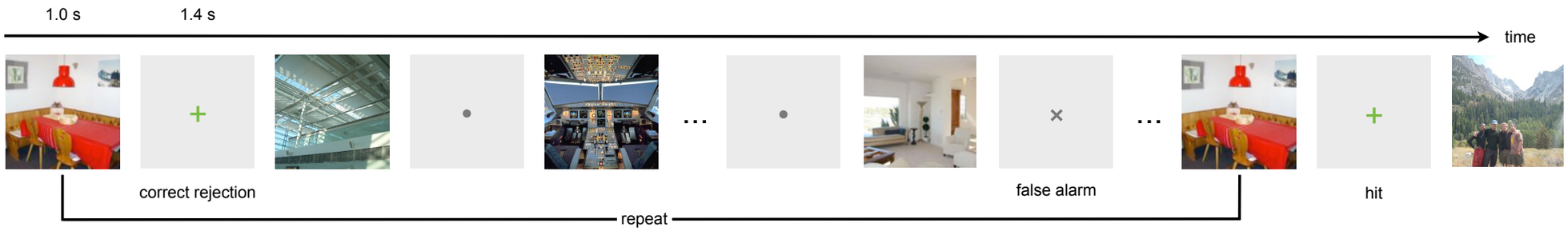


Computational Understanding of Image Memorability

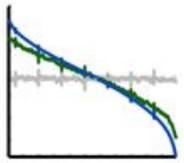
A general overview

Joint work with Aude Oliva, Antonio Torralba, Phillip Isola,
Michelle Borkin, and Melissa Le-Hoa Võ.

Image Memorability

- objective and quantifiable measure of images
- consistent across observers
- measures utility of information
- filter for visual data

Application areas



understand human memory

design better user interfaces

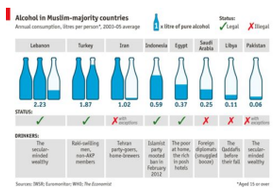
diagnose memory problems

design better logos

face memory accuracy, biases, and mistakes

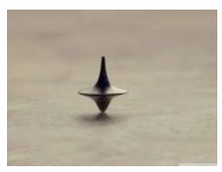
design better educational material

design mnemonic aids



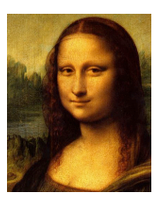
design better data visualizations

smarter visual search



inception, image manipulation

summarize big data and videos



understand and predict cultural trends

Welcome to the

Visual Memory Game

A stream of images will be presented on the screen for 1 second each.

Your task:

Clap your hands (press a key) anytime you see an image you saw before.

Be attentive, repeats may be separated by many images !

Whenever you press a key, you will get feedback:

You may exit the game at any time and you will be paid in proportion to your progress at that time

Start Game!

Ready?

(Seriously, get ready to clap. The images go by fast…)

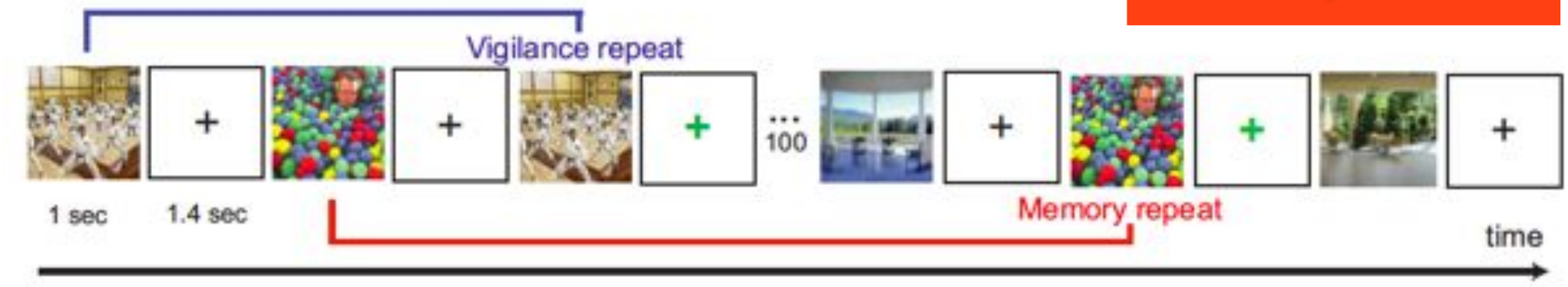
Repeat!

Repeat!

Repeat!

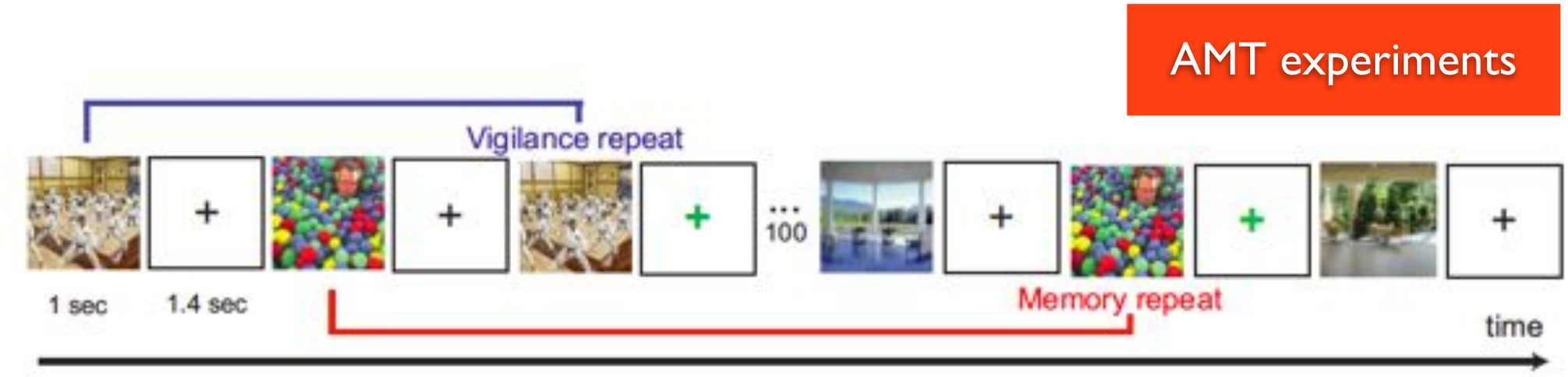
Image Memorability

AMT experiments



Isola, P., Xiao, J., Torralba, A., Oliva, A. What makes an image memorable? IEEE CVPR, 2011.

Image Memorability



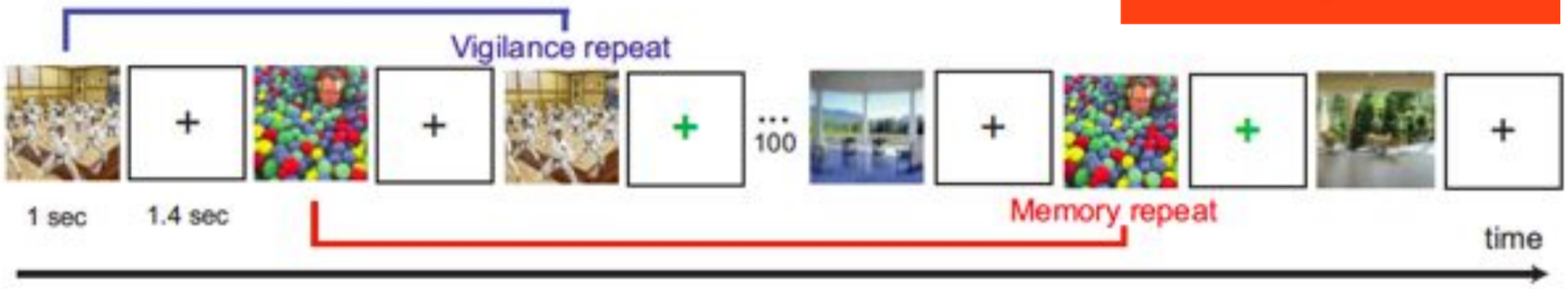
measuring memorability:

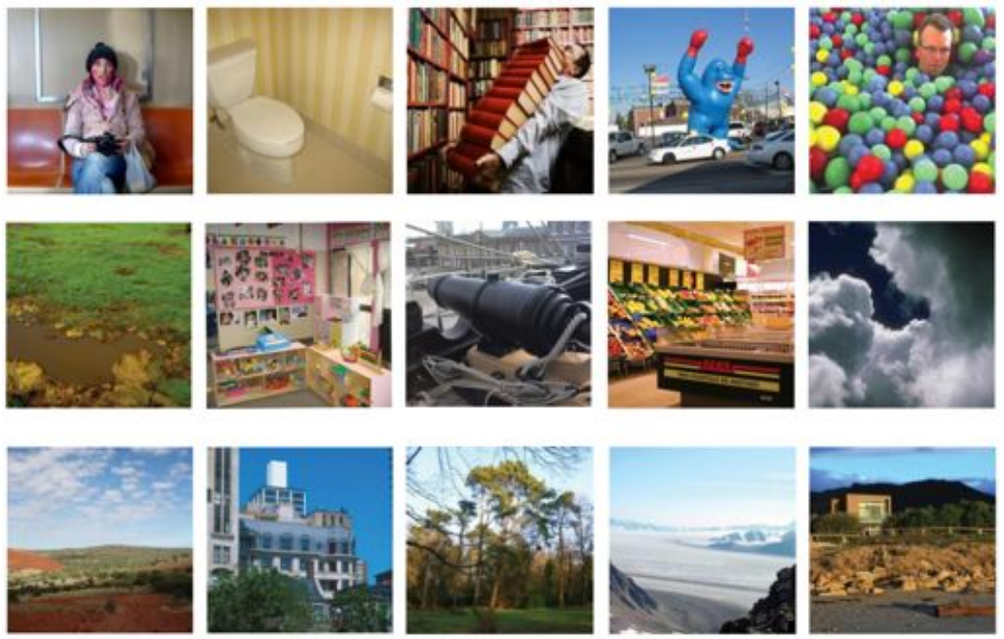
$$\mathrm{HR(I)} = \frac{\mathrm{hits(I)}}{\mathrm{hits(I)+misses(I)}} \times 100\%$$

Isola, P., Xiao, J., Torralba, A., Oliva, A. What makes an image memorable? IEEE CVPR, 2011.

Image Memorability

AMT experiments





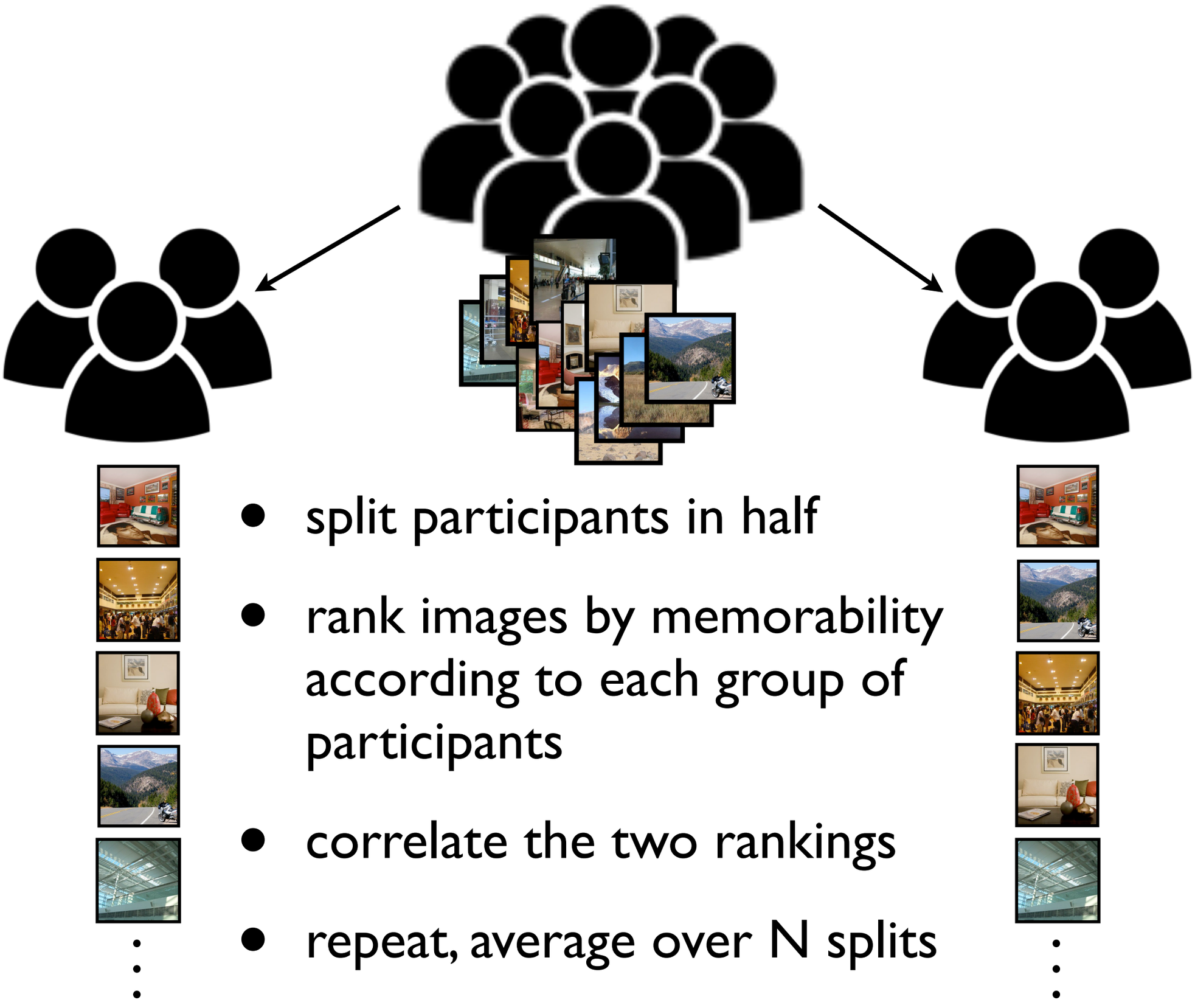
Memorable
~ 90%

Average
~ 67%

Forgettable
~40%

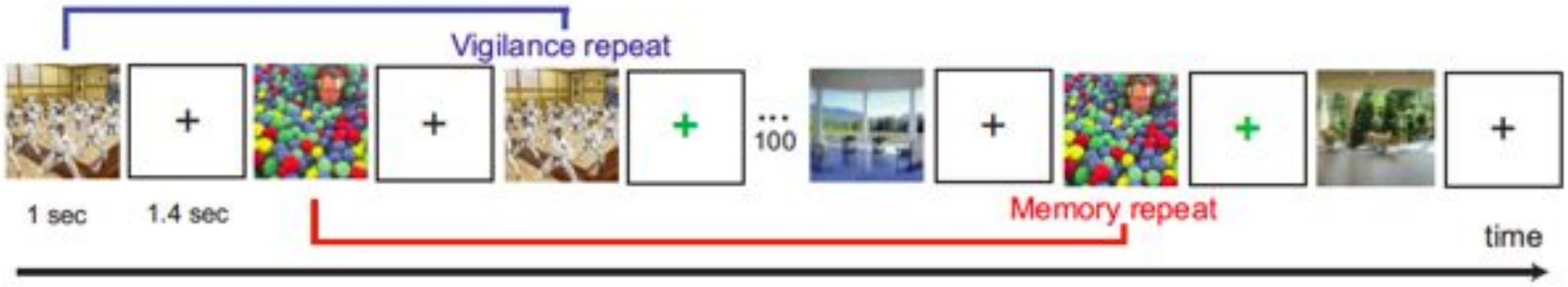
Isola, P., Xiao, J., Torralba, A., Oliva, A. What makes an image memorable? IEEE CVPR, 2011.

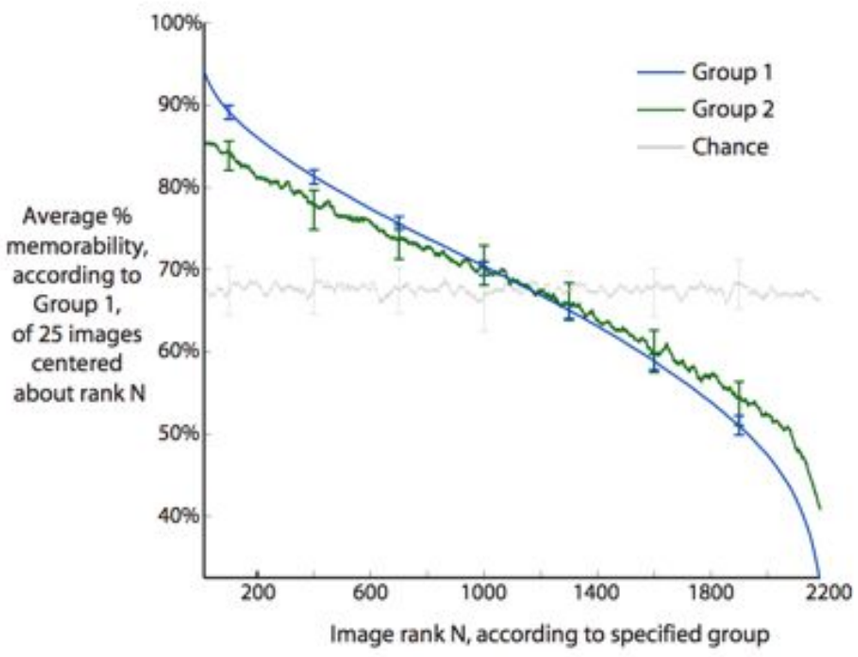
Measuring consistency



- split participants in half
- rank images by memorability according to each group of participants
- correlate the two rankings
- repeat, average over N splits

Measuring consistency





consistency r = 0.75

Isola, P., Xiao, J., Torralba, A., Oliva, A. What makes an image memorable? IEEE CVPR, 2011.

Previous findings on image memorability...

some images are consistently memorable, forgettable

Isola, P., Xiao, J., Torralba, A., Oliva, A. What makes an image memorable? IEEE CVPR, 2011.

Previous findings on image memorability...

some images are consistently memorable, forgettable

↓

memorability is an intrinsic property of images, independent of observer

Isola, P., Xiao, J., Torralba, A., Oliva, A. What makes an image memorable? IEEE CVPR, 2011.

Previous findings on image memorability...

some images are consistently memorable, forgettable

↓

memorability is an intrinsic property of images, independent of observer

↓

can be computationally predicted

Isola, P., Xiao, J., Torralba, A., Oliva, A. What makes an image memorable? IEEE CVPR, 2011.

