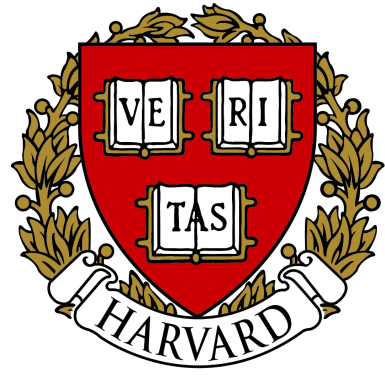




Zoya
Bylinskii



Aude
Oliva



Nam Wook
Kim



Michelle
Borkin



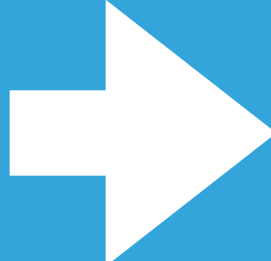
Fredo
Durand

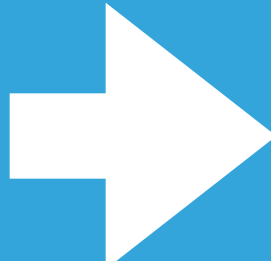


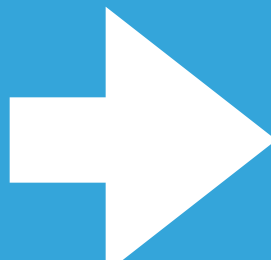
Hanspeter
Pfister

AUDE OLIVA & ZOYA BYLINSKII

**WHERE DO PEOPLE LOOK ON
DATA VISUALIZATIONS?**

 **ATTENTION & MEMORY**

 **CROWDSOURCING ATTENTION**

 **PREDICTING IMPORTANCE**

Eye-tracking for capturing human visual attention

in-lab experiment

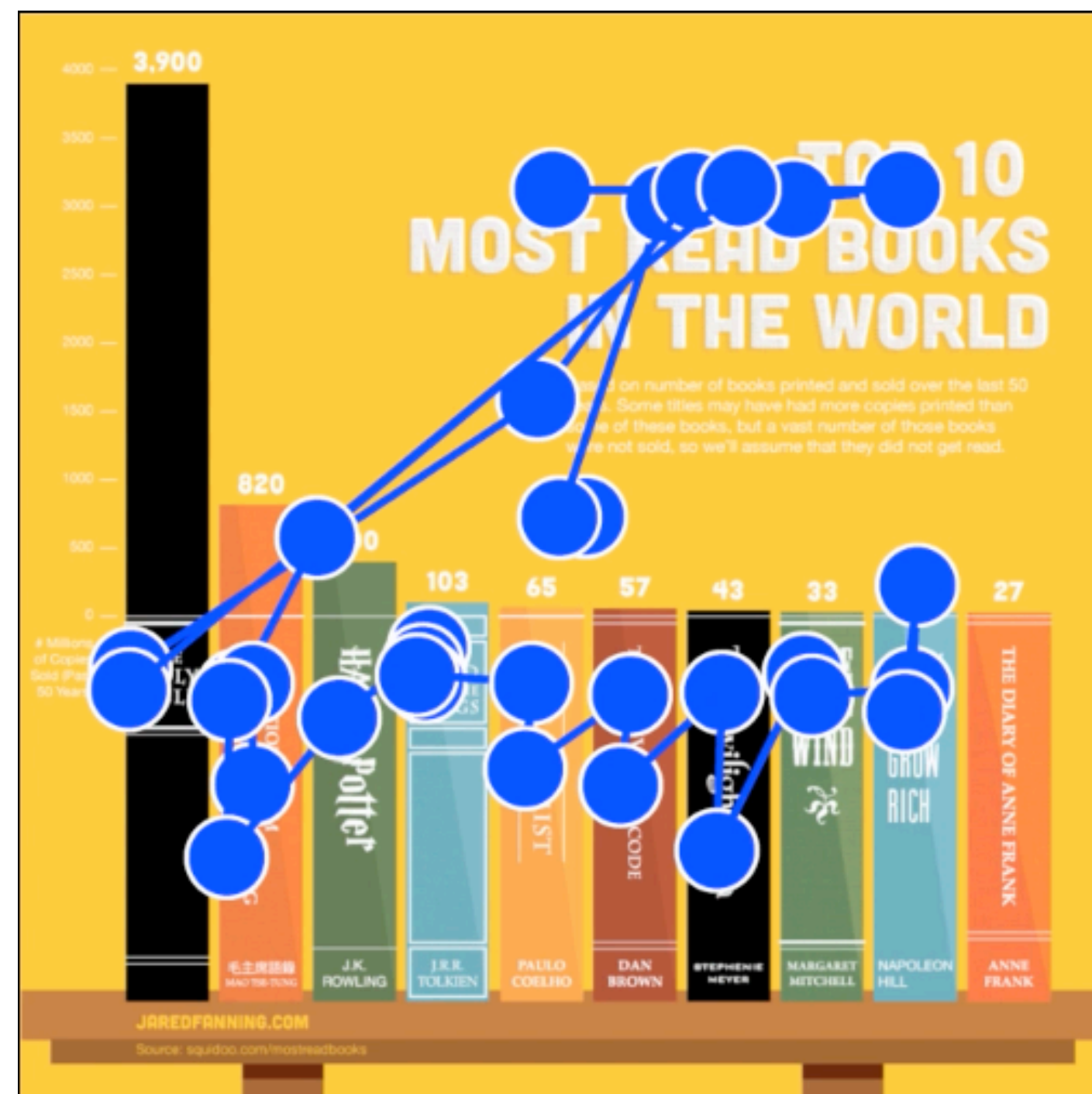
careful calibration

specialized hardware



EYE MOVEMENTS CAN GIVE CLUES ABOUT MEMORY

Encoding



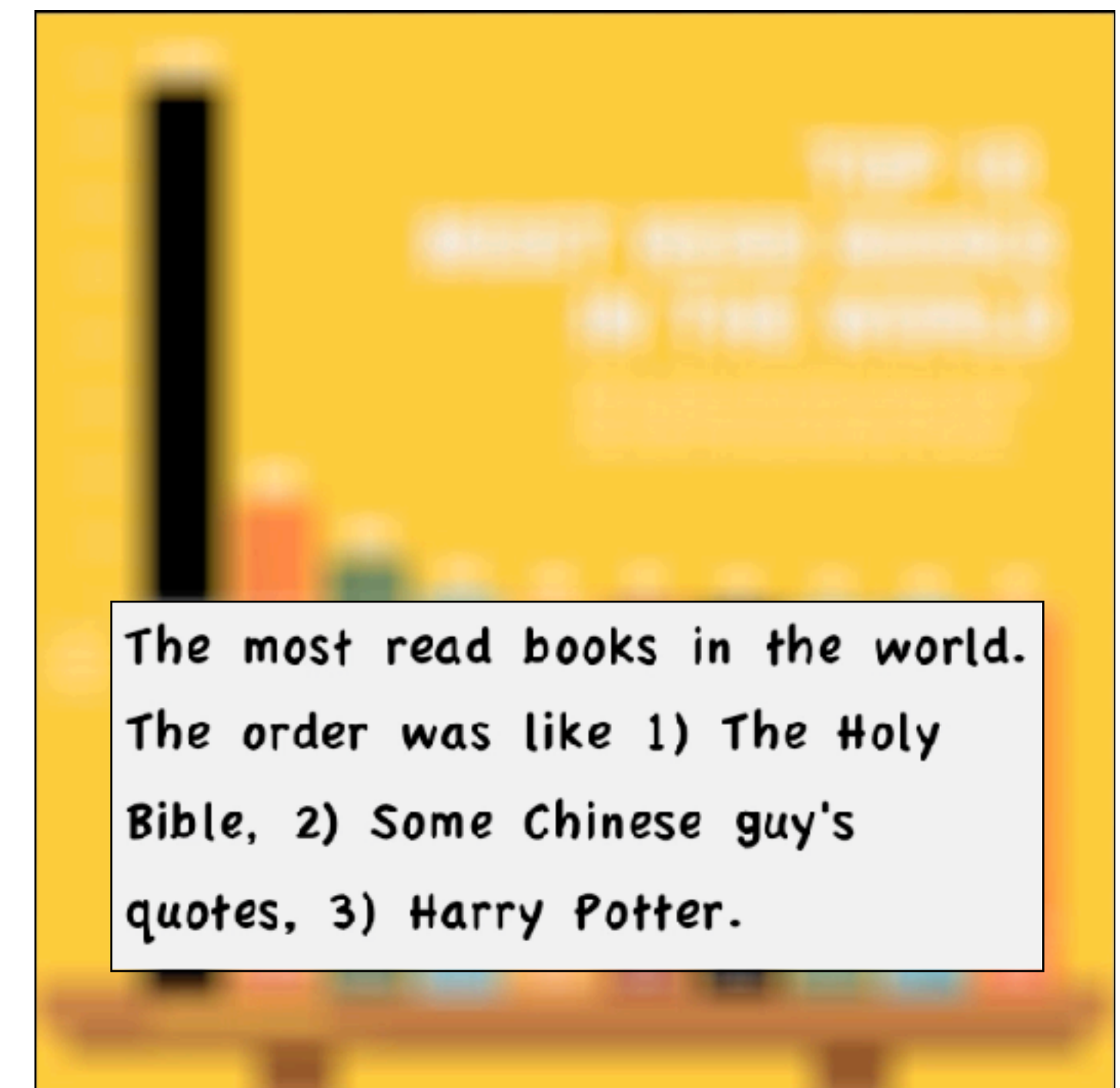
10 sec/image

Recognition



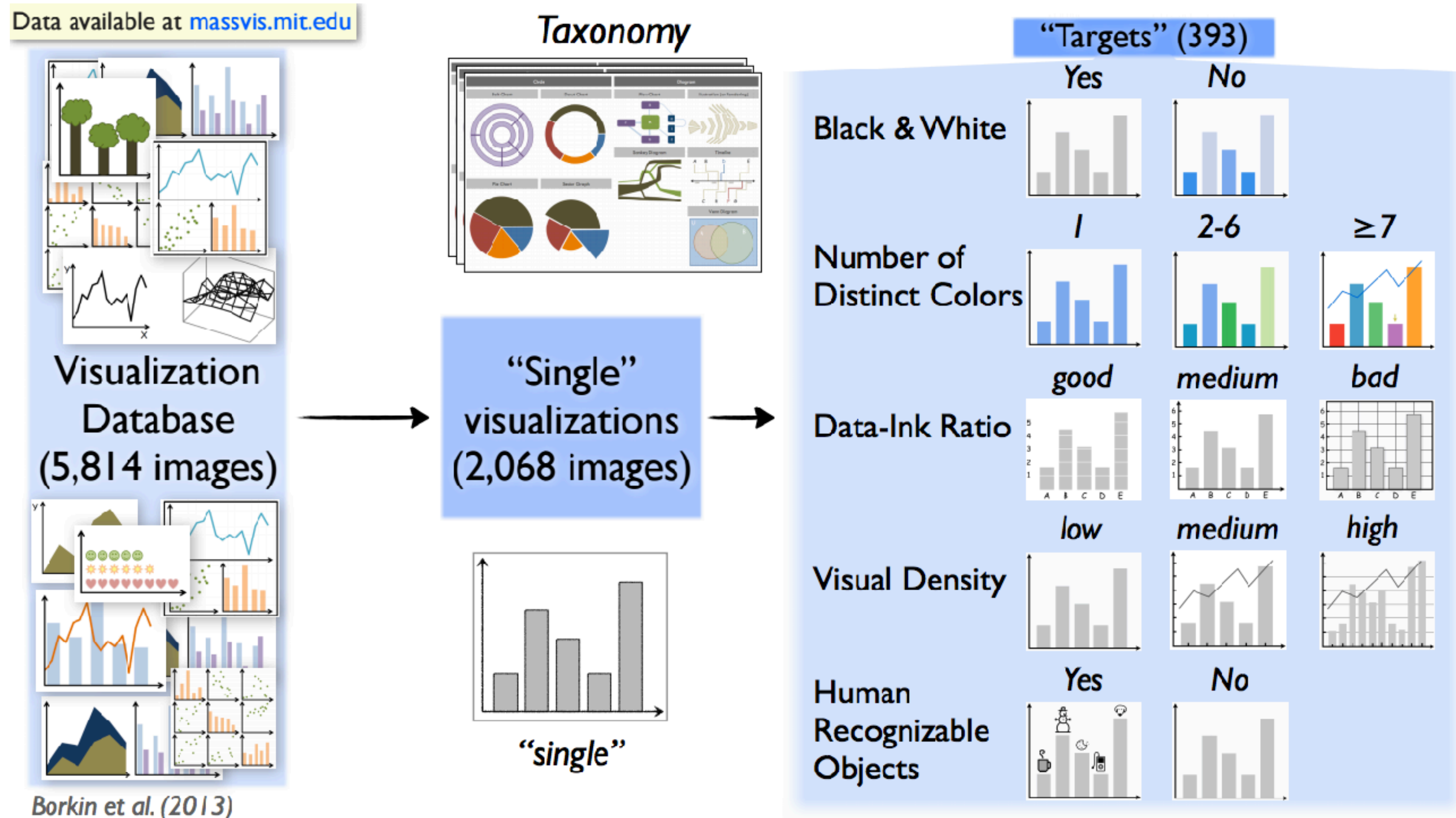
2 sec/image

Recall



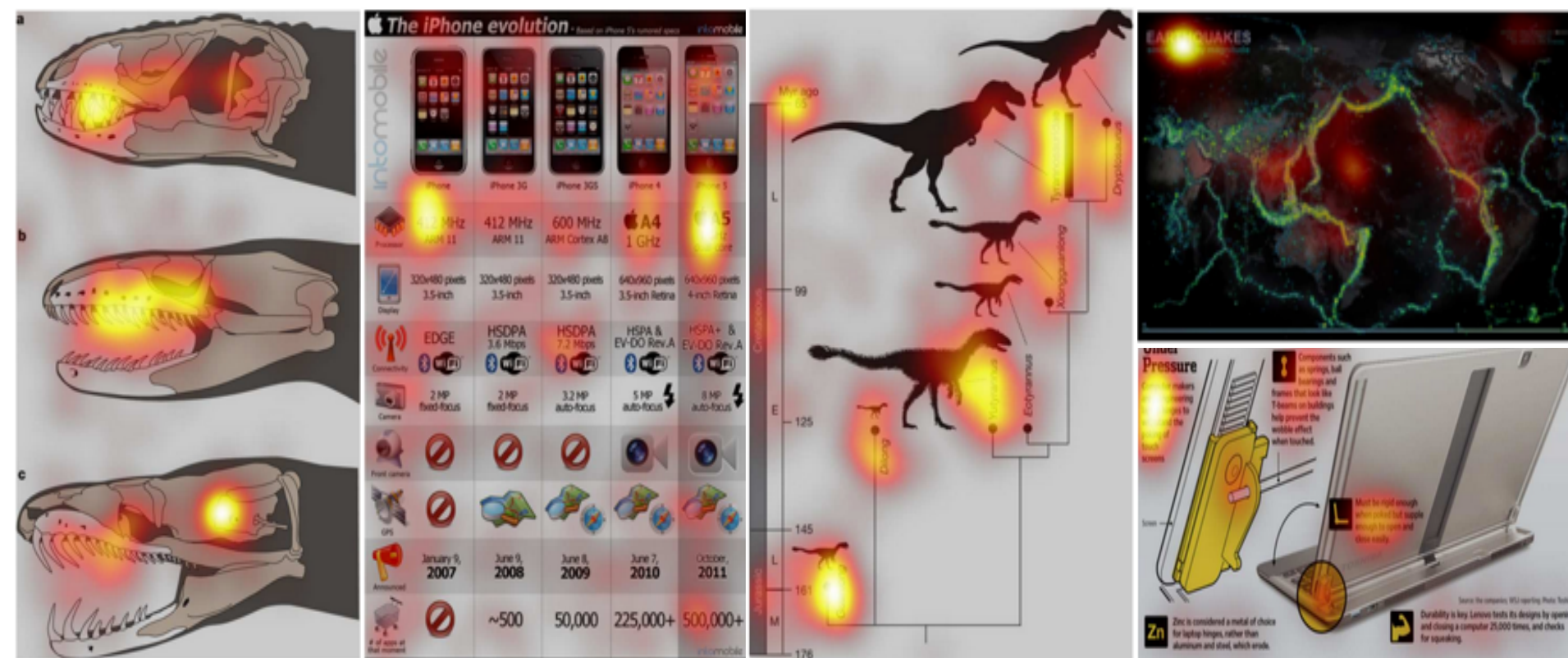
20 min

MASSIVE VISUALIZATION (MASSVIS) DATASET

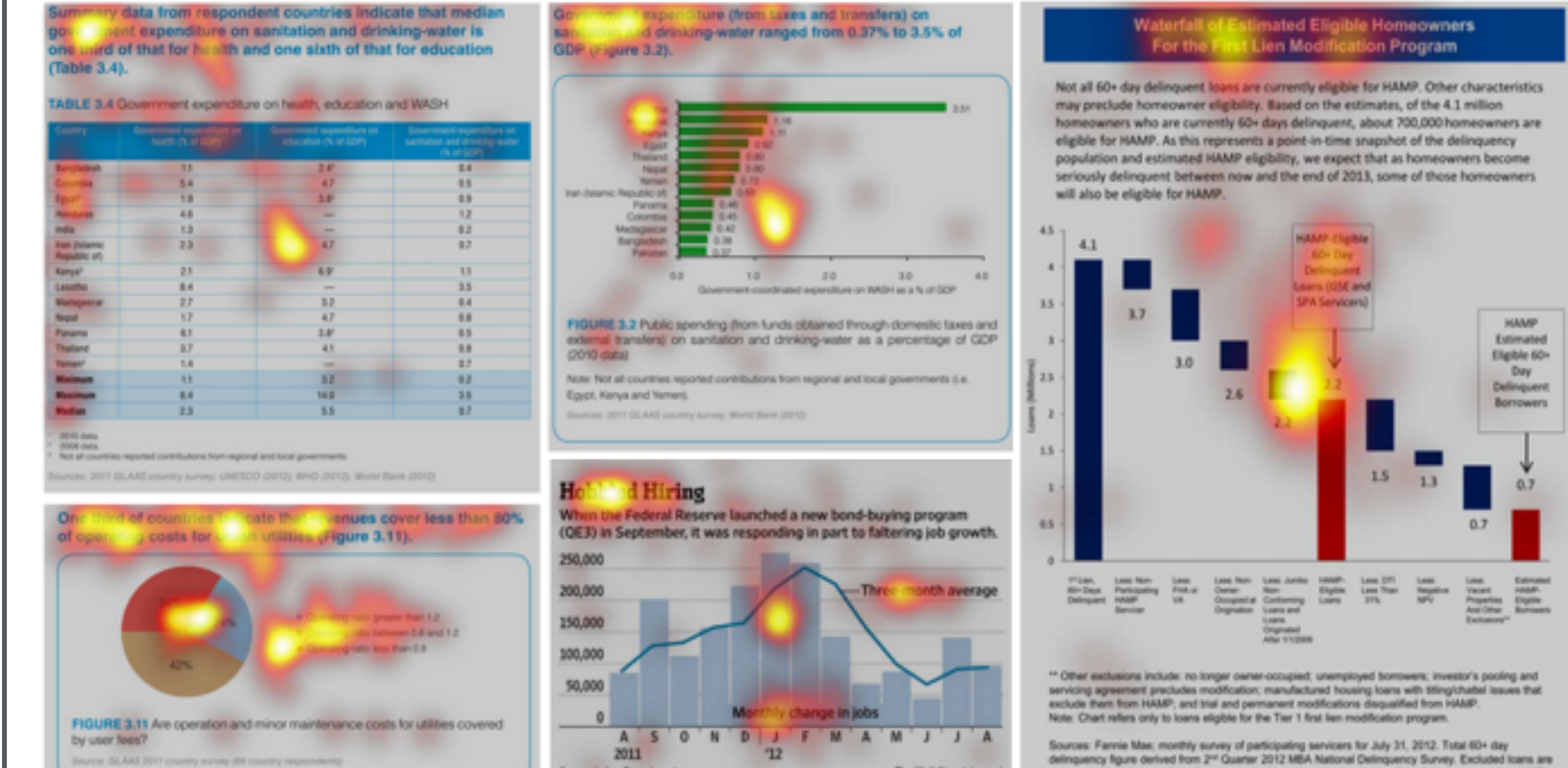
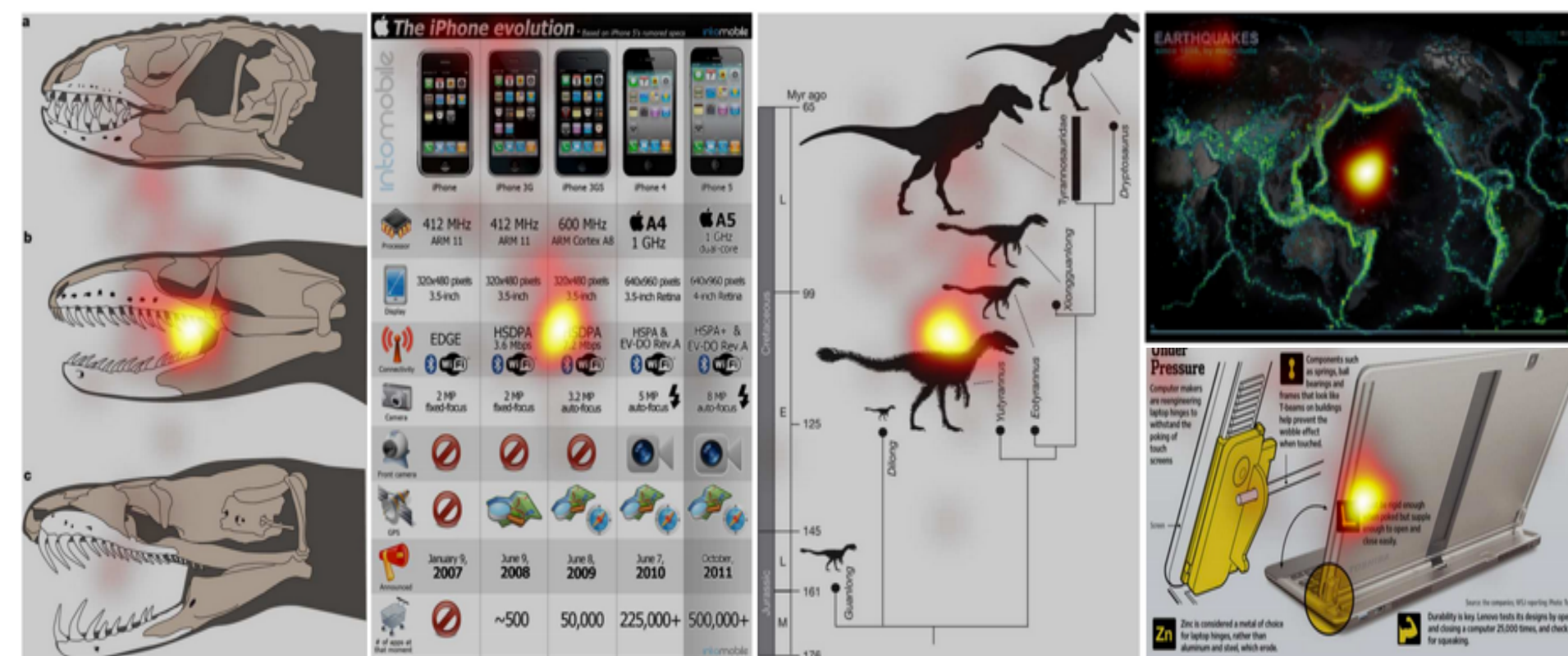