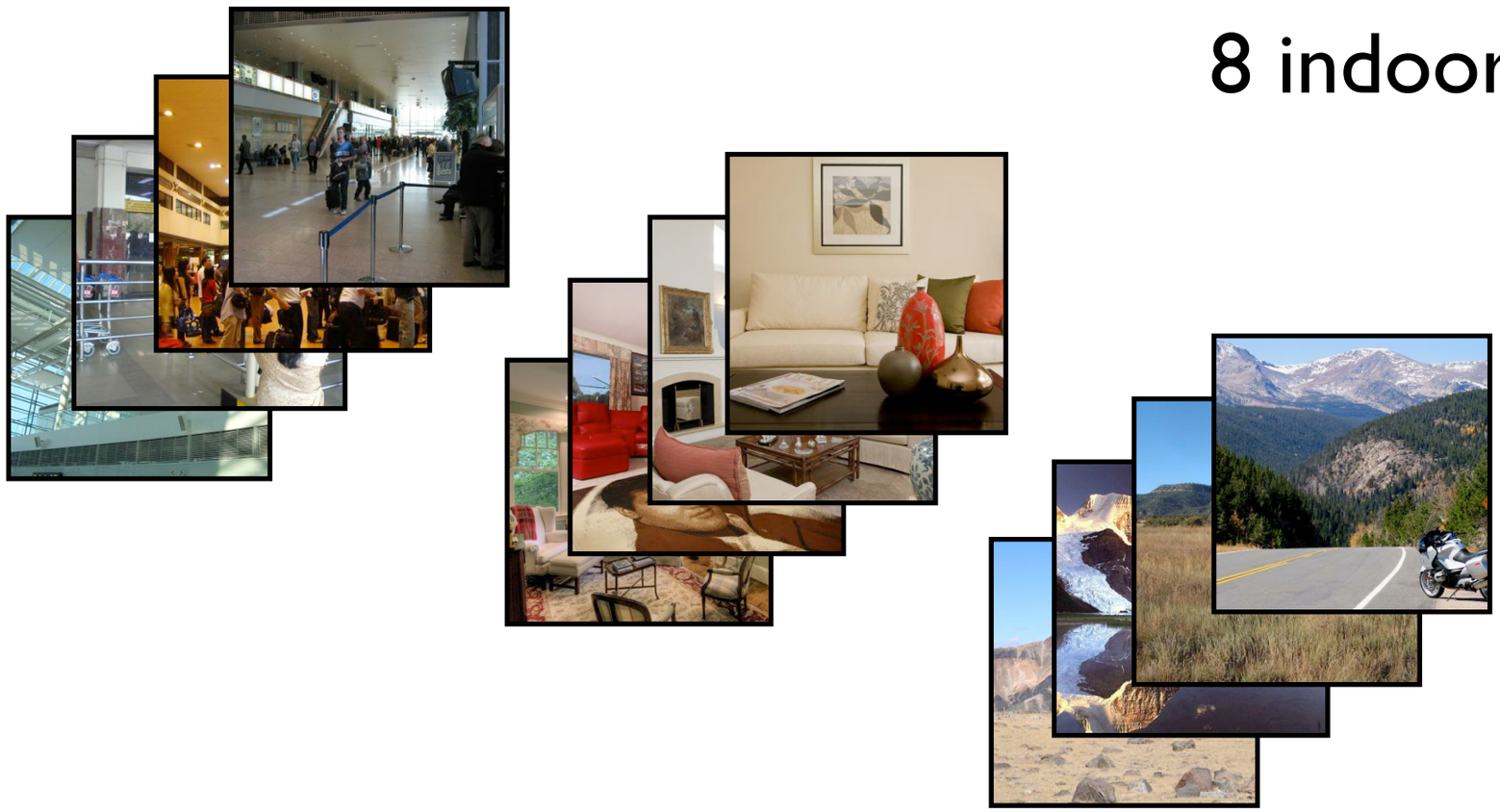
Outstanding questions

- does the consistency of human visual memory generalize?
- what factors can modulate image memorability?
- how do differences in memorability behave over time?

- does the consistency of human visual memory generalize?
- what factors can modulate image memorability?
- how do differences in memorability behave over time?

FIGRIM data collection

21 SUN categories:
8 indoor, 13 outdoor



airport terminal
amusement park
badlands
bathroom
bedroom
bridge
castle
cockpit
conference room
dining room
golf course
highway
house
kitchen
lighthouse
living room
mountain
pasture
playground
skyscraper
tower

those with at least 300
700x700 images

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

FIGRIM data collection

21 SUN categories:
8 indoor, 13 outdoor

airport terminal
amusement park
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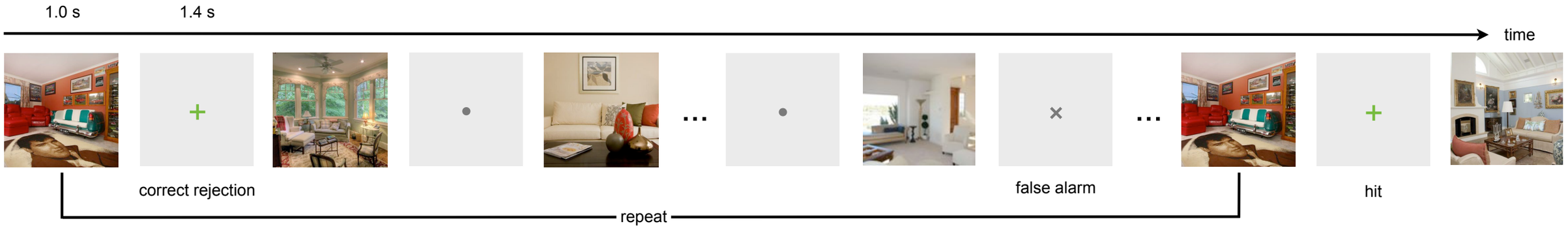
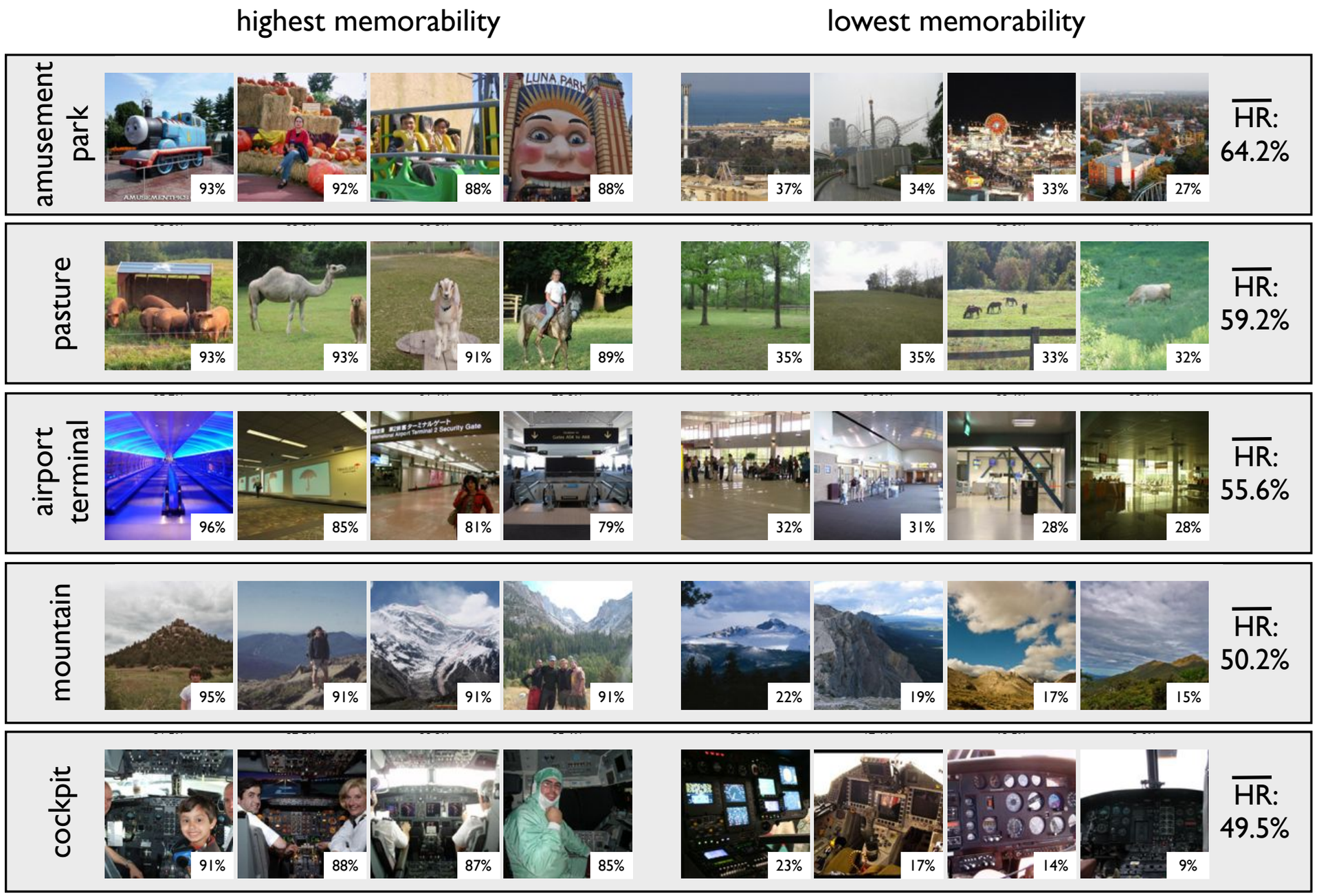
dining room
golf course
highway
house
kitchen
lighthouse
living room
mountain
pasture
playground
skyscraper
tower

ran 21 separate experiments:
one per scene category



Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

sample of FIGRIM Dataset



memorability scores for 1754 targets across 21 categories (7296 fillers)

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

What about within individual scene categories?

92.9%

36.8%

91.5%

36.6%

- people are still consistent, even within categories!
- consistency ranges from r = 0.69 to 0.86 for HR of individual categories

95.7%

32.3%

91.5%

22.9%

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

All scene categories have intrinsically memorable and forgettable images

92.9%

36.8%

91.5%

36.6%

95.7%

32.3%

91.5%

22.9%

- people are still consistent, even within categories!
- consistency ranges from r = 0.69 to 0.86 for HR of individual categories
- memorable instances have unusual objects, layouts, perspectives, or colors

will be quantified

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

- does the consistency of human visual memory generalize? yes, within scene categories
- what factors can modulate image memorability?
- how do differences in memorability behave over time?

- does the consistency of human visual memory generalize?

- what factors can modulate image memorability?

- how do differences in memorability behave over time?

FIGRIM data collection

ran 21 separate experiments:
one per scene category

AND

an additional experiment, combining images from all categories

21 SUN categories:
8 indoor, 13 outdoor

airport terminal
amusement park
badlands
bathroom
bedroom
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living room
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skyscraper
tower

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Data collection

ran 21 separate experiments: one per scene category → within-category experiment

AND

an additional experiment, combining images from all categories → across-category experiment

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Data collection

ran 21 separate experiments:
one per scene category

→ within-category experiment

AND

an additional experiment, combining images from all categories

→ across-category experiment

both sets of experiments contain the same images in different contexts.

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Quantifying context effects on memorability

- large body of memory literature suggests that "distinct" or "unique" items (those that stand out from their context) are better remembered
- our goal is to quantify this intuition using our large set of natural scene images

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

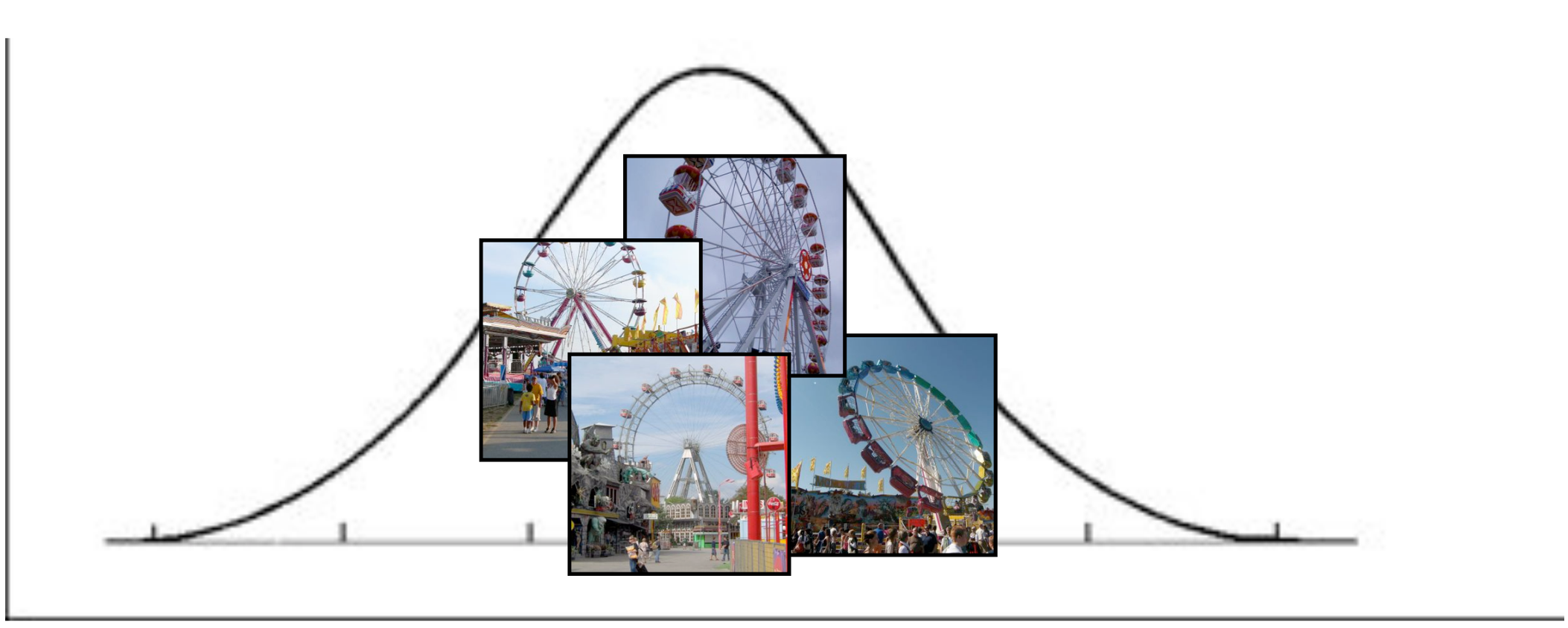
Quantifying context effects on memorability

- call an image contextually distinct if it is distinct with respect to the other images in its context

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Applying classical principles of information theory

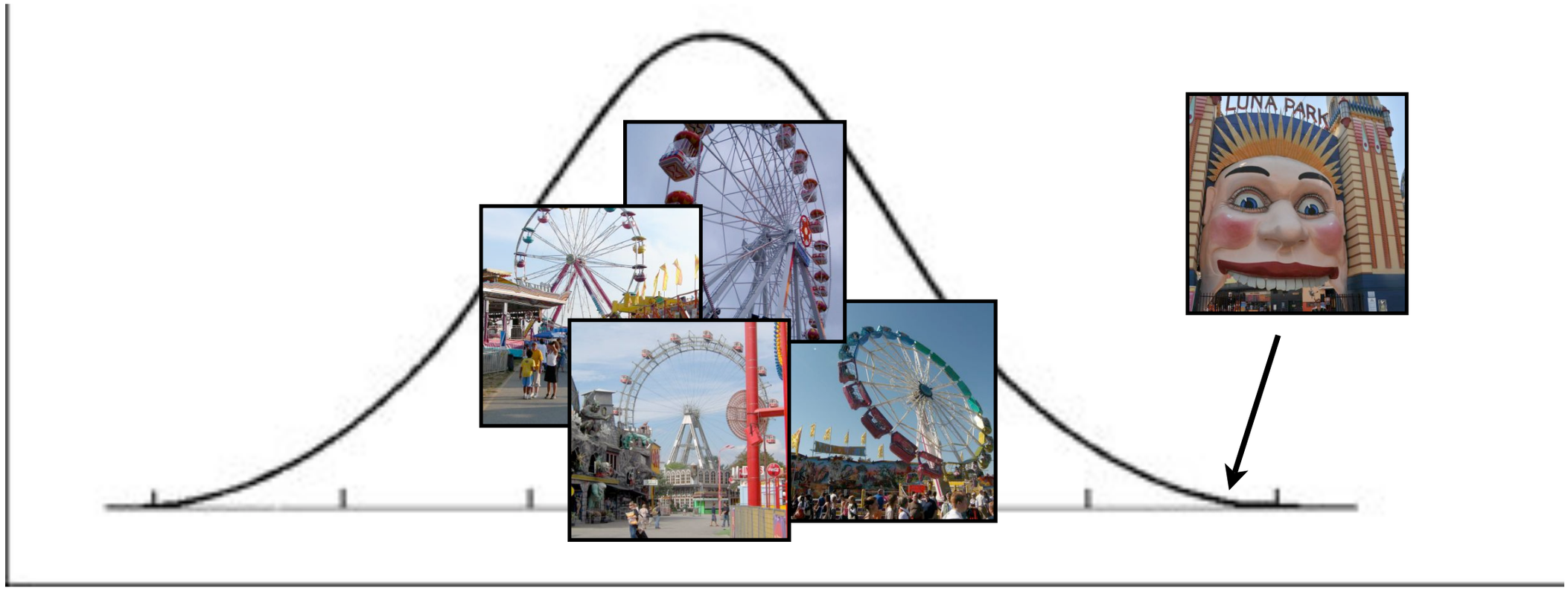
- compute a probability distribution over the images in a given context (in some feature space)



Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Applying classical principles of information theory

- compute a probability distribution over the images in a given context (in some feature space)
- estimate the likelihood of the image under this distribution



Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Applying classical principles of information theory

feature mapping

image

$$f_i = F(I)$$

kernel distribution

Epanechnikov kernel

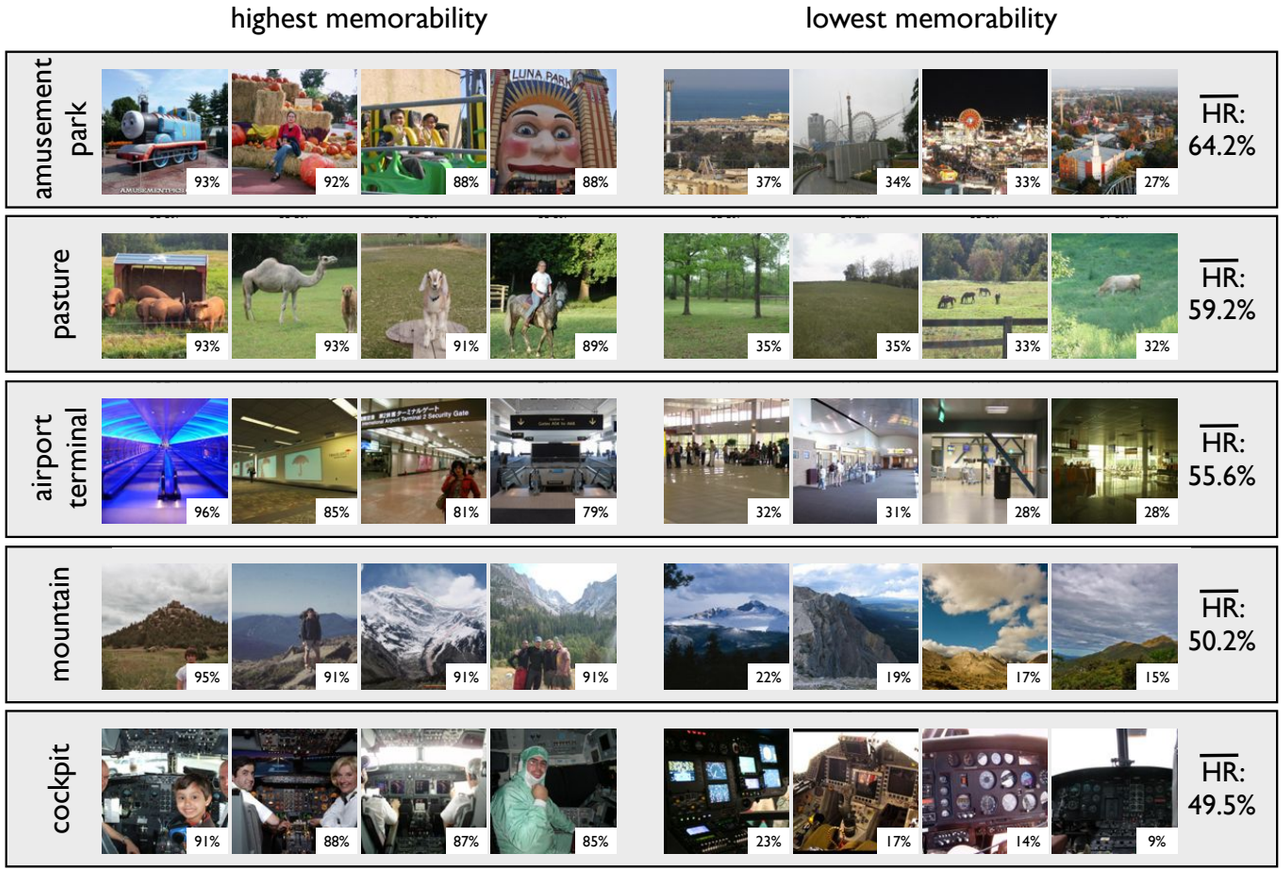
$$P_c(f_i) = \frac{1}{\|C\|} \sum_{j \in C} K(f_i - f_j)$$

distinctiveness of an image
with respect to a context C

$$D(I; C) = -\log P_c(f_i)$$

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Contextually distinct images are more memorable



Spearman correlation: 0.24 (p<0.01)

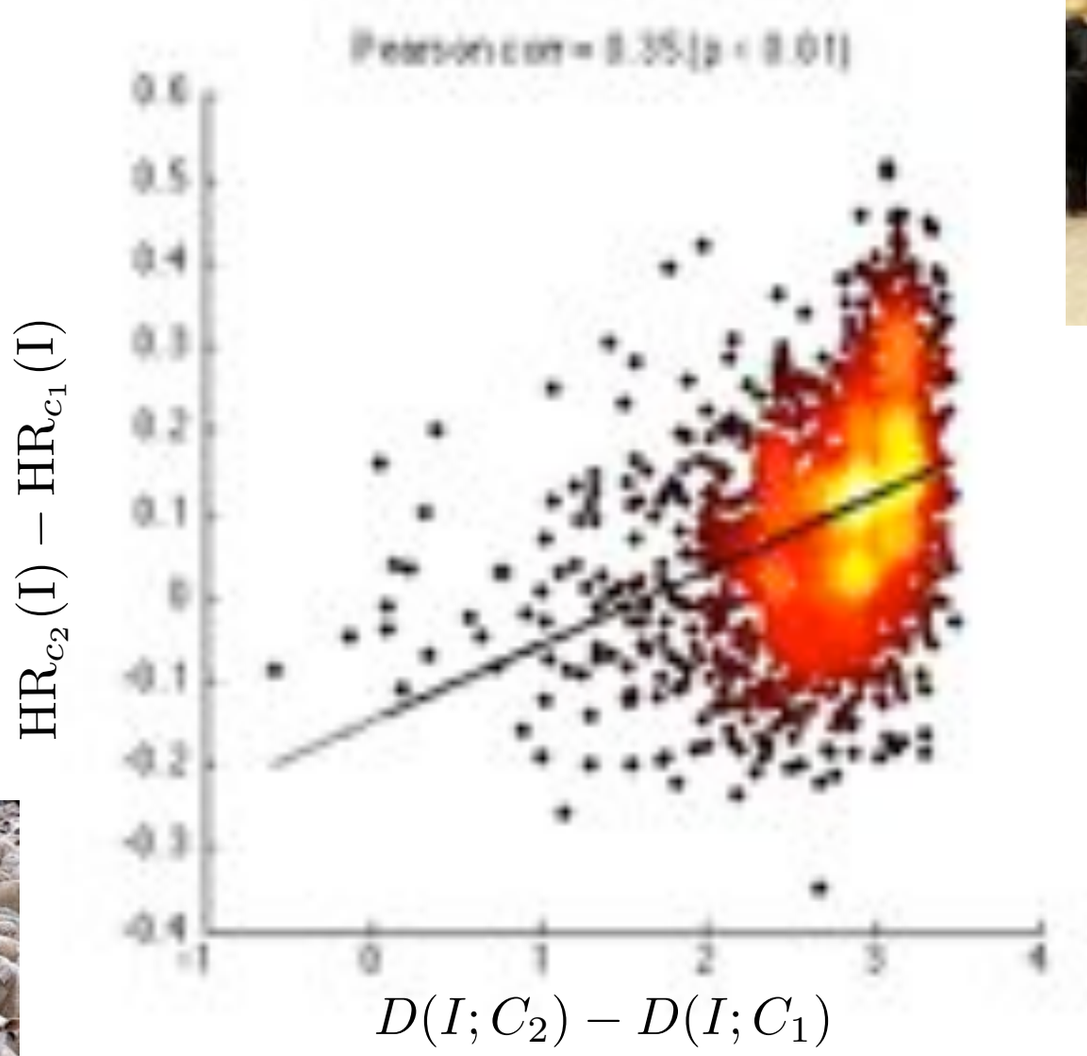
$$\mathrm{HR(I)} = \frac{\mathrm{hits(I)}}{\mathrm{hits(I)+misses(I)}} \times 100\%$$

$$D(I;C) = -\log P_c(f_i)$$

using: Places-CNN features

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Changing context changes memorability



using: Places-CNN features

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Contextually distinct images are more memorable

memorable within-categories

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

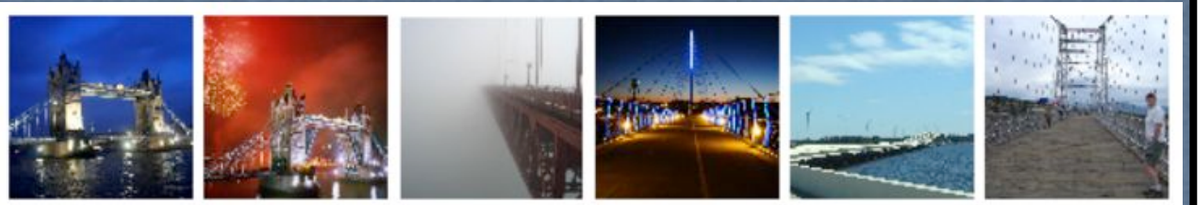
Contextually distinct images are more memorable

memorable within-categories	memorable across categories
	

want to select images like these
with more stable memorability

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Contextually distinct images are more memorable

memorable within-categories	memorable across categories
	
	
corr. b/w HR and D(I;AMT1) = 0.26 (p<0.01)	corr. b/w HR and D(I;AMT2) = 0.24 (p<0.01)

using: Places-CNN features

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

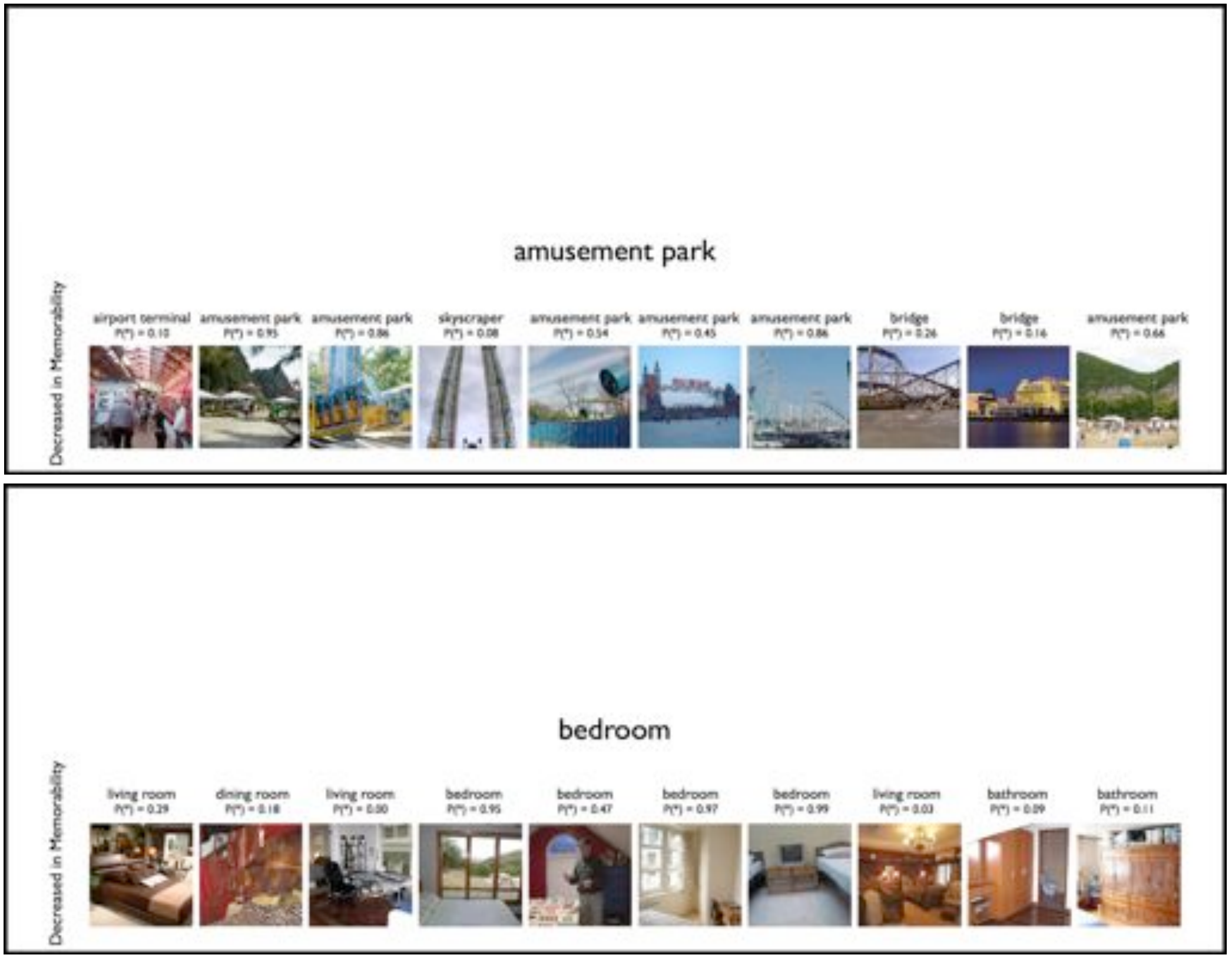
Images most affected by context

amusement parks that dropped in memorability when combined with other categories

bedrooms that dropped in memorability when combined with other categories

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

What does a classifier think?

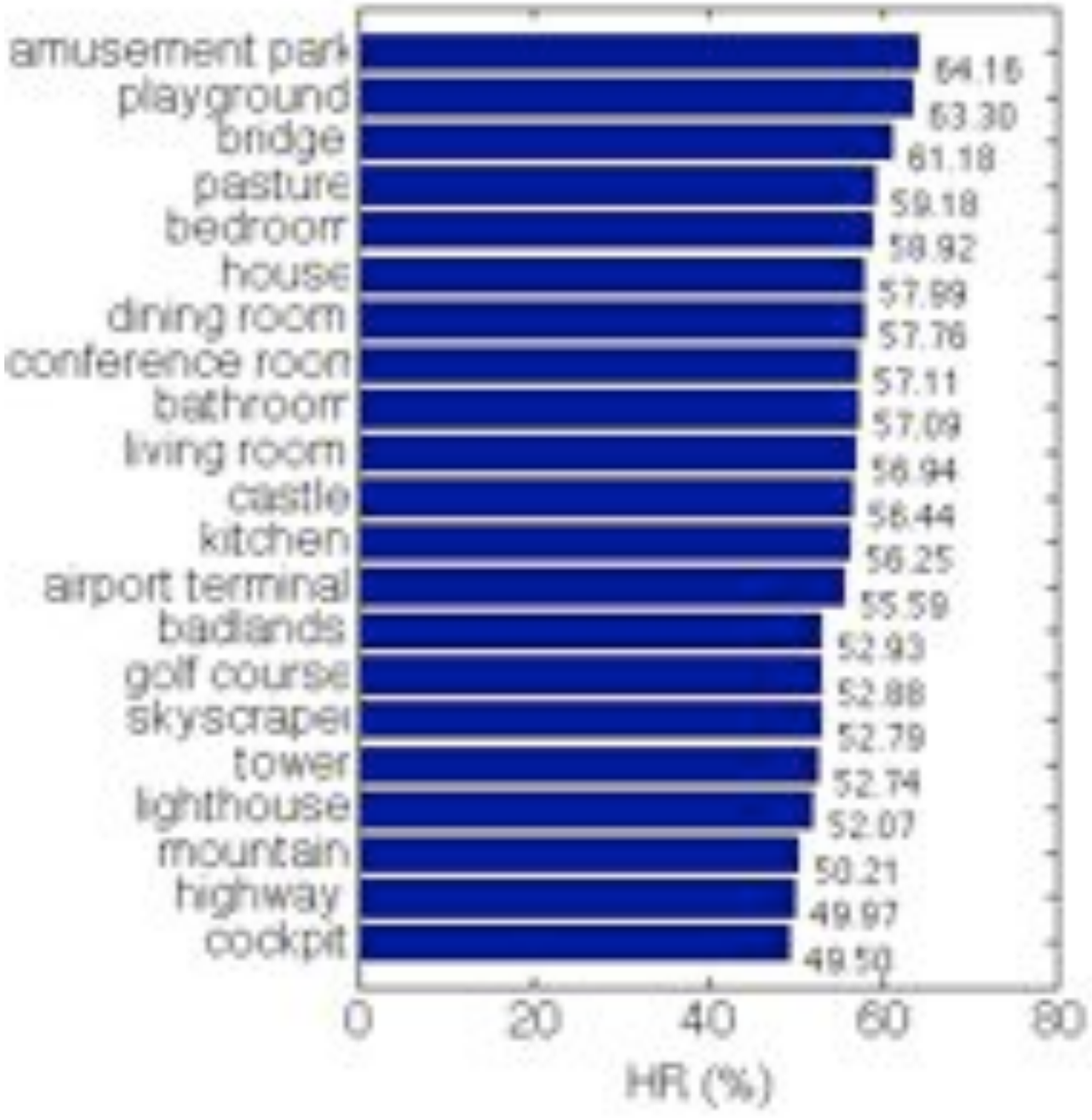


Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

What does a classifier think?

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

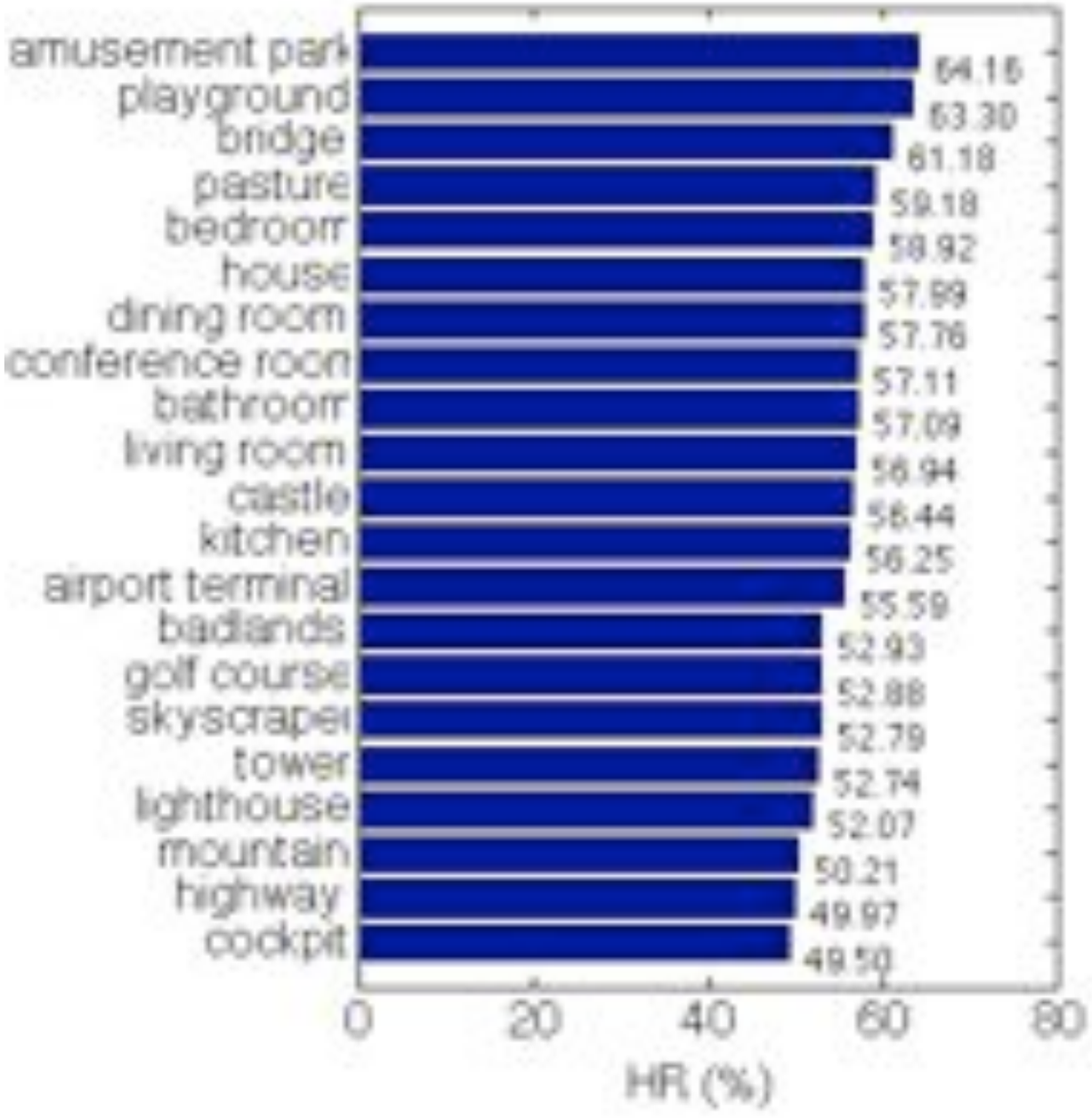
Memorability of a context



- some scene categories are intrinsically more memorable
- relative ranking of the scene categories is stable (correlation of 0.68 across different splits of images)