EYE MOVEMENTS CAN GIVE CLUES ABOUT MEMORY

Encoding



Recognition

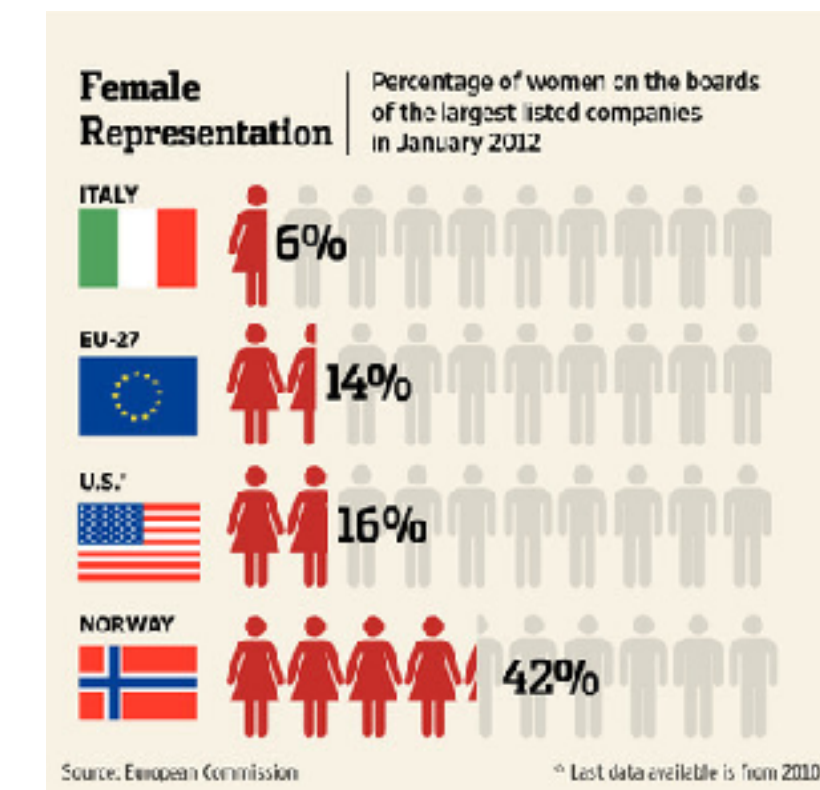
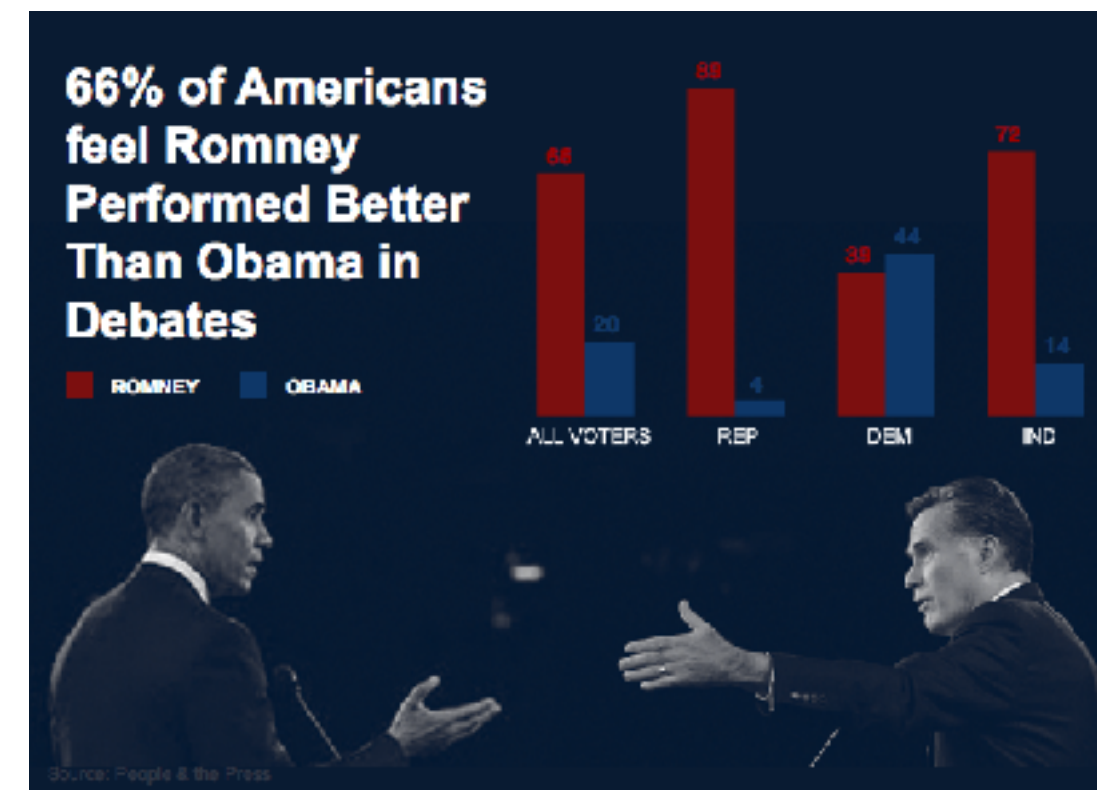


Most recognizable

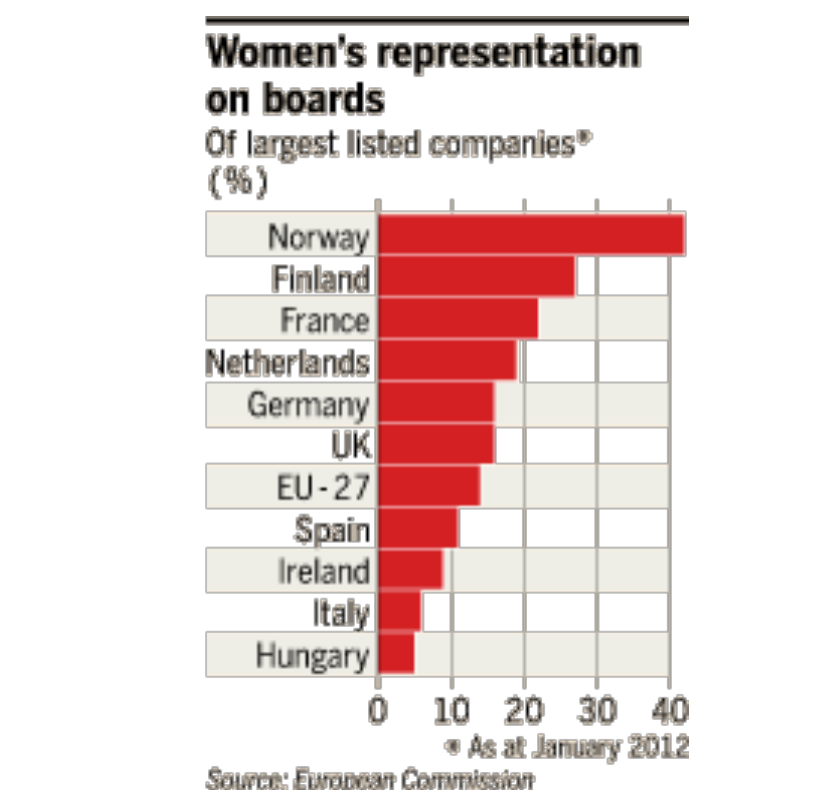
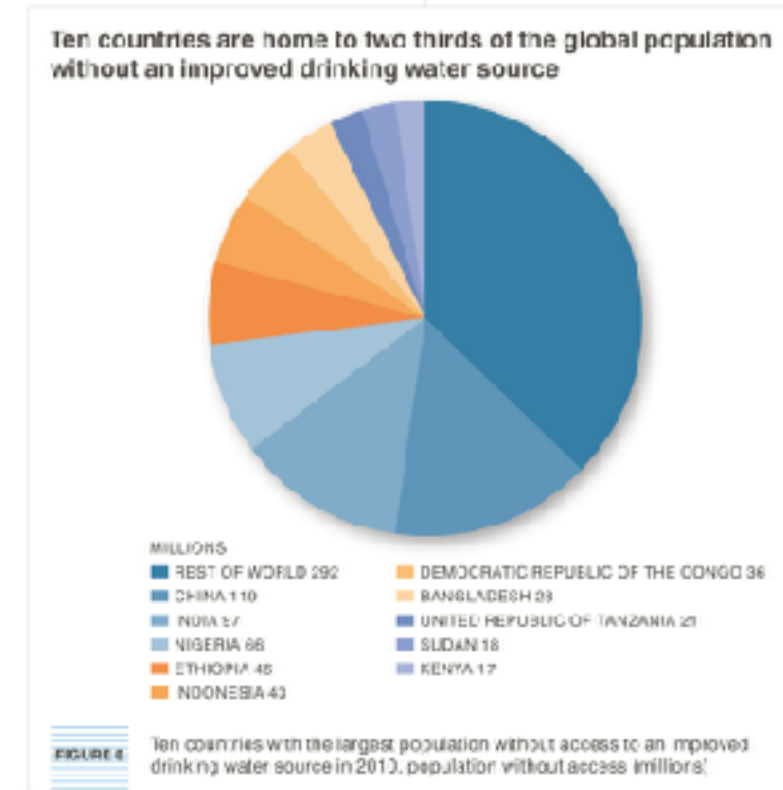
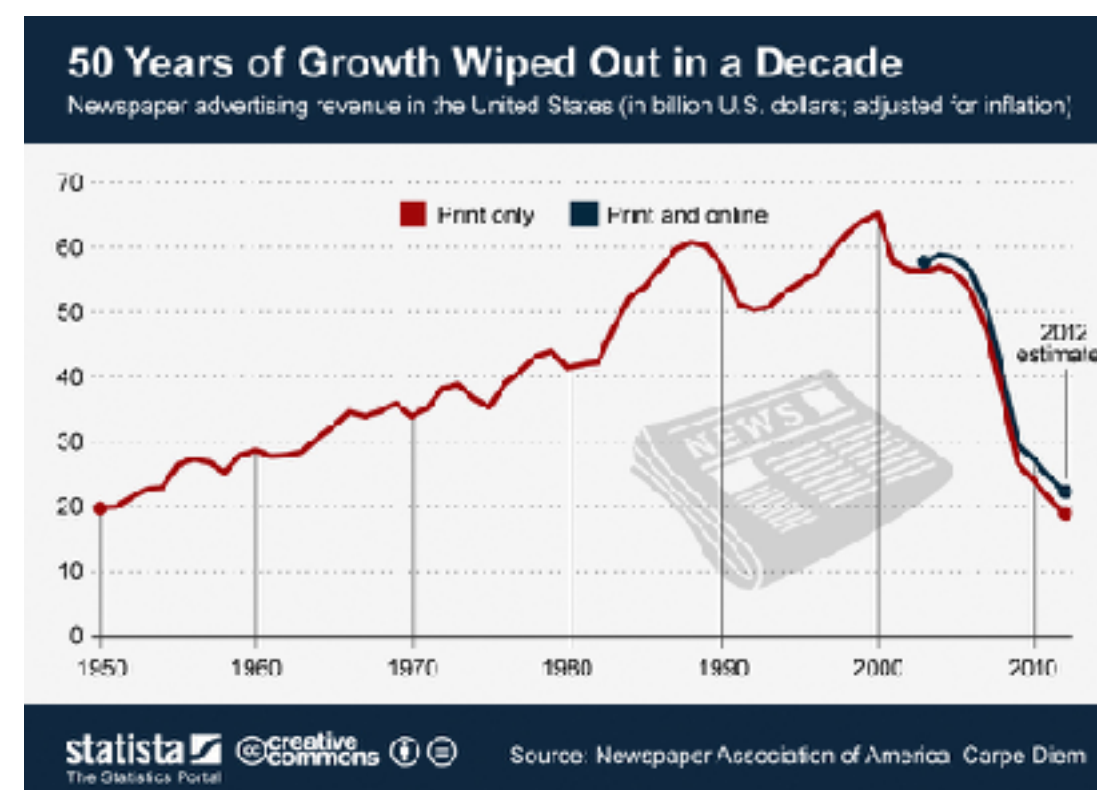
Least recognizable

MEMORABLE VISUALIZATIONS ARE VISUALLY DISTINCT

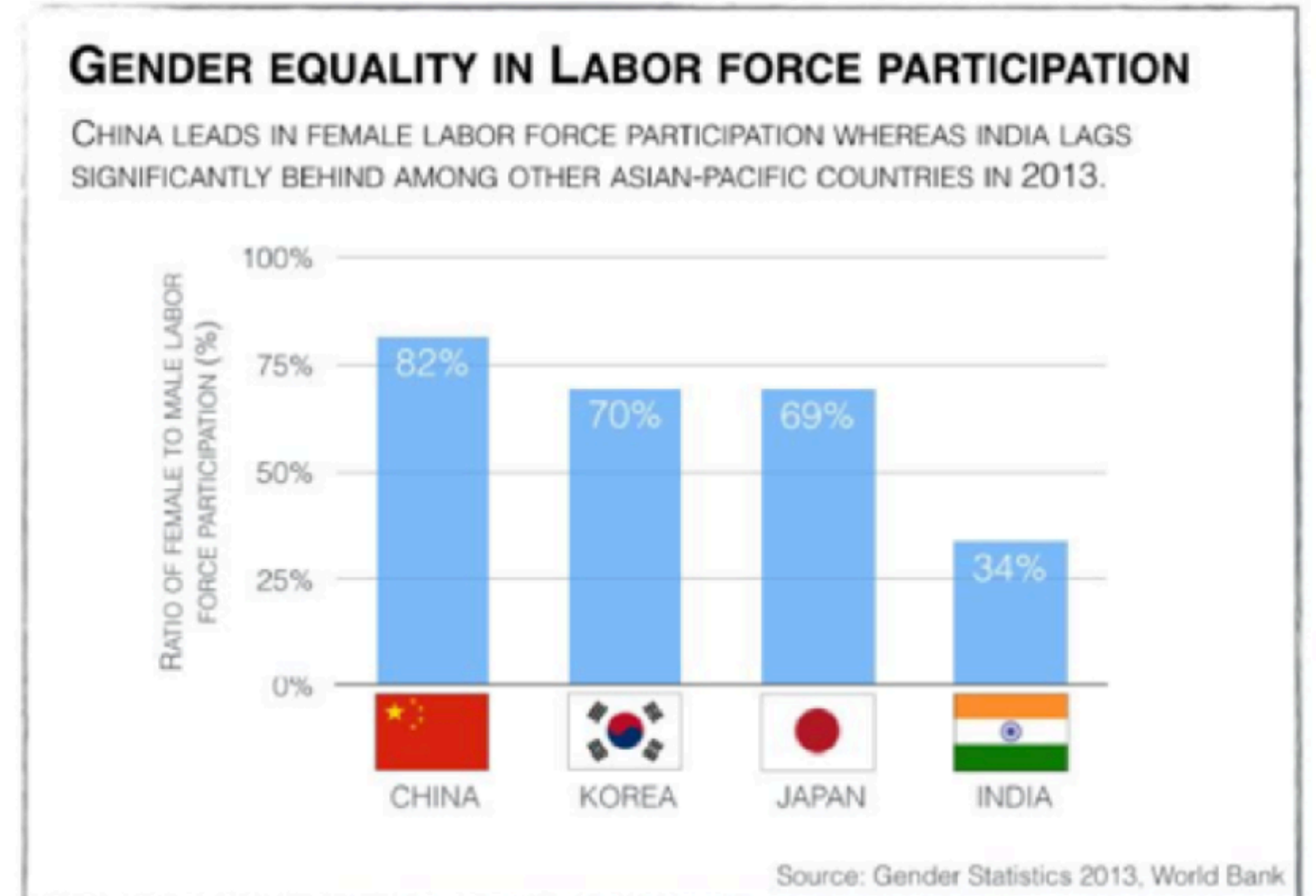
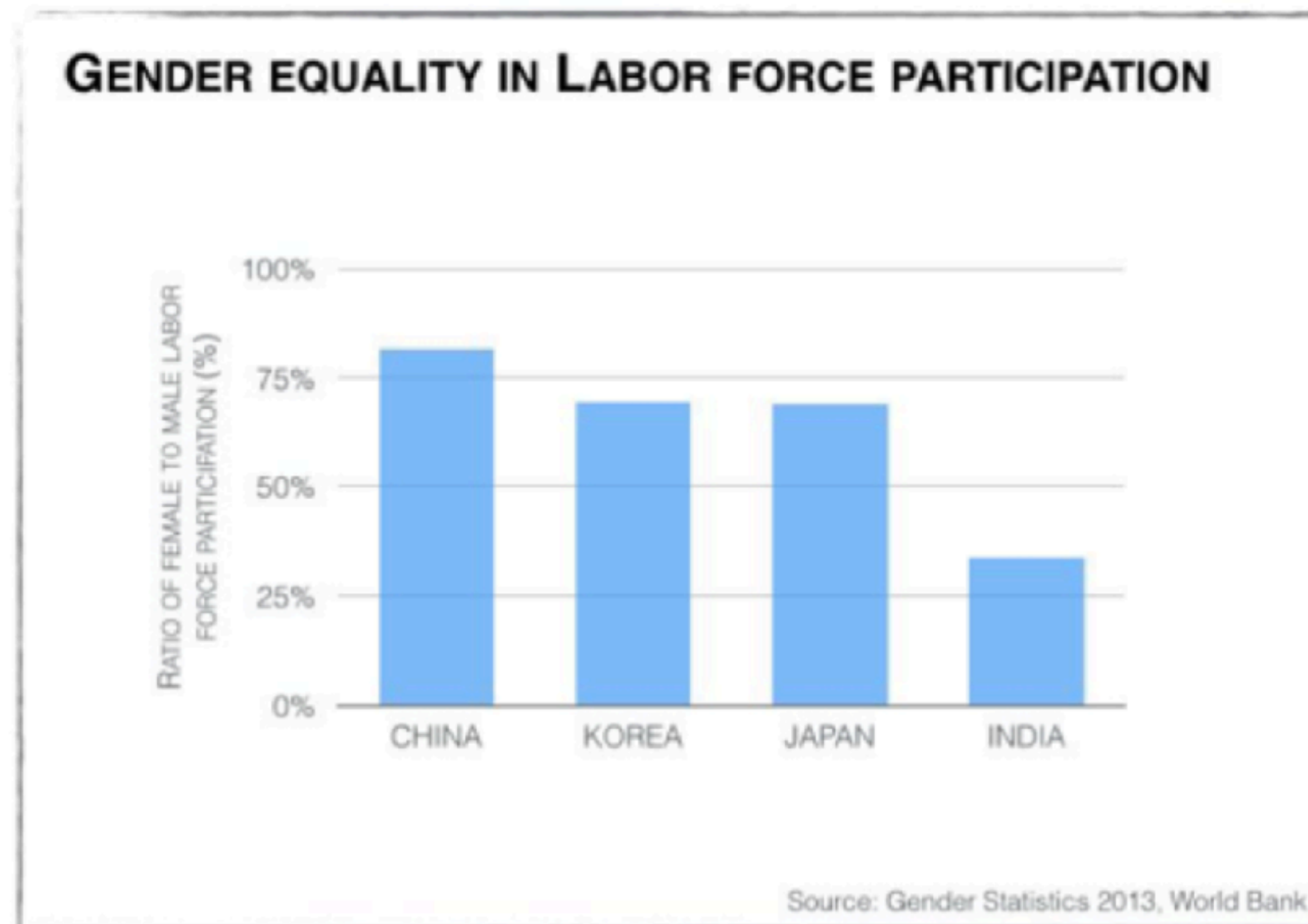
Memorable