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Memorability of a context



- some scene categories are intrinsically more memorable

will be quantified

  - they contain more variety

- relative ranking of the scene categories is stable (correlation of 0.68 across different splits of images)

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Quantifying context entropy

distinctiveness of an image
with respect to a context C

$$D(I;C) = -\log P_c(f_i)$$

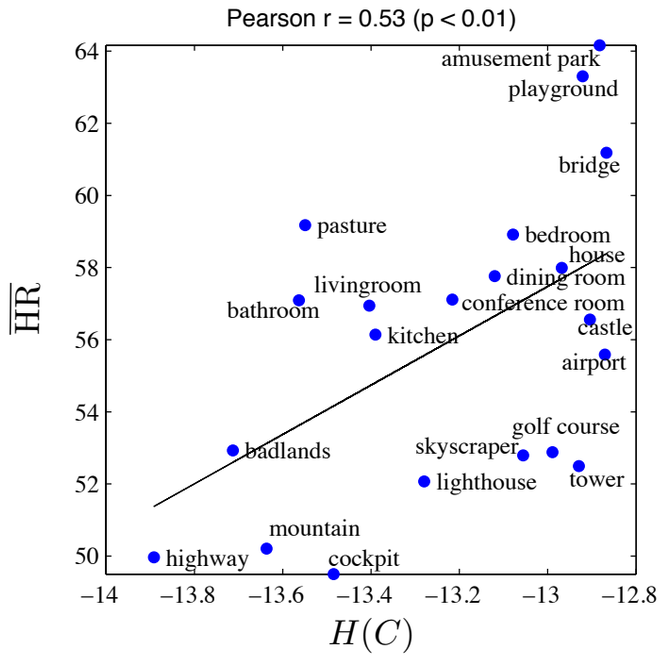
context entropy

$$H(C) = \mathbb{E}_c[-\log P_c(f_i)]$$

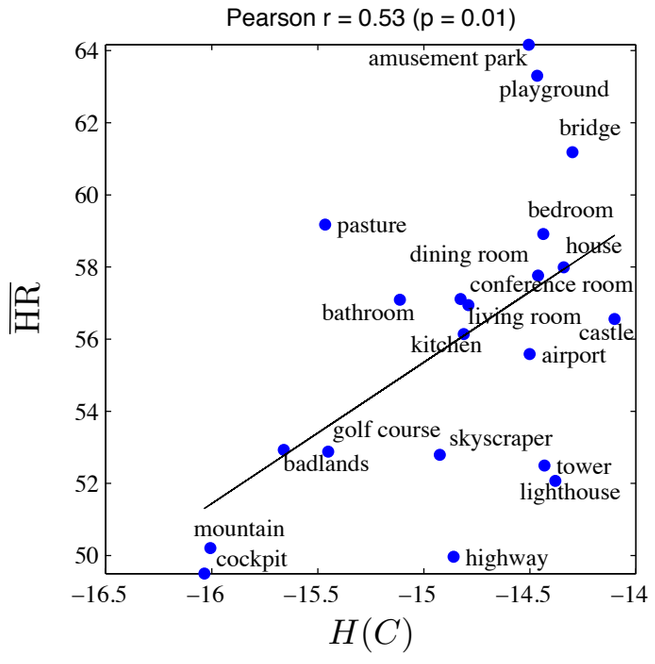
Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Memorability increases with context variability

GIST features



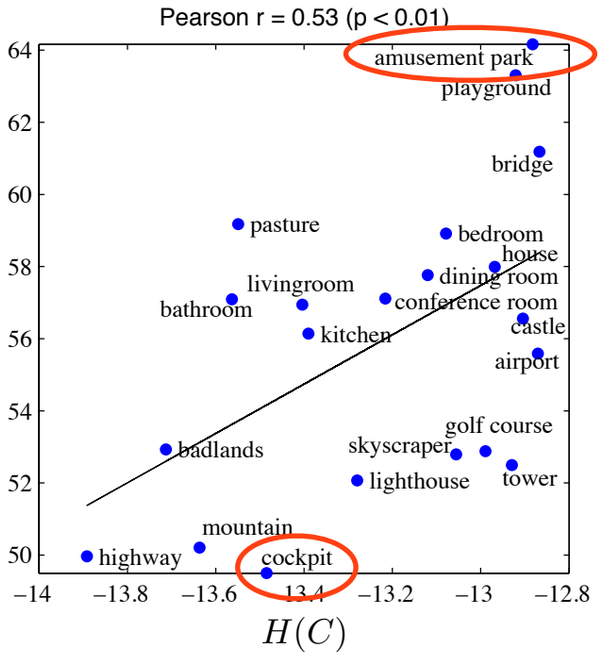
CNN features



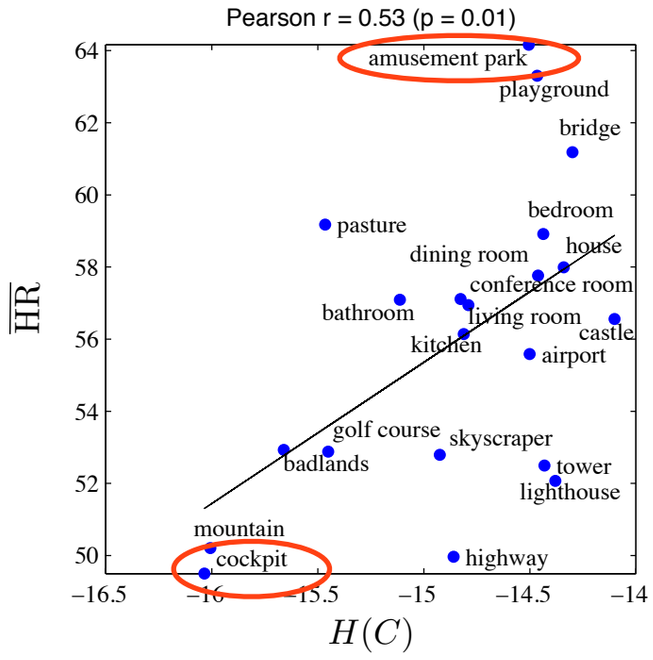
Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

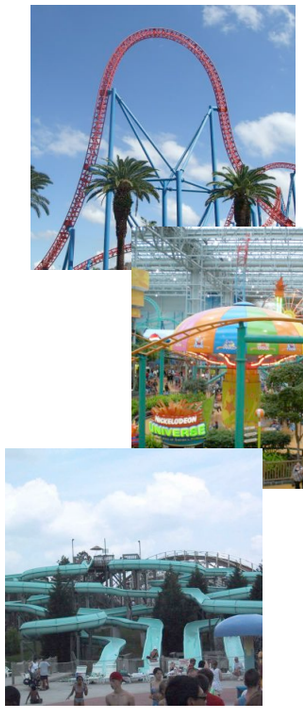
Memorability increases with context variability

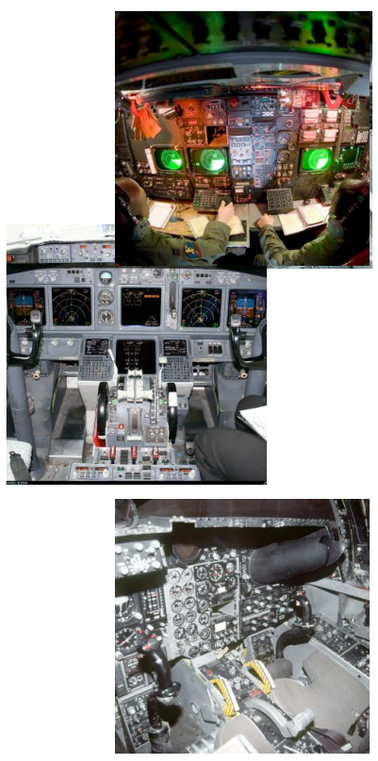
GIST features



CNN features

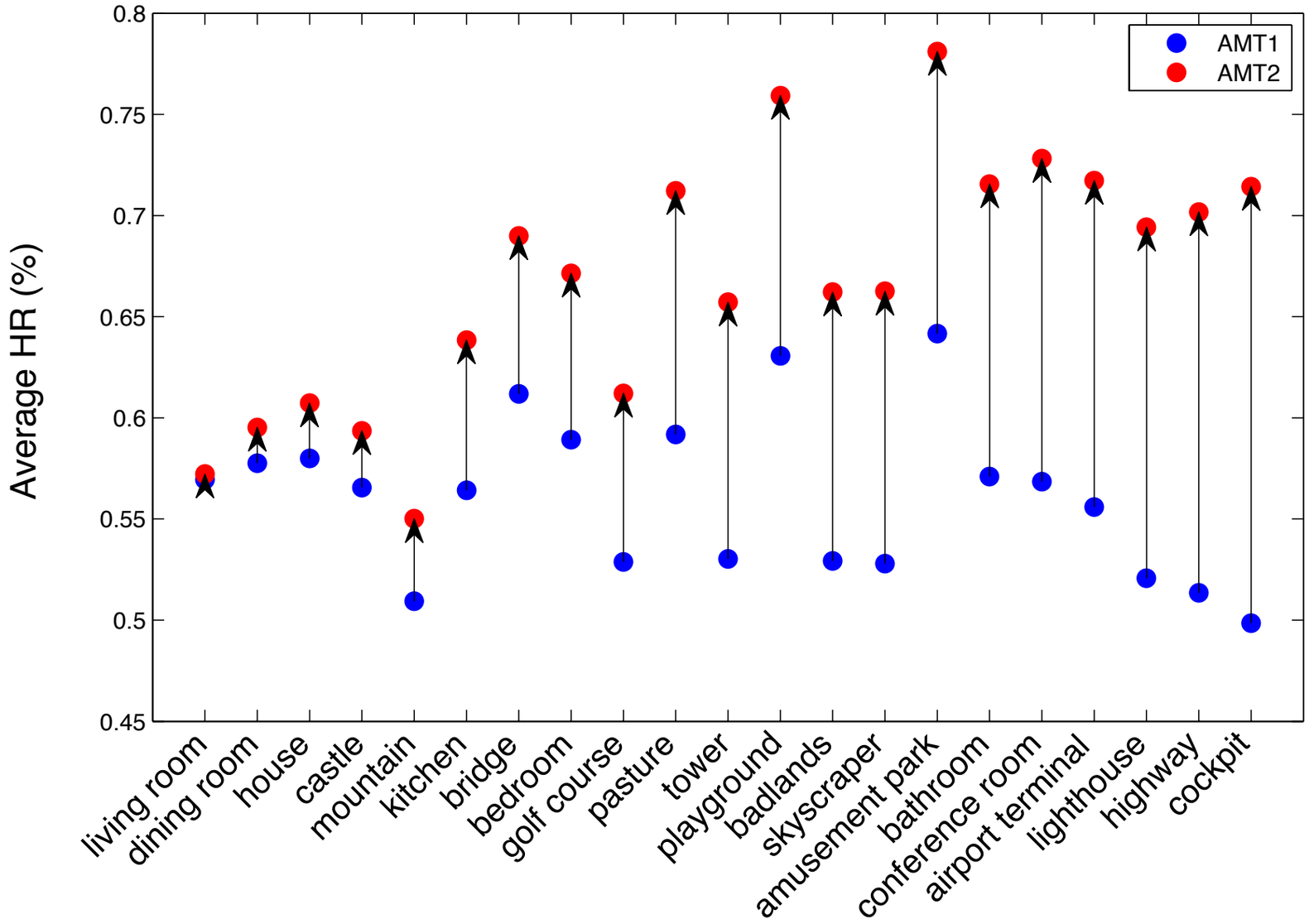






Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Memorability increases with context variability

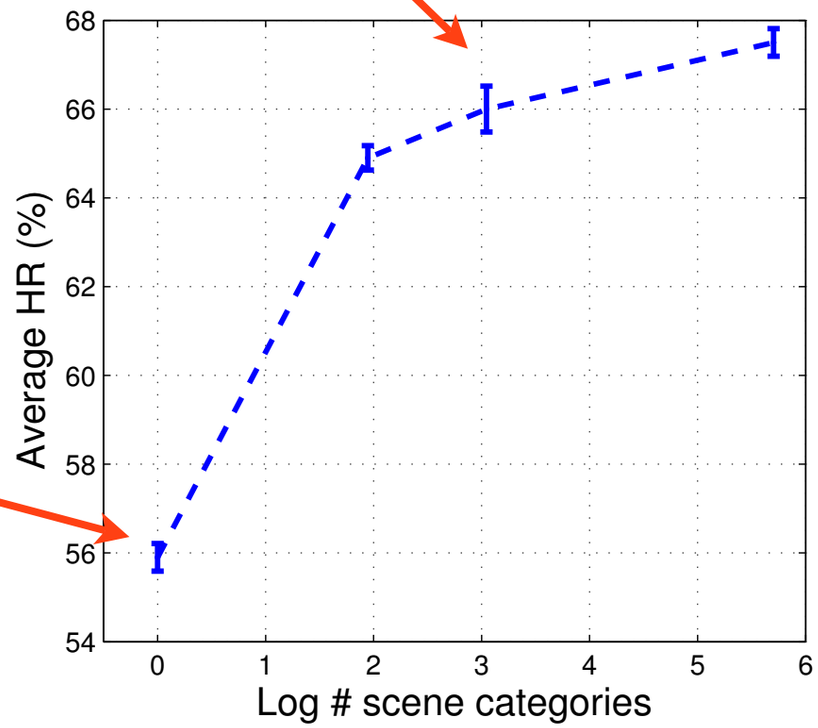


Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Memorability increases with context variability

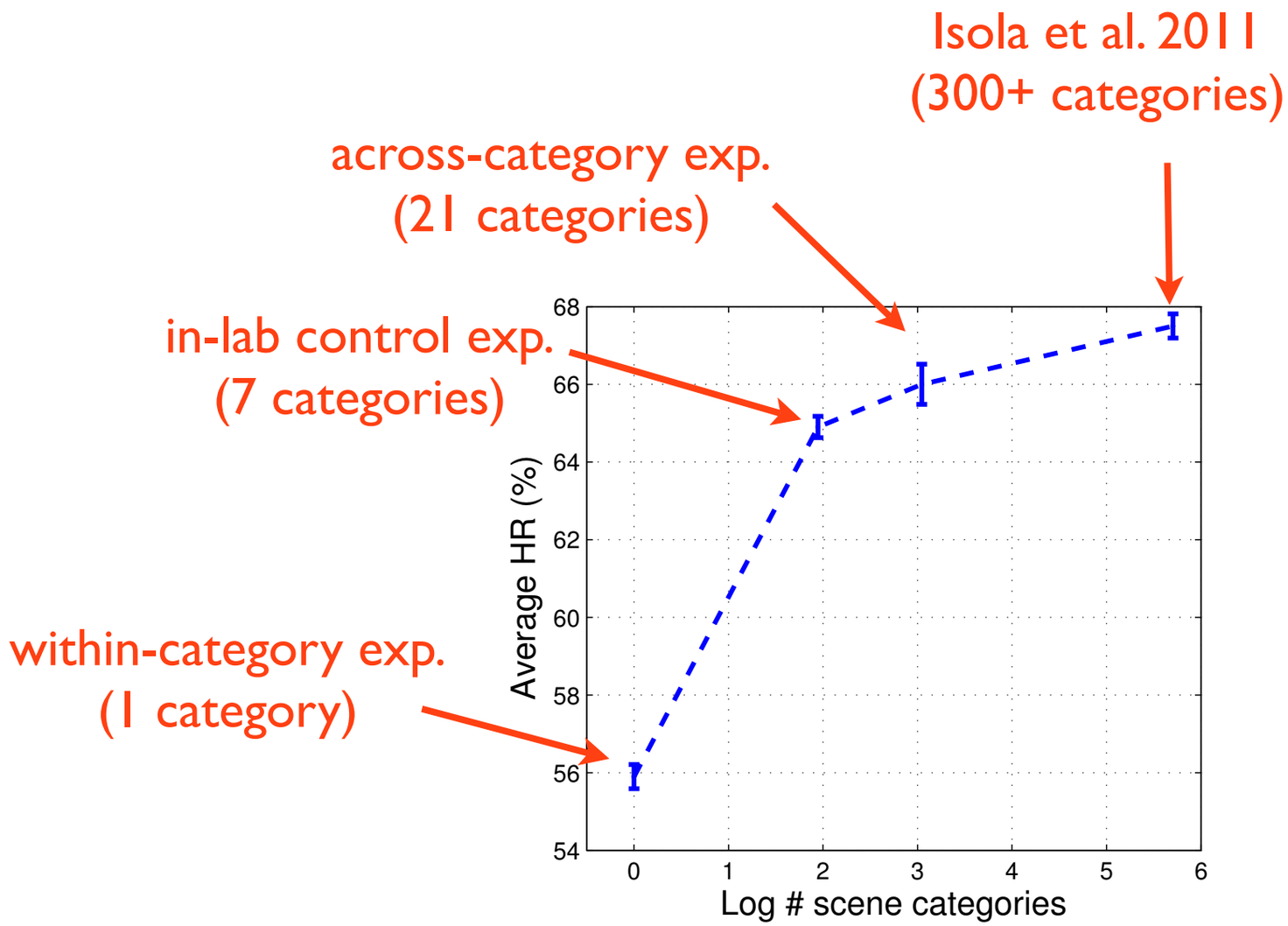
across-category exp.
(21 categories)

within-category exp.
(1 category)



Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

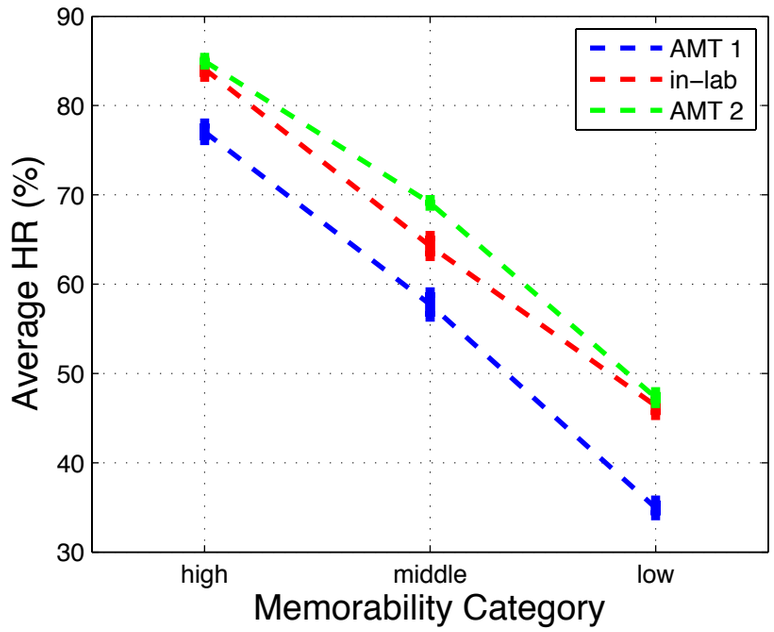
Memorability increases with context variability



supports classical results in memory research!