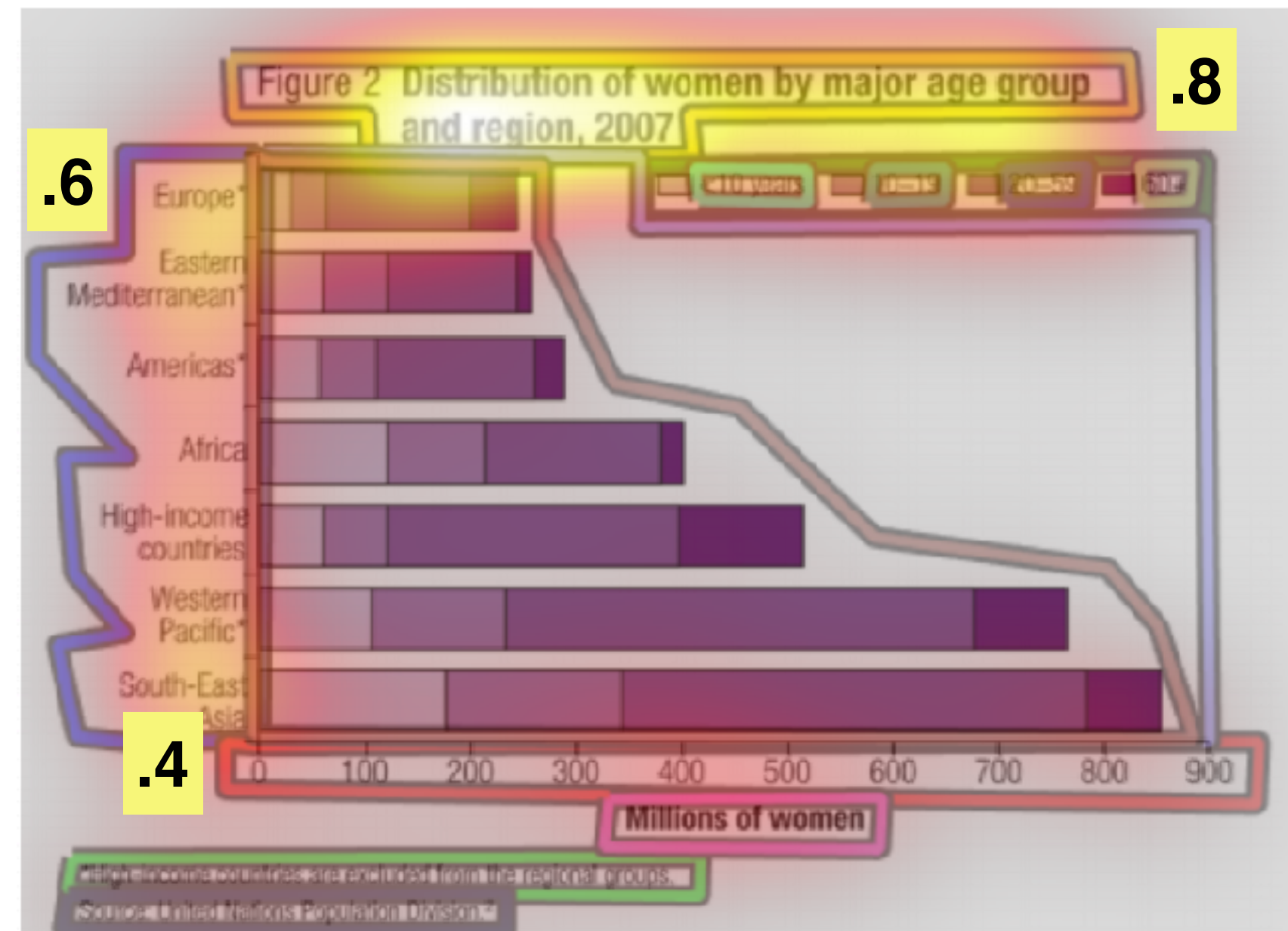
Forgettable



PICTOGRAPHS ADD VISUAL HOOKS INTO MEMORY



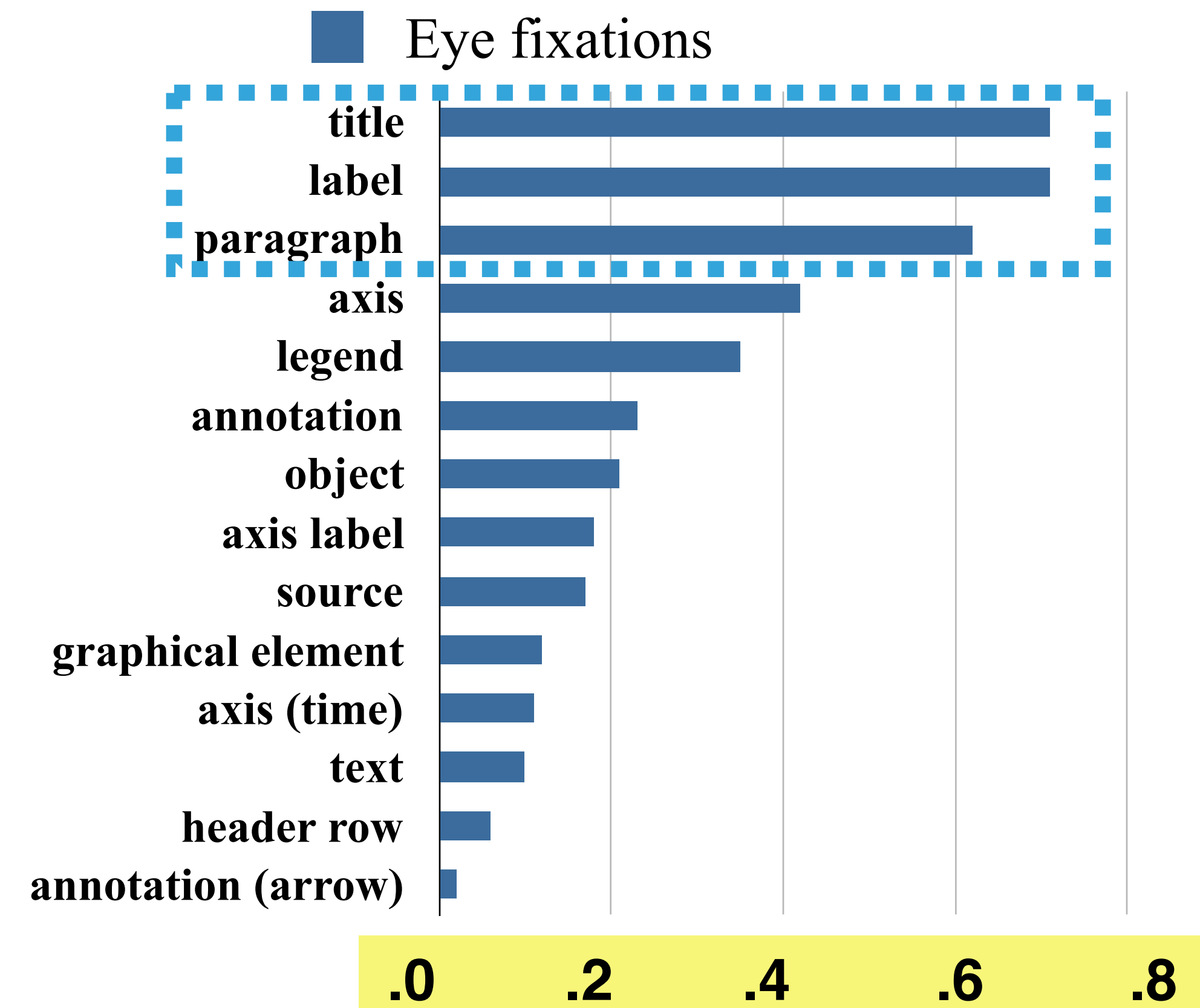
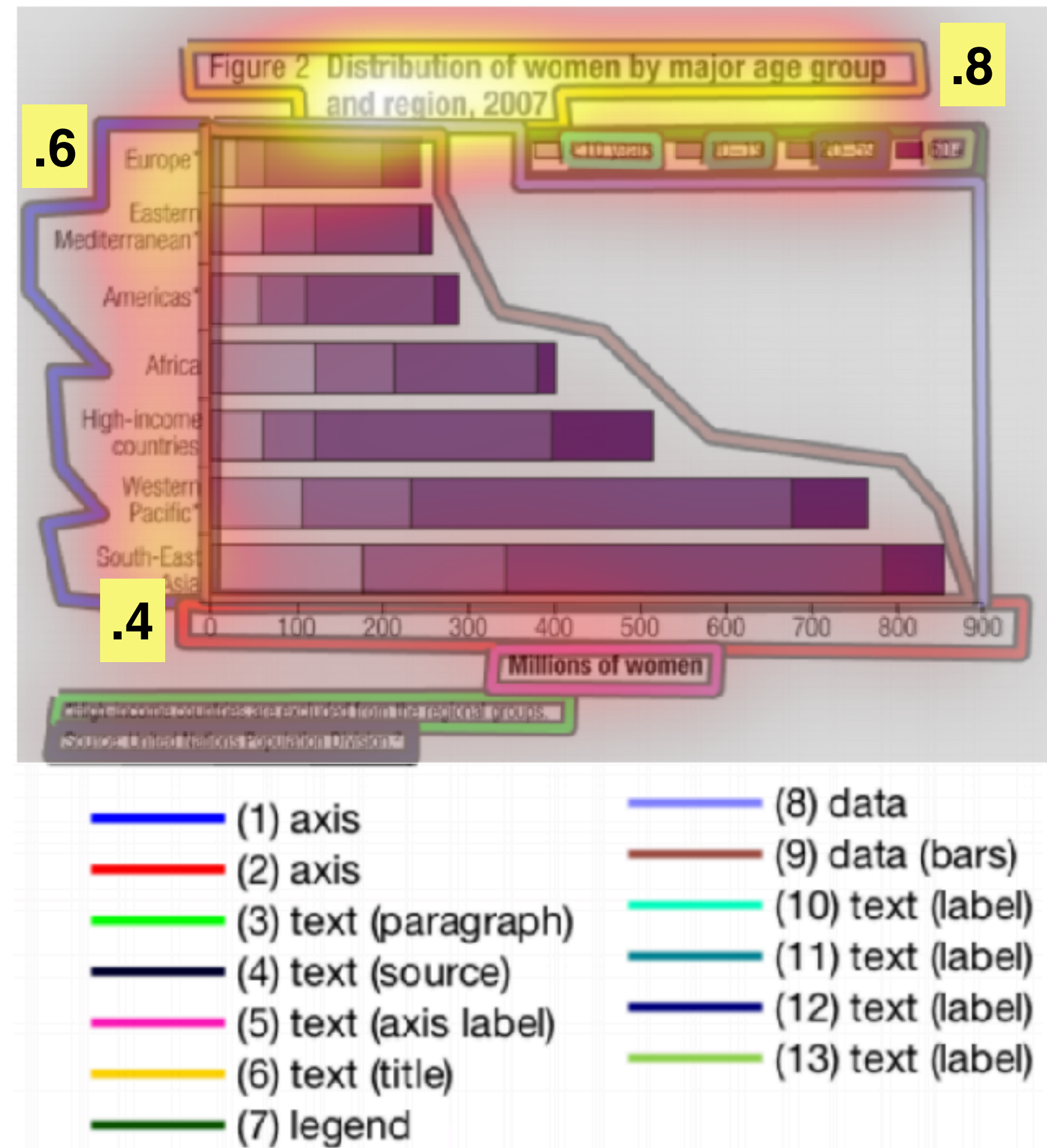
WHERE DO PEOPLE LOOK MOST?



- | | |
|-----------------------|-------------------|
| (1) axis | (8) data |
| (2) axis | (9) data (bars) |
| (3) text (paragraph) | (10) text (label) |
| (4) text (source) | (11) text (label) |
| (5) text (axis label) | (12) text (label) |
| (6) text (title) | (13) text (label) |
| (7) legend | |

393 MASSVIS visualizations
with element annotations

WHERE DO PEOPLE LOOK MOST?



Eye-tracking for capturing human visual attention

in-lab experiment

careful calibration

specialized hardware



0 clicks

0 characters

Describe the image in as much detail as possible...

Bubble View

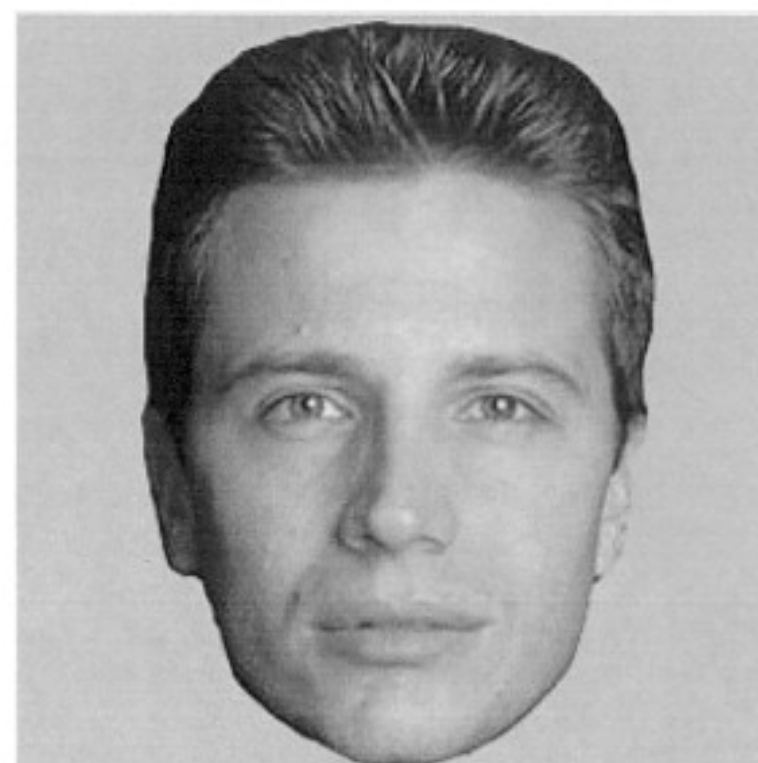
An alternative for eye tracking using **discrete mouse clicks** to measure which information people **consciously** choose to examine.

>> 2x

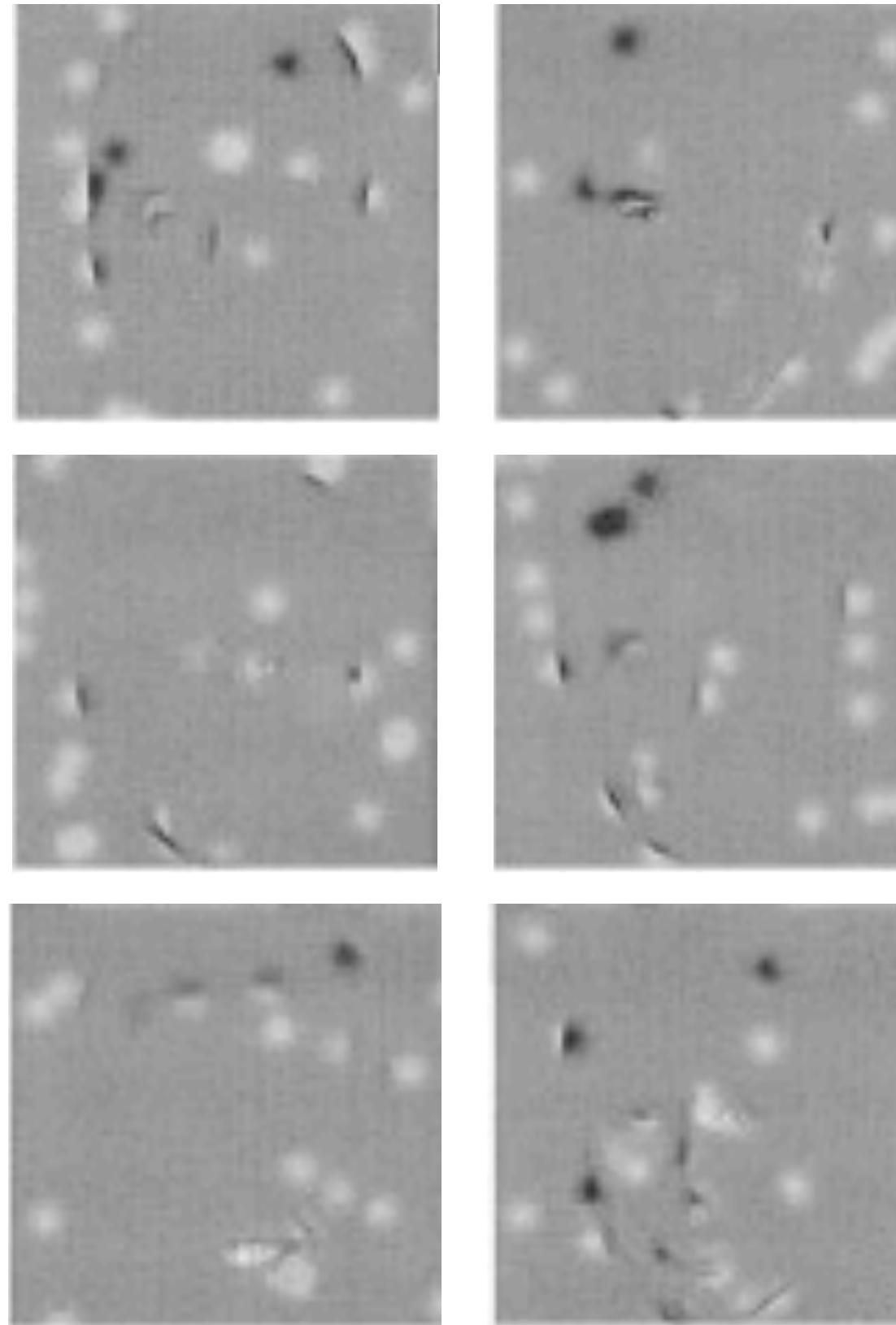
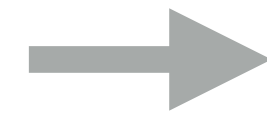
NEXT