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Consistency across memorability experiments



Dataset	targets	fillers	datapoints/target	mean HR (%)	mean FAR (%)	HR cons. (ρ)	FAR cons. (ρ)
FIGRIM	1754	7296	74	66.0 (SD: 13.9)	11.1 (SD: 9.5)	0.74	0.72
Isola [2]	2222	8220	78	67.5 (SD: 13.6)	10.7 (SD: 7.6)	0.75	0.66
Faces [4]	2222	6468	82	51.6 (SD: 12.6)	14.4 (SD: 8.7)	0.68	0.69
Visualizations [5]	410	1660	87	55.4 (SD: 16.5)	13.2 (SD: 10.7)	0.83	0.78

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

- does the consistency of human memory generalize?

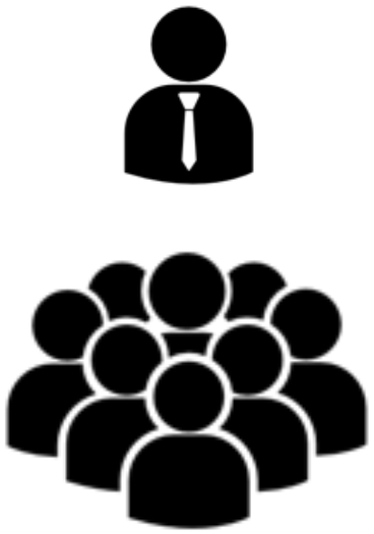
- what factors can modulate image memorability?

- how do differences in memorability behave over time?

Goal: to make memory predictions for a <u>specific individual on a specific trial</u>

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. <u>Intrinsic and Extrinsic Effects on Image Memorability</u>, Vision Research, 2015.

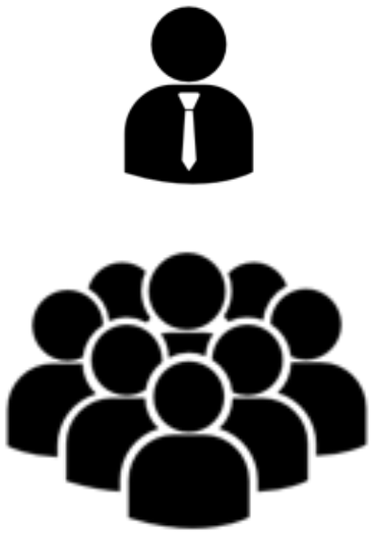
Procedure



- leave one user out
- to predict if that user will remember a particular image...
- we use the rest of the crowd to make predictions on a per-image, per-trial basis

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Procedure

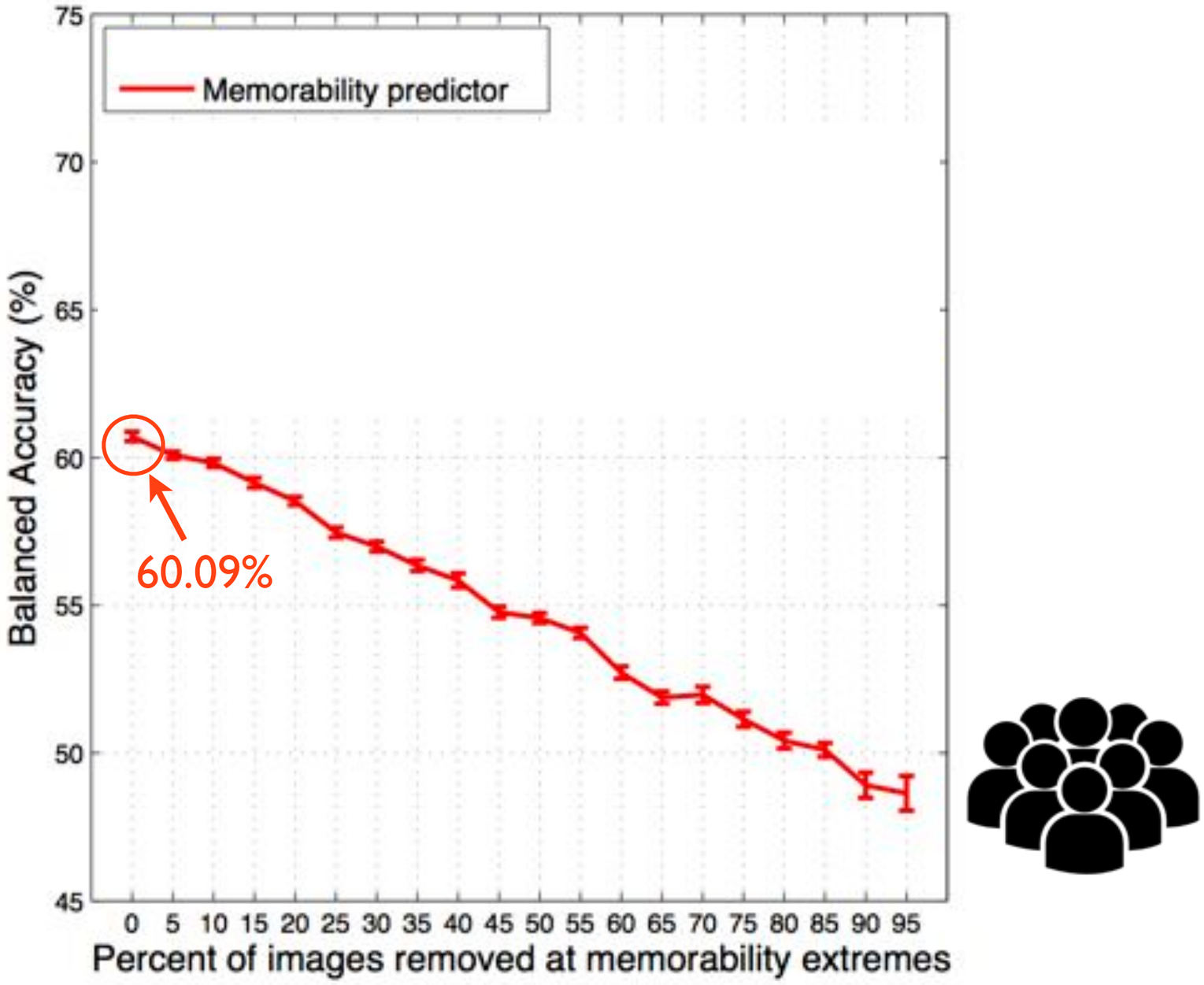


- leave one user out
- to predict if that user will remember a particular image...
- we use the rest of the crowd to make predictions on a per-image, per-trial basis

$$\text{balanced accuracy} = \frac{0.5 \times \text{true positives}}{\text{true positives} + \text{false negatives}} + \frac{0.5 \times \text{true negatives}}{\text{true negatives} + \text{false positives}}$$

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

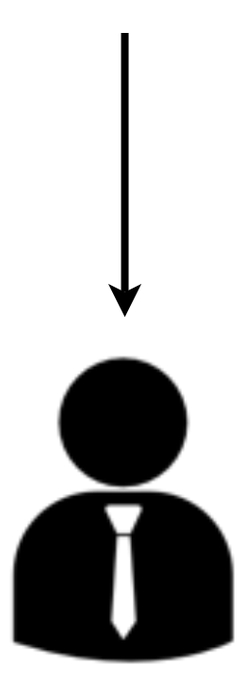
How well can we predict if people will remember an image?



Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Need to make better memory predictions for a specific user on a specific trial

Consider the behavior, attentional biases of the user



Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

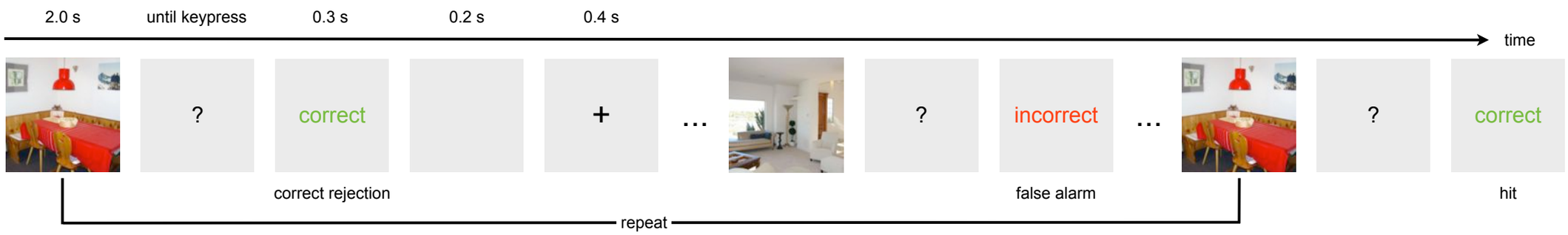
We use eye-movements to predict if an image will be remembered

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Eye-tracking experiments

We use eye-movements to predict if an image will be remembered

note: can only respond after image, forced-choice keypress



- 630 targets/experiment
- 42 participants in total (~16.2 per image)

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Eye-tracking model

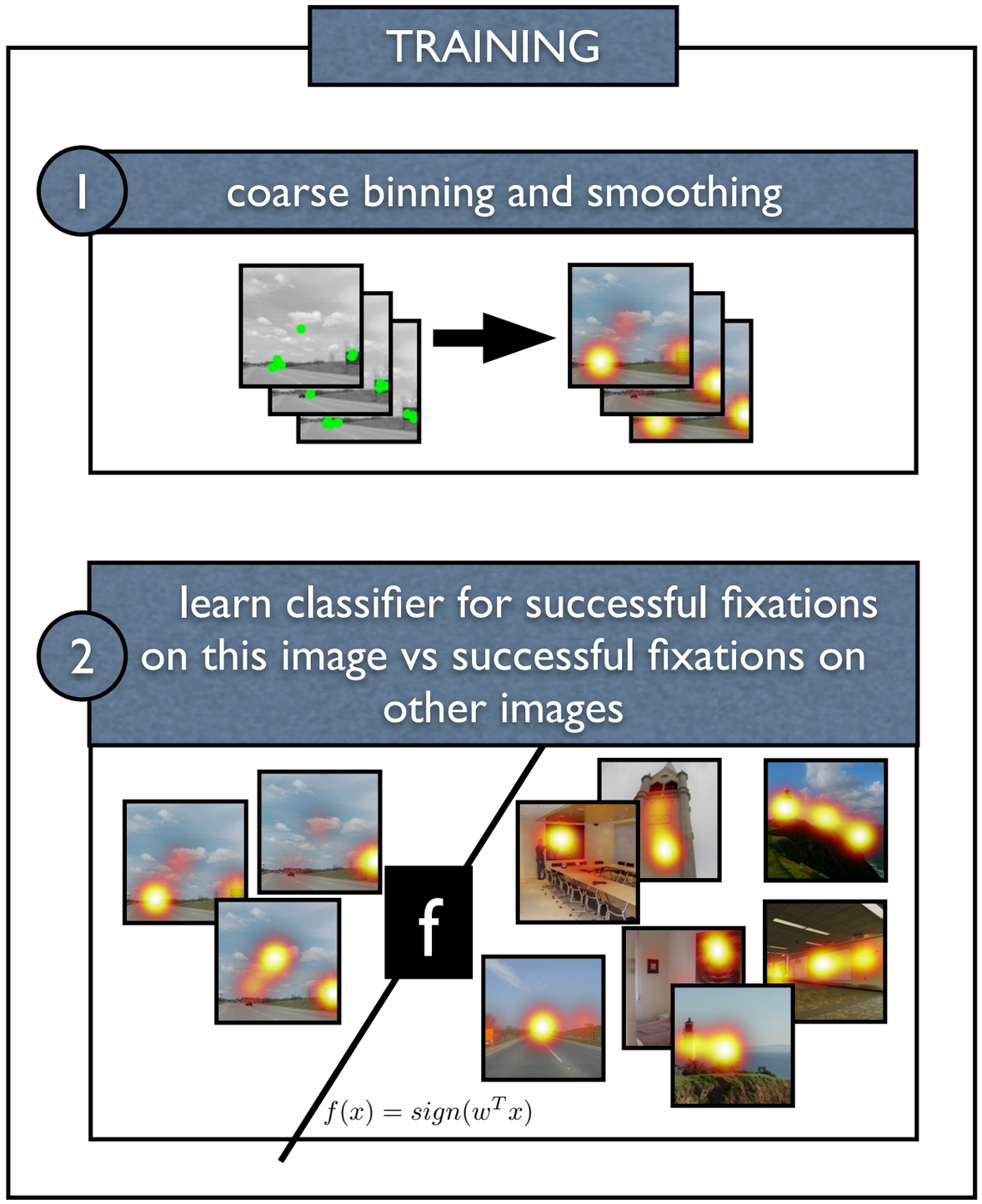
Idea: for a set of fixations on an image, evaluate how likely it is that they came from this image

if very likely, assume user was paying attention to the image, successfully encoded it, and will remember it later

if not very likely, assume user was not paying attention to the image, failed to encode it, and will not remember it later

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Classification of fixations

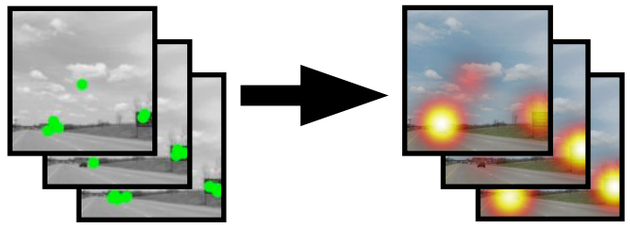


Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

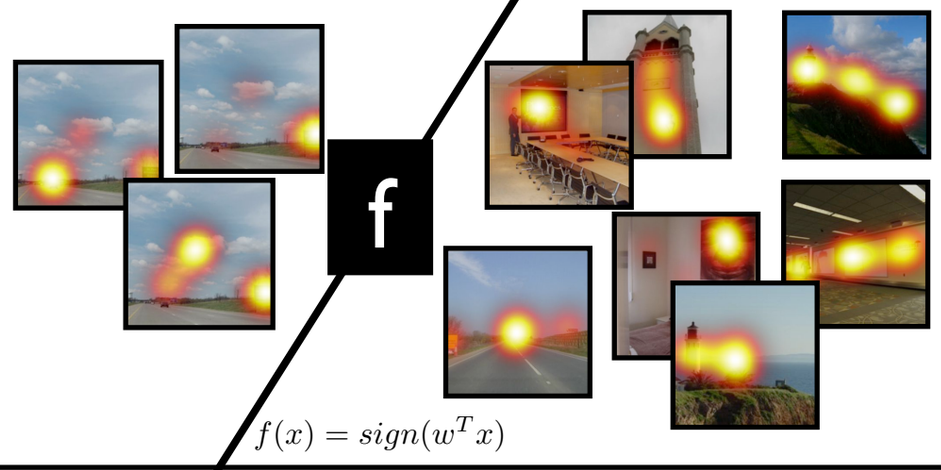
Classification of fixations

TRAINING

1 coarse binning and smoothing

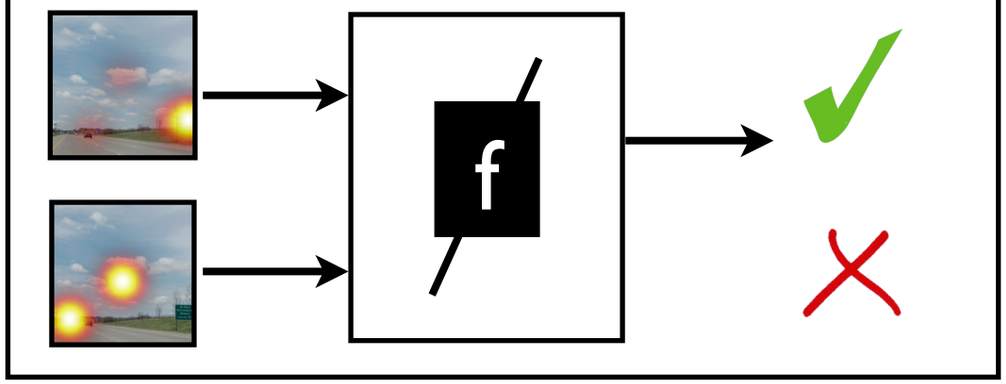


2 learn classifier for successful fixations on this image vs successful fixations on other images