INSPIRATION: BUBBLES

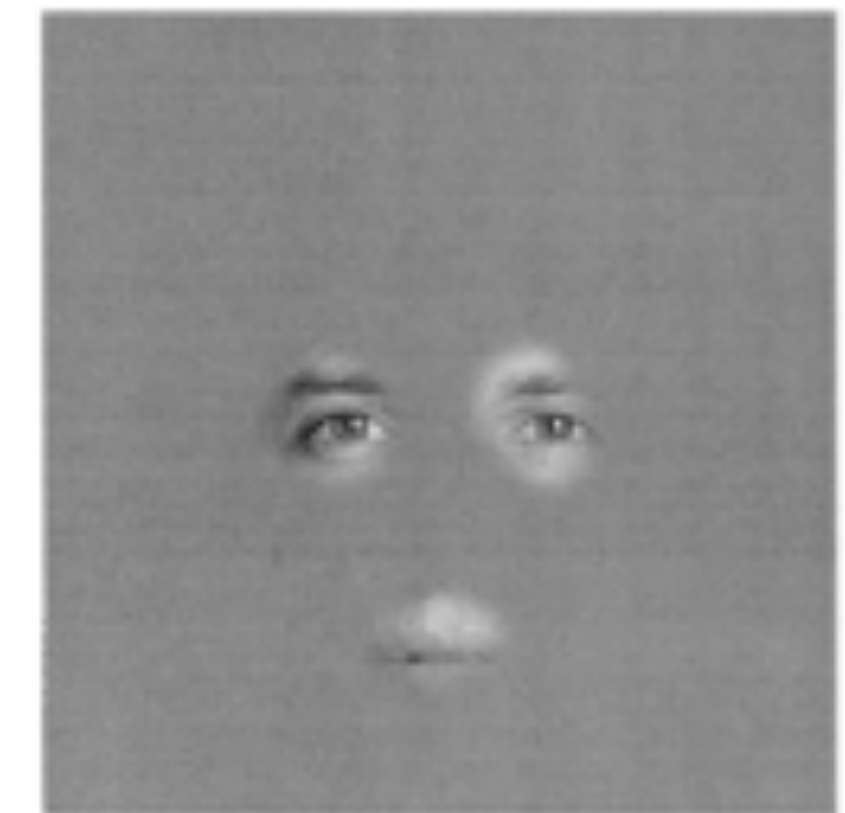
[GOSSELIN & SCHYNS, 2001]



Face stimuli



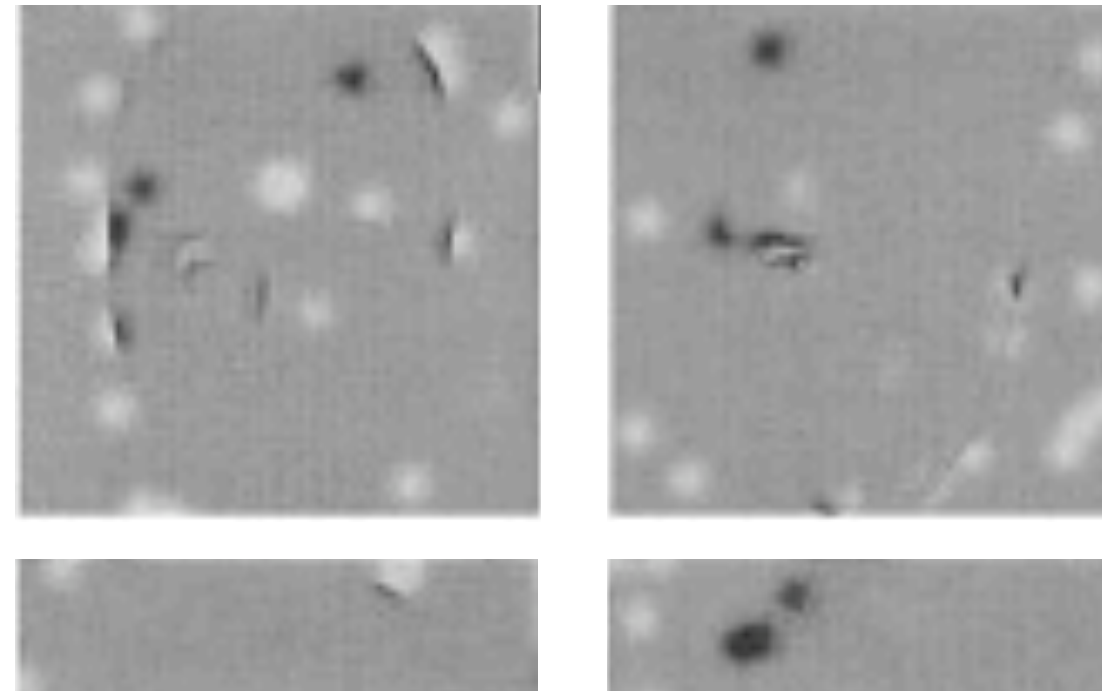
Punctured by bubbles



Discriminative features

Gender categorization

INSPIRATION: BUBBLES [GOSSELIN & SCHYNS, 2001]



BubbleView generalizes this idea to allow users to control where they want to look.

Face stimuli

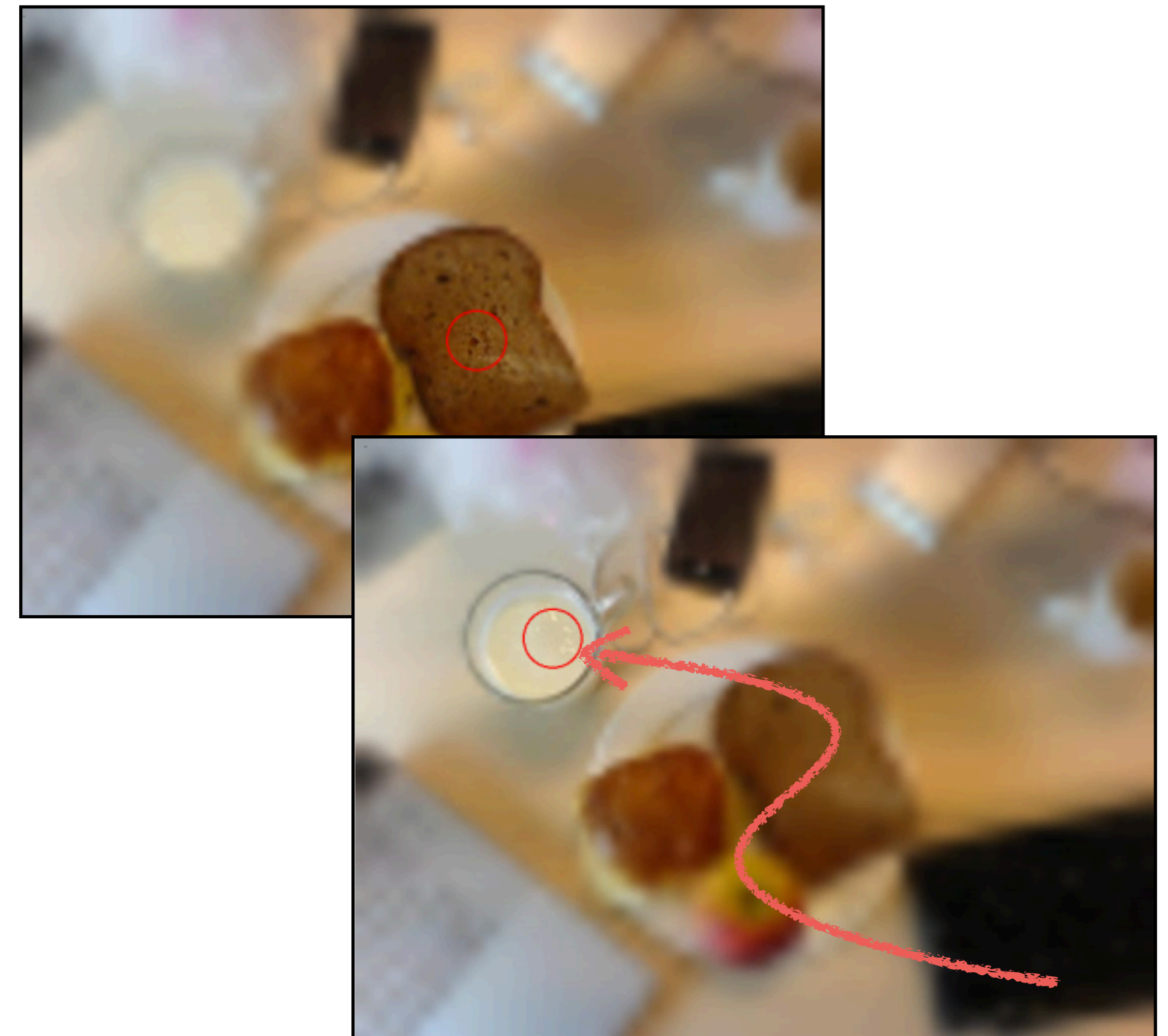
Punctured by bubbles

Gender categorization

RELATED MOVING-WINDOW METHODOLOGIES

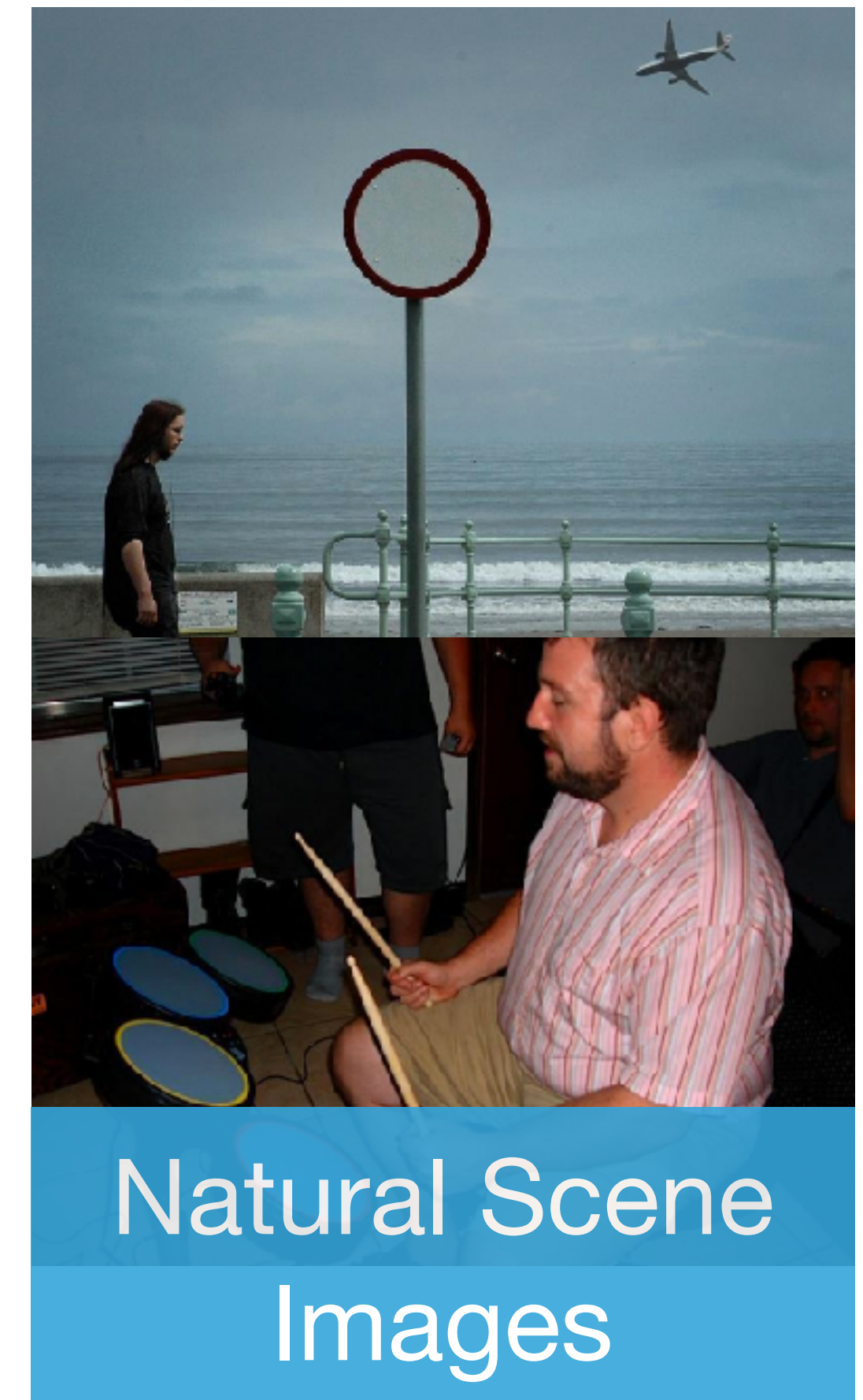
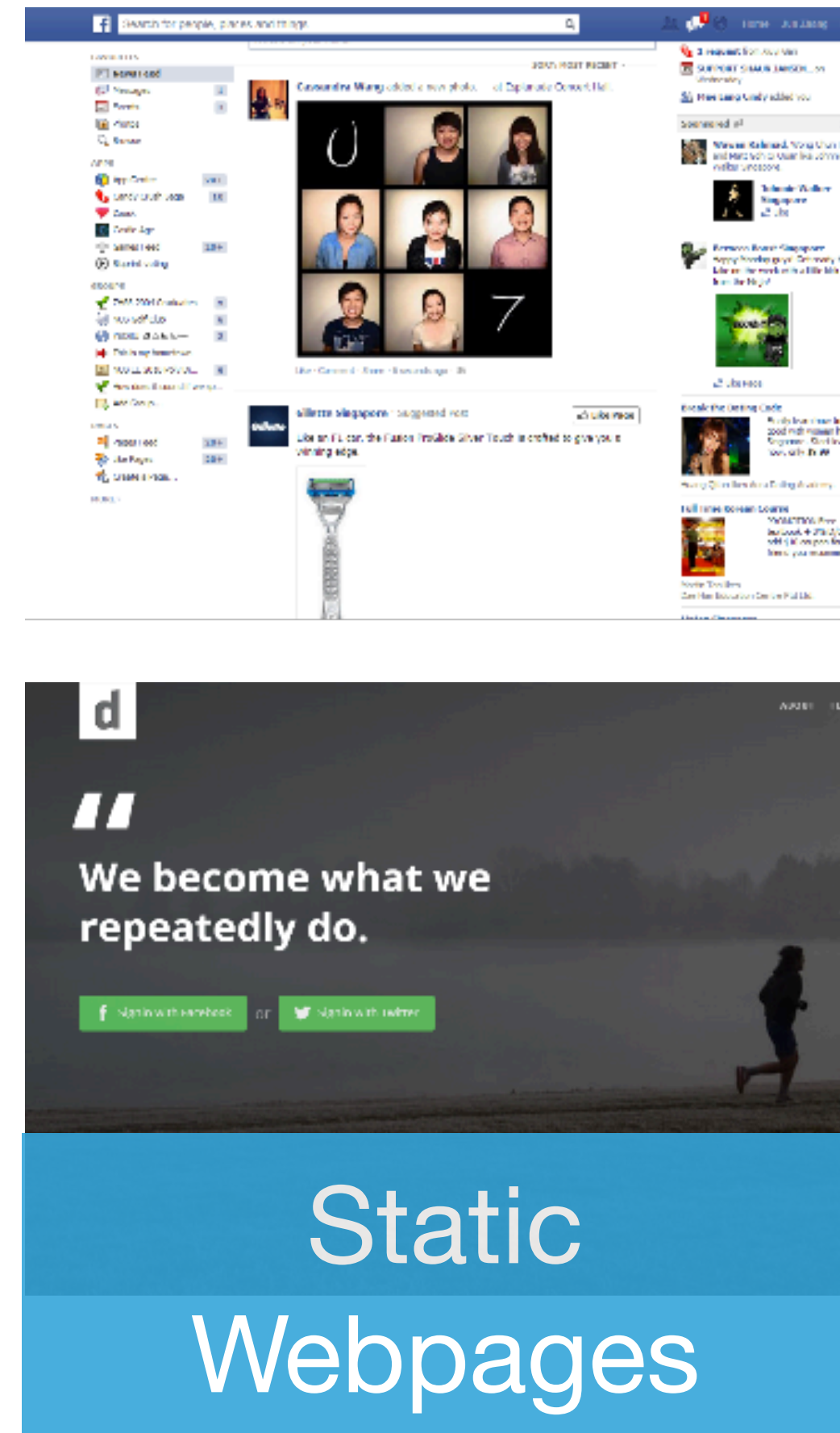
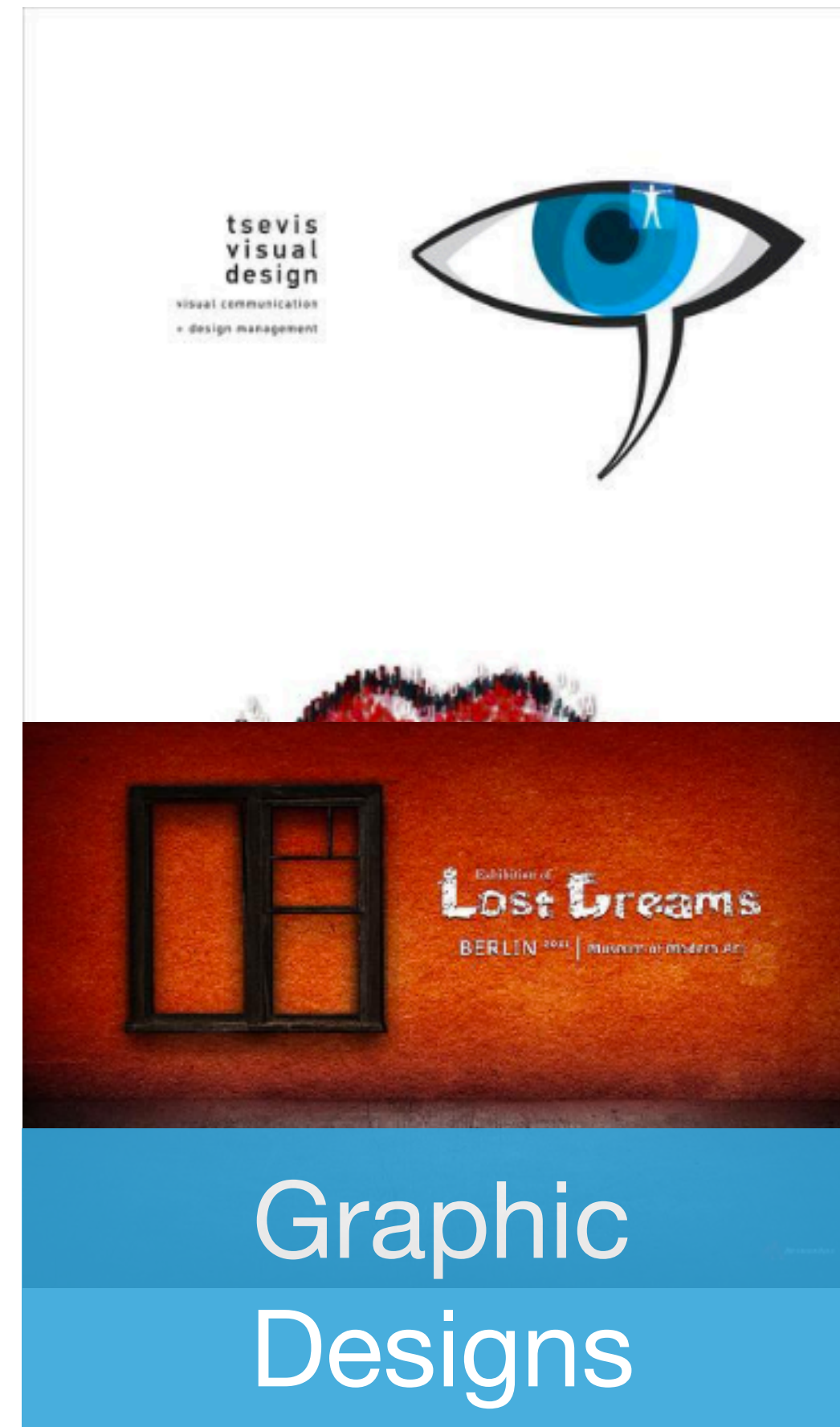