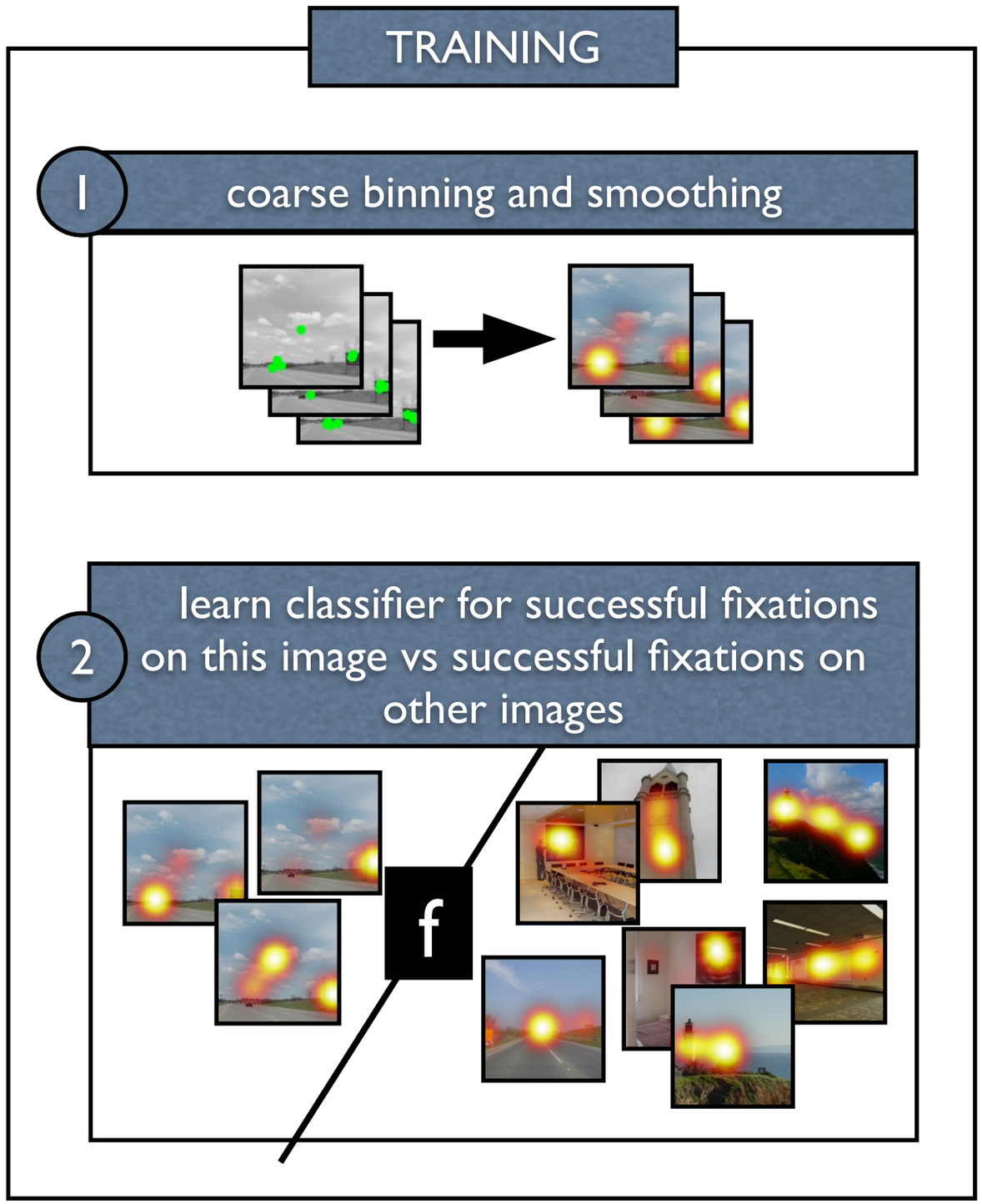
TESTING

compute confidence of new fixation map under classifier for image



Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

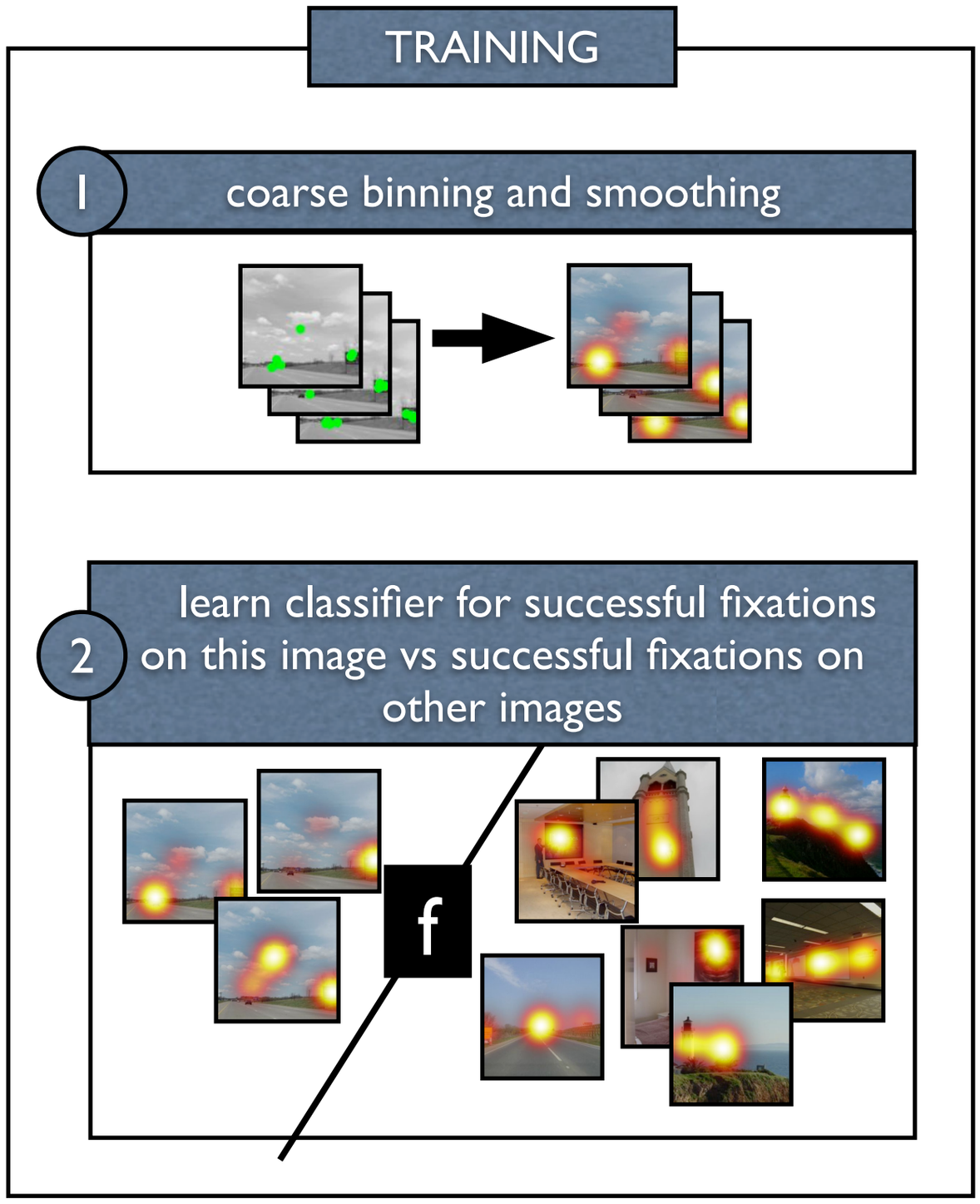
Classification of fixations



Just the task of classifying whether fixations come from this VS other image achieves 79.7% balanced accuracy

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

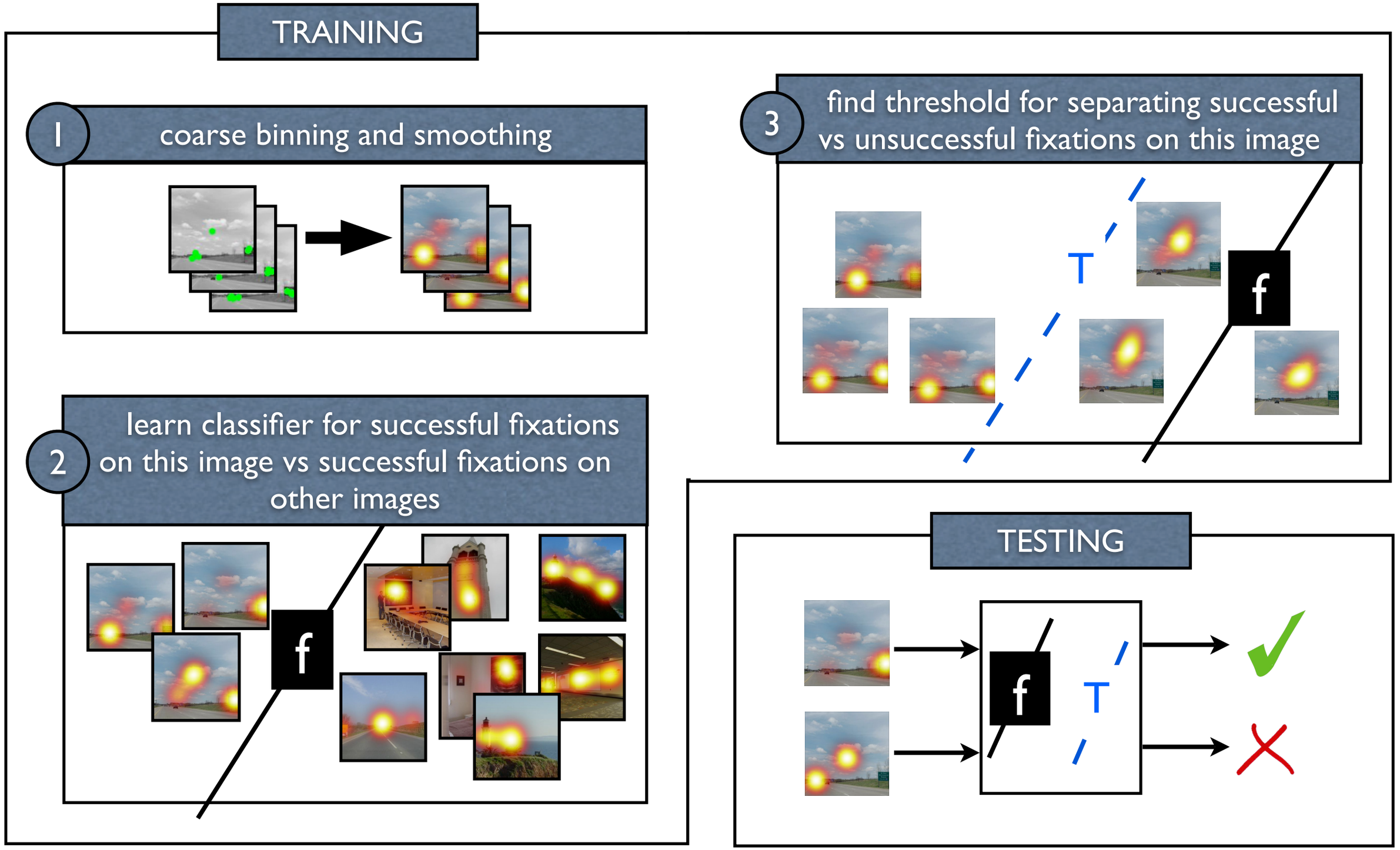
Classification of fixations



But want to solve a harder problem: successful fixations on this image VS unsuccessful fixations on this image

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Classification of fixations



Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Model details:

representation:
- fixation map computed by coarse binning and smoothing (20x20 grid, sigma=2)

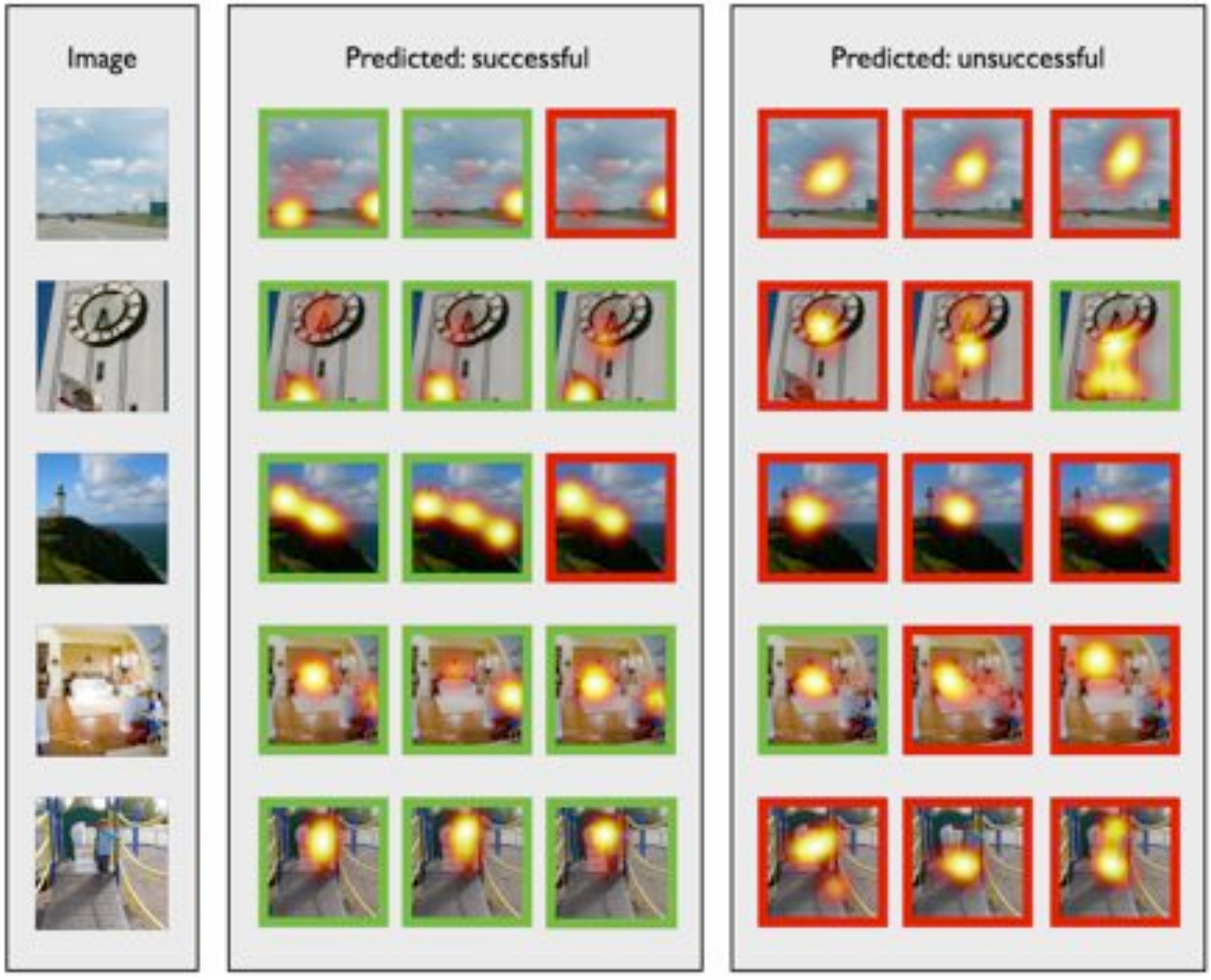
positives:
- successful encoding fixations on image I

negatives:
- successful encoding fixations on other images

to handle class imbalance:
- classifier: RUSboost
- performance metric: balanced accuracy

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Classifying fixations as successful or unsuccessful



Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

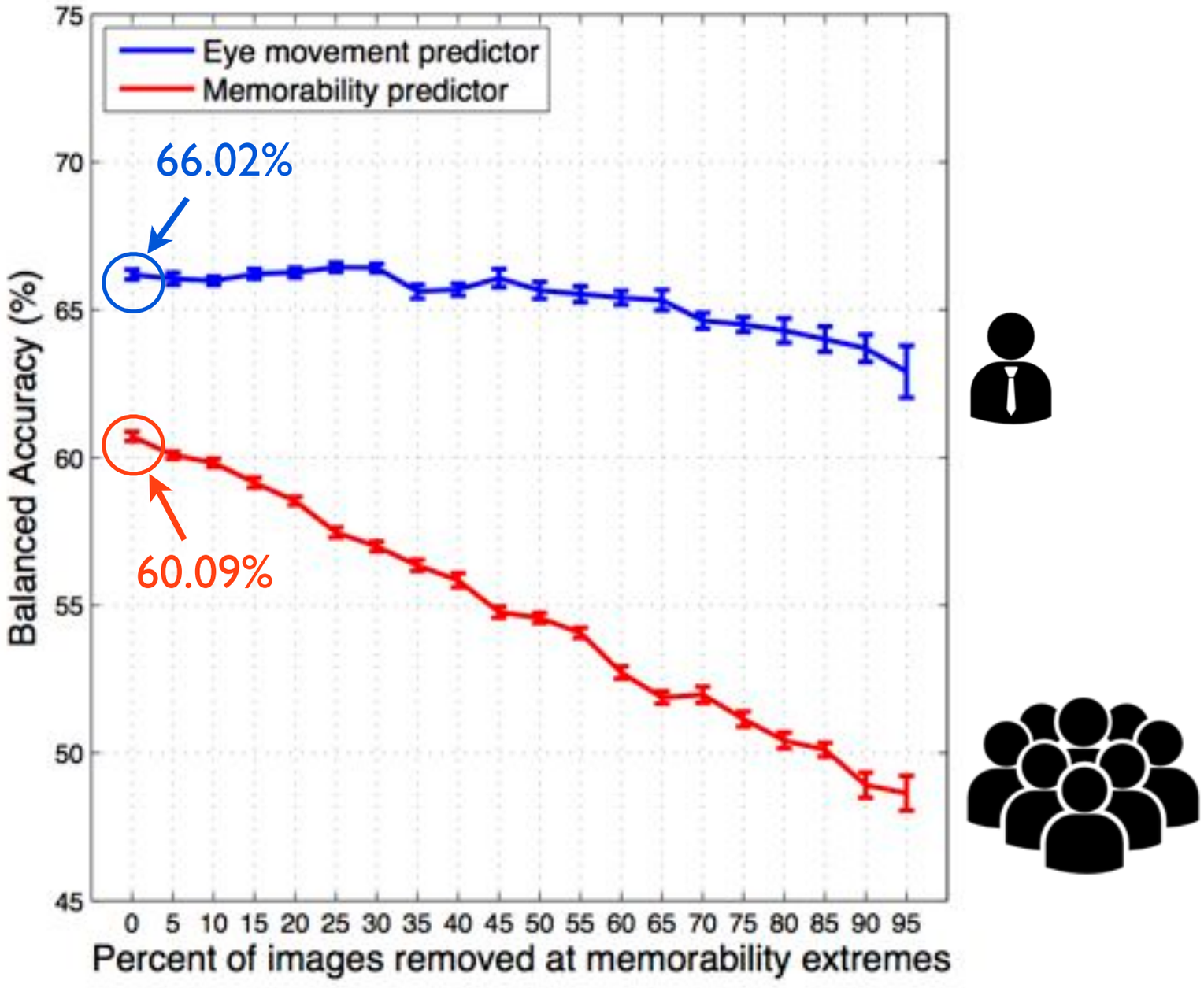
Model details:

During training (on training participants):
- learn a classifier for each image I to differentiate fixations on this image VS fixations on other image
- for each participant, evaluate score (of fixation map) under the classifier
- learn a threshold that optimizes balanced accuracy on the task: successful VS failed fixations on this image

During testing (on novel participants):
- evaluate fixation map on image I under classifier
- use learned threshold as a cut-off to label fixations as successful or not

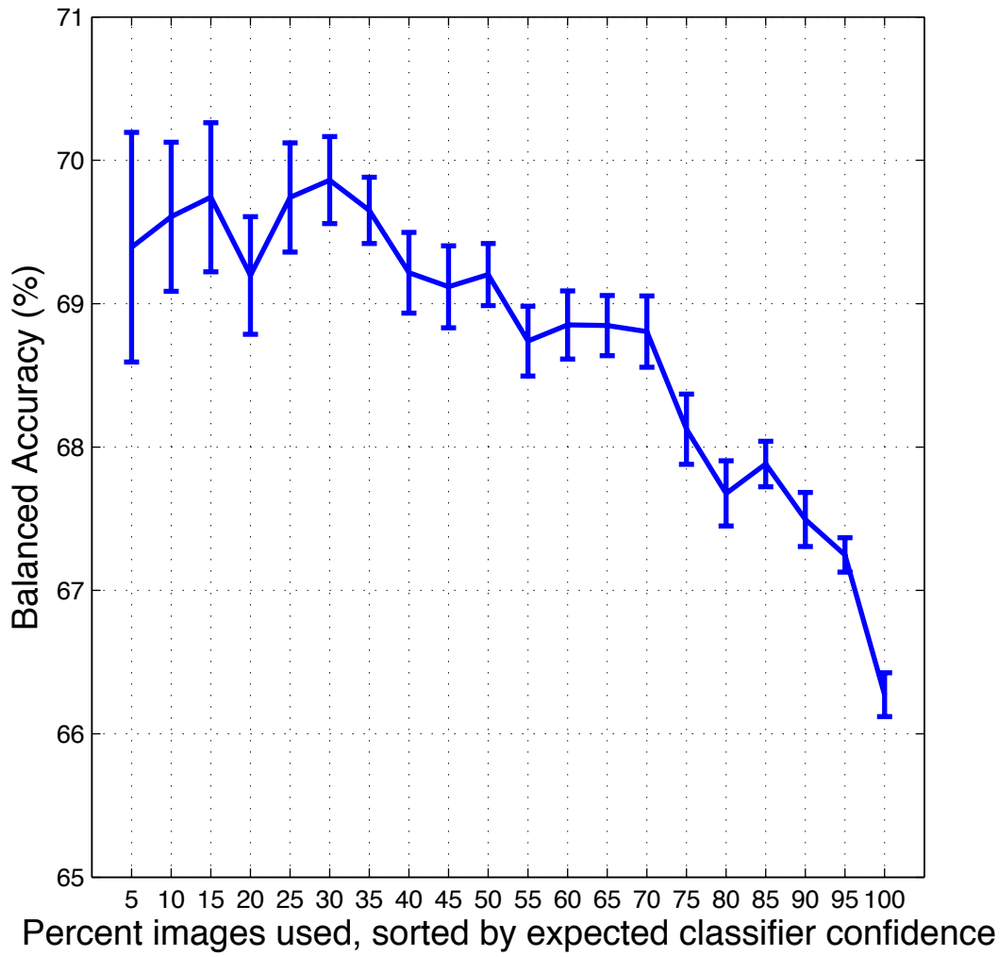
Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

How well can we predict if people will remember an image?



Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

Not all images are equally predictable



images sorted by the average score (confidence) of the positive training examples under the classifier

Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability, Vision Research, 2015.

- does the consistency of human memory generalize?

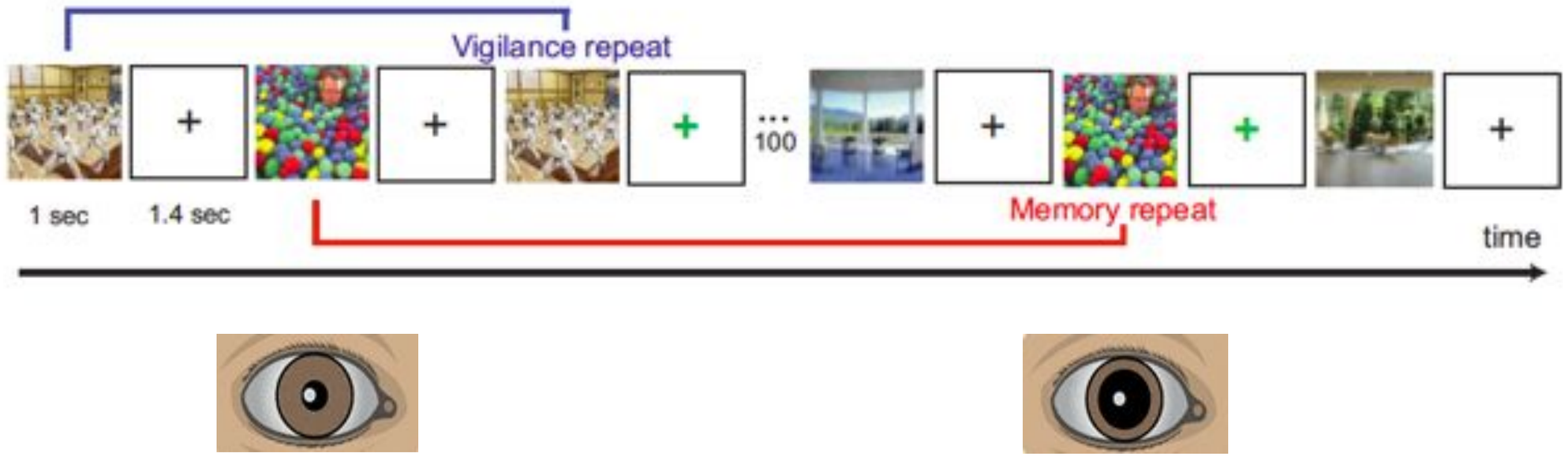
- what factors can modulate image memorability? context, attentional biases (e.g. eye movements), ...

- how do differences in memorability behave over time?

- pupils and blinks have been linked to cognitive load

↑ cognitive effort ↑ pupil dilations ↓ blink rates

Võ, M., Bylinskii, Z., Oliva, A. Image memorability in the eye of the beholder: tracking the decay of visual scene representations (in prep).



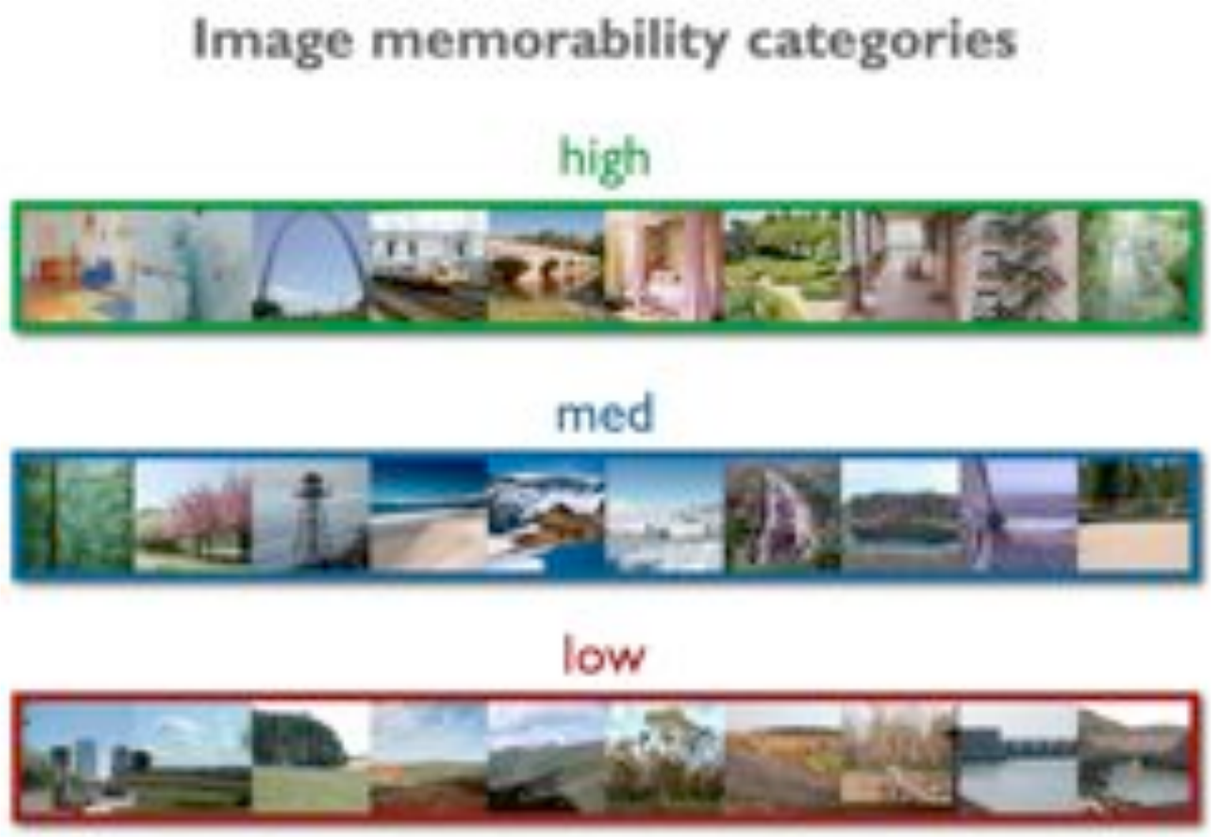
pupil old/new effect

- PONE: difference in pupillary responses b/w hits and correct rejections
- BONE: difference in blink rates b/w hits and correct rejections

Võ, M., Bylinskii, Z., Oliva, A. Image memorability in the eye of the beholder: tracking the decay of visual scene representations (in prep).

80 images with highest, middle, and lowest memorability scores from the dataset of Isola et al. 2011

Võ, M., Bylinskii, Z., Oliva, A. Image memorability in the eye of the beholder: tracking the decay of visual scene representations (in prep).



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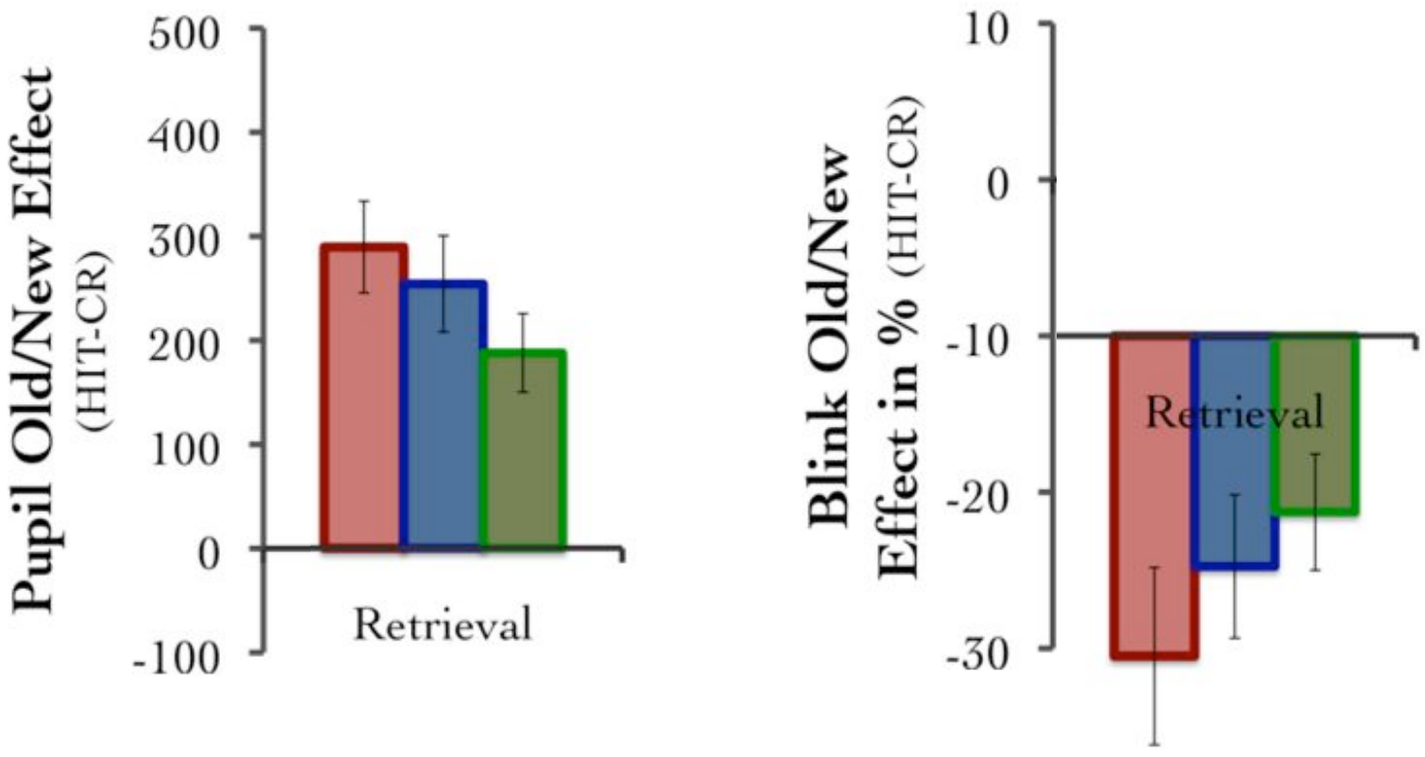


Võ, M., Bylinskii, Z., Oliva, A. Image memorability in the eye of the beholder: tracking the decay of visual scene representations (in prep).

- does the consistency of human memory generalize?

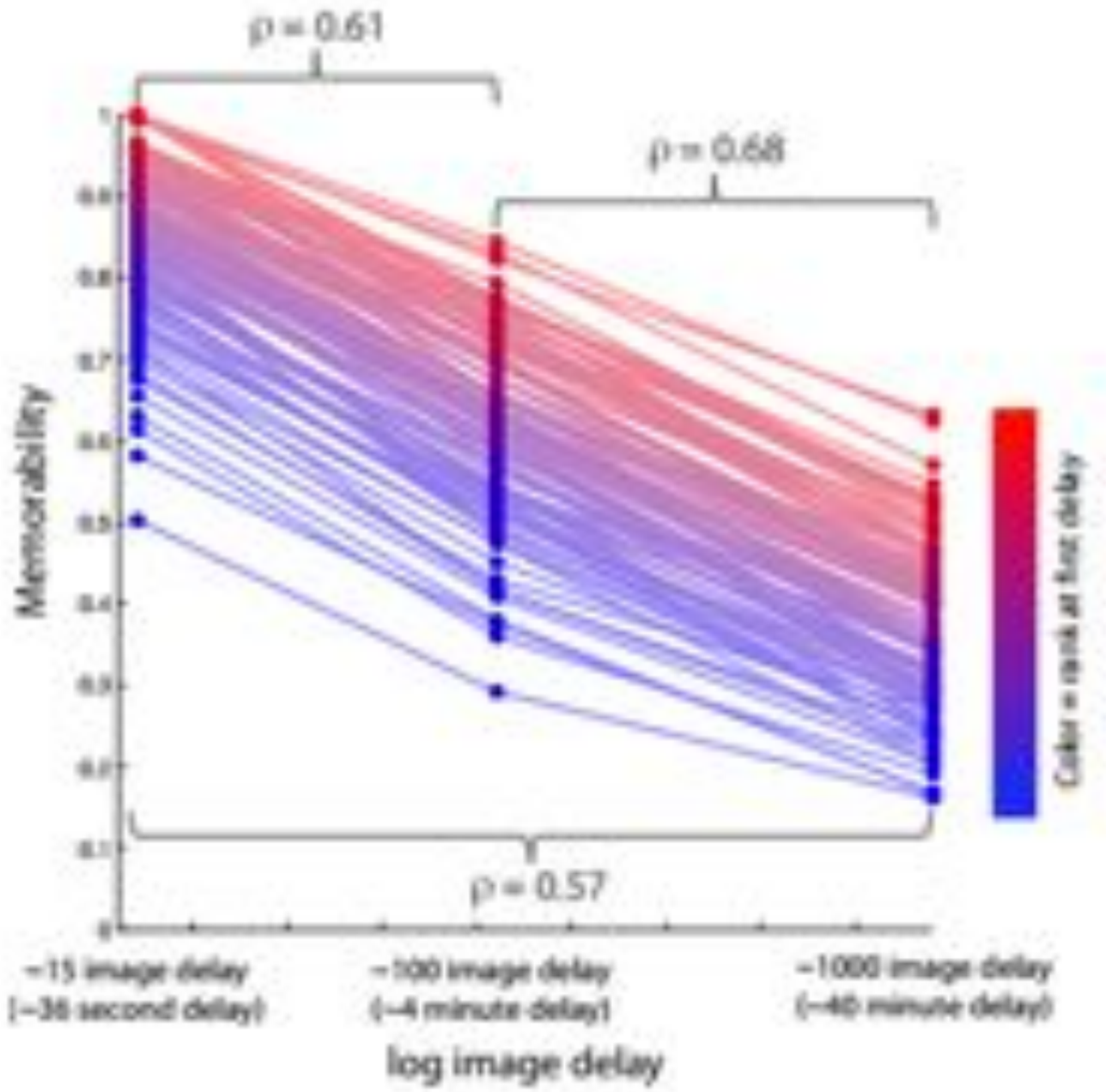
- what factors can modulate image memorability? context, attentional biases (e.g. eye movements, pupils, blinks), ...

- how do differences in memorability behave over time?

- what factors can modulate image memorability?
  - context
  - observer's attention, behavior (measured as: eye movements, pupils, blinks)
  - observer's expertise
  - time for task
  - familiarity
  - utility

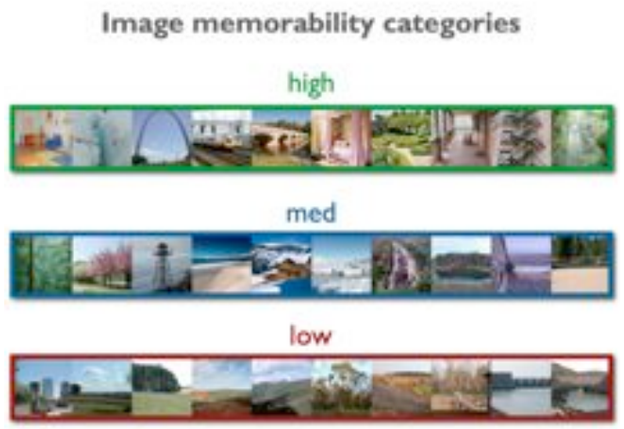
- does the consistency of human memory generalize?
- what factors can modulate image memorability?
- how do differences in memorability behave over time?

Ranks of memorability are conserved over time

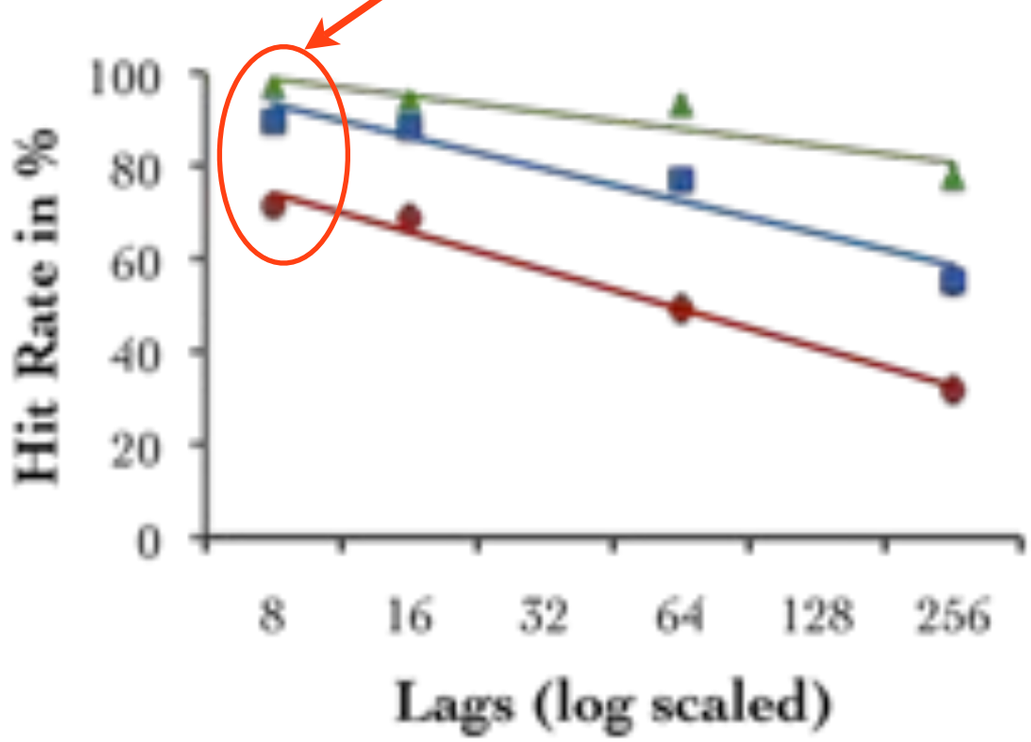


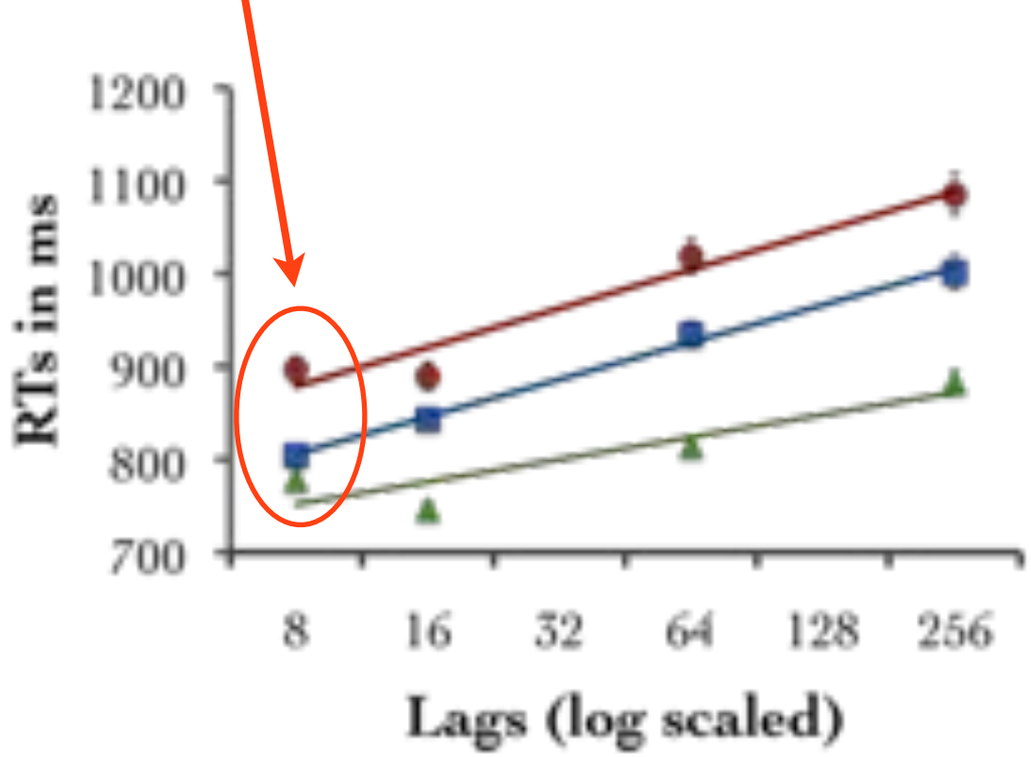
Isola, P., Xiao, J., Parikh, D., Torralba, A., Oliva, A. What makes a photograph memorable? PAMI, 2013

Differences in memorability show up early



differences in memorability already become apparent after 20 sec

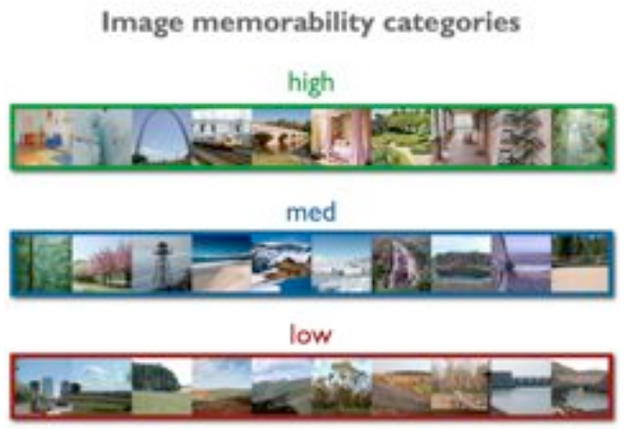


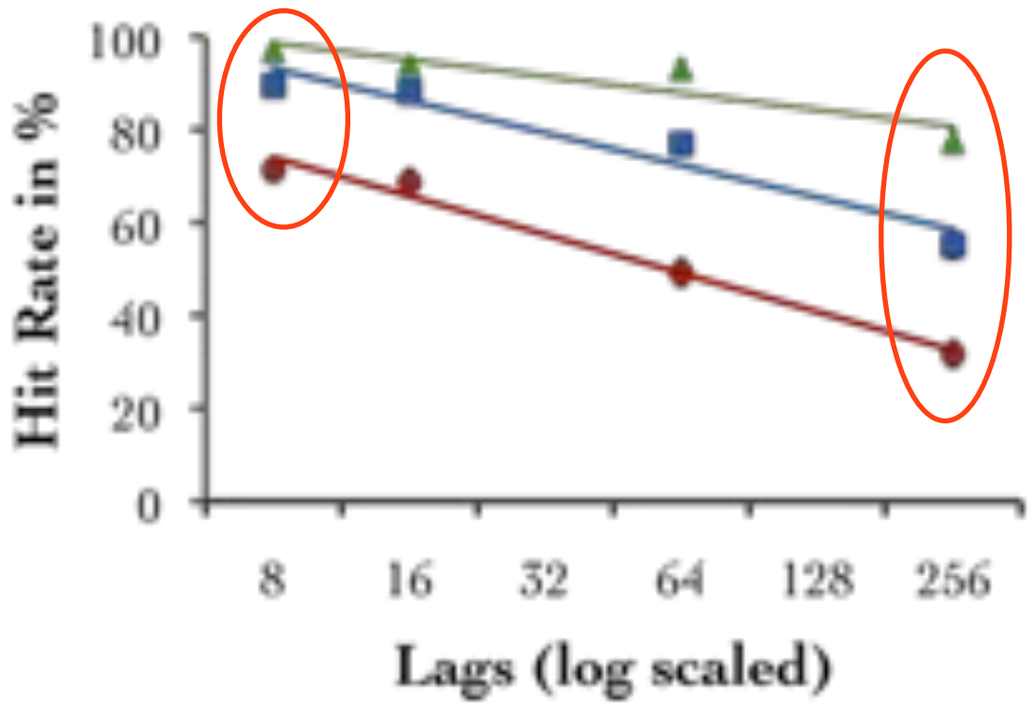


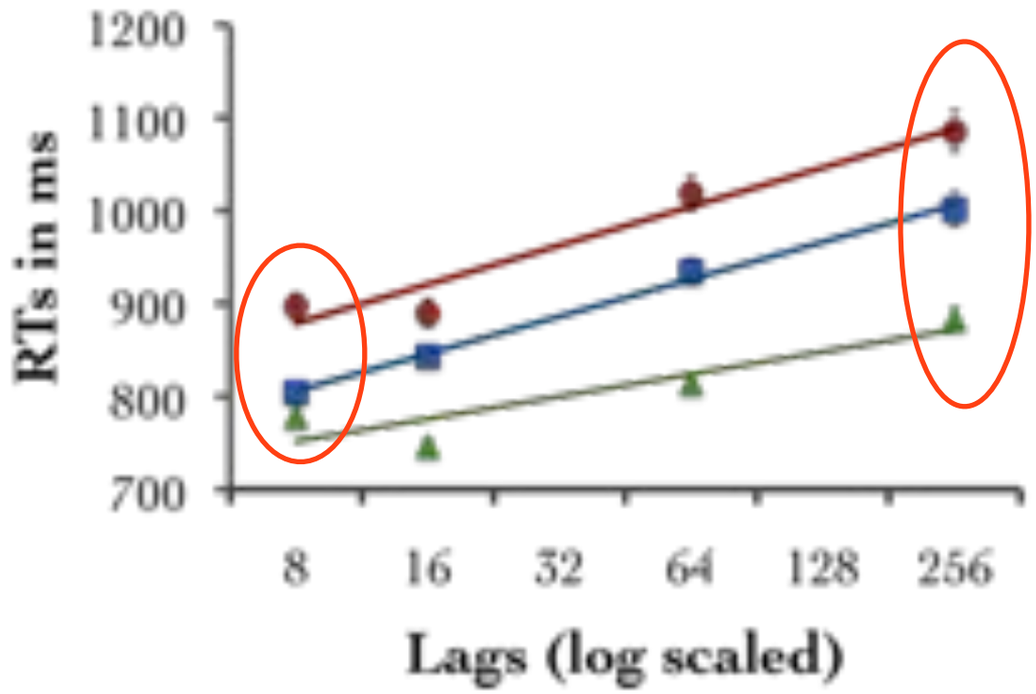
Võ, M., Bylinskii, Z., Oliva, A. Image memorability in the eye of the beholder: tracking the decay of visual scene representations (in prep).

Differences in memorability increase over time

memorable images stay memorable
for longer, forgettable images are
forgotten even faster







Võ, M., Bylinskii, Z., Oliva, A. Image memorability in the eye of the beholder: tracking the decay of visual scene representations (in prep).

- does the consistency of human memory generalize?
- what factors can modulate image memorability?
- how do differences in memorability behave over time?

ranks conserved,
differences show up early,
and increase over time

- does the consistency of human memory generalize?
- what factors can modulate image memorability?
- how do differences in memorability behave over time?

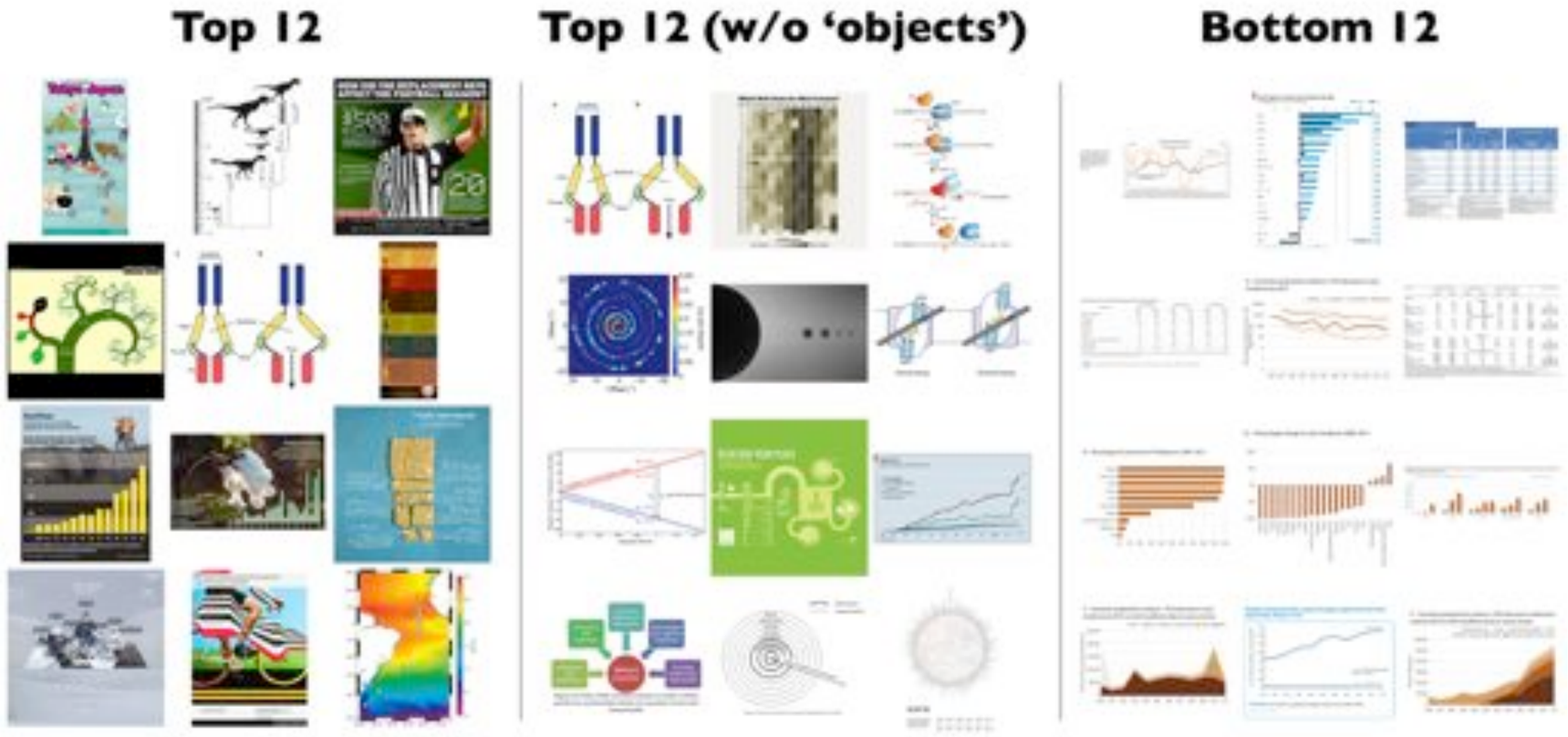
Faces

Forgettable Faces

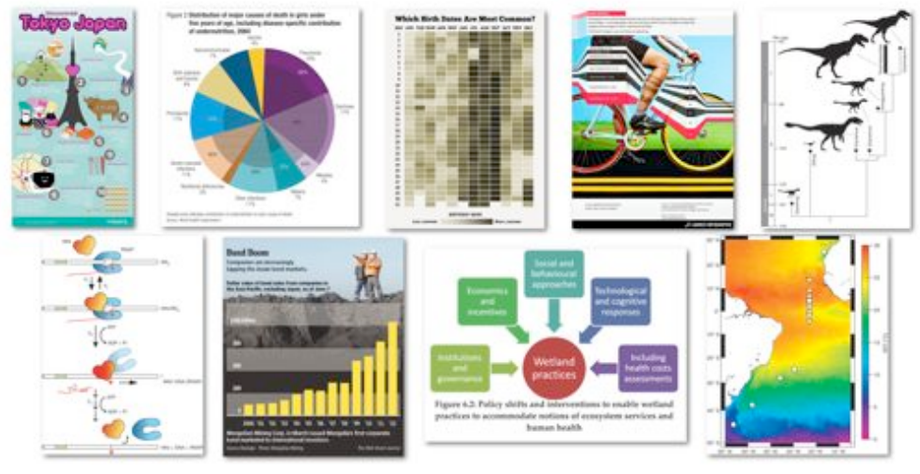
Memorable Faces

Bainbridge, W., Isola, P., Oliva, A. The Intrinsic Memorability of Face Photographs. J. Exp Psych: General, 2013

Visualizations



Distinct visualizations are more memorable.



Borkin, M., Vo, A., Bylinskii, Z., Isola, P., Sunkavalli, S. Oliva, A., Pfister, H. What makes a visualization memorable? InfoVis, 2013

- does the consistency of human memory generalize?

different scene categories, faces, visualizations,...

- what factors can modulate image memorability?
- how do differences in memorability behave over time?

Questions answered

- **does the consistency of human visual memory generalize?**
  - to fine-grained categories
  - to scenes, faces and visualizations
  - across experiments and populations

Questions answered

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- **what factors can modulate image memorability?**
  - image context
  - observer behavior and attentional biases

Questions answered

- **does the consistency of human visual memory generalize?**
  - to fine-grained categories
  - to scenes, faces and visualizations
  - across experiments and populations

- **what factors can modulate image memorability?**
  - image context
  - observer behavior and attentional biases

- **how do differences in memorability behave over time?**
  - memorability ranks are conserved
  - differences in memorability show up early and increase over time

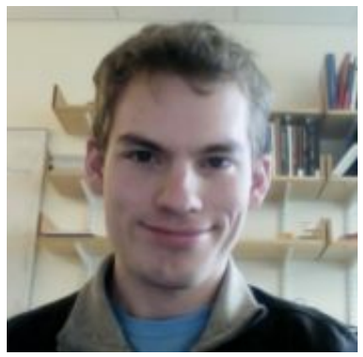
Questions remaining

- how generalizable is the consistency of human visual memory?
  - other natural and artificial visual stimuli
  - expert domains
- what factors can modulate image memorability?
  - observer's expertise
  - time for task
  - familiarity
  - utility
- how do differences in memorability behave over time?
  - longer time course
  - interference in memory

Thank you

Aude Oliva

Antonio Torralba



Phillip Isola

Michelle Borkin

Melissa Le-Hoa Võ

Constance Bainbridge

Wilma Bainbridge

Bolei Zhou

Questions answered

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    Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability. Vision Research, 2015
  - to scenes, faces and visualizations
    Bainbridge, W., Isola, P., Oliva, A. The Intrinsic Memorability of Face Photographs. J. Exp Psych: General, 2013
    Borkin, M., Vo, A., Bylinskii, Z., Isola, P., Sunkavalli, S. Oliva, A., Pfister, H. What makes a visualization memorable? InfoVis, 2013
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  - observer behavior and attentional biases
    Võ, M., Bylinskii, Z., Oliva, A. Image memorability in the eye of the beholder: tracking the decay of visual scene representations (in prep).
    Bylinskii, Z., Isola, P., Bainbridge, C., Torralba, A., Oliva, A. Intrinsic and Extrinsic Effects on Image Memorability. Vision Research, 2015
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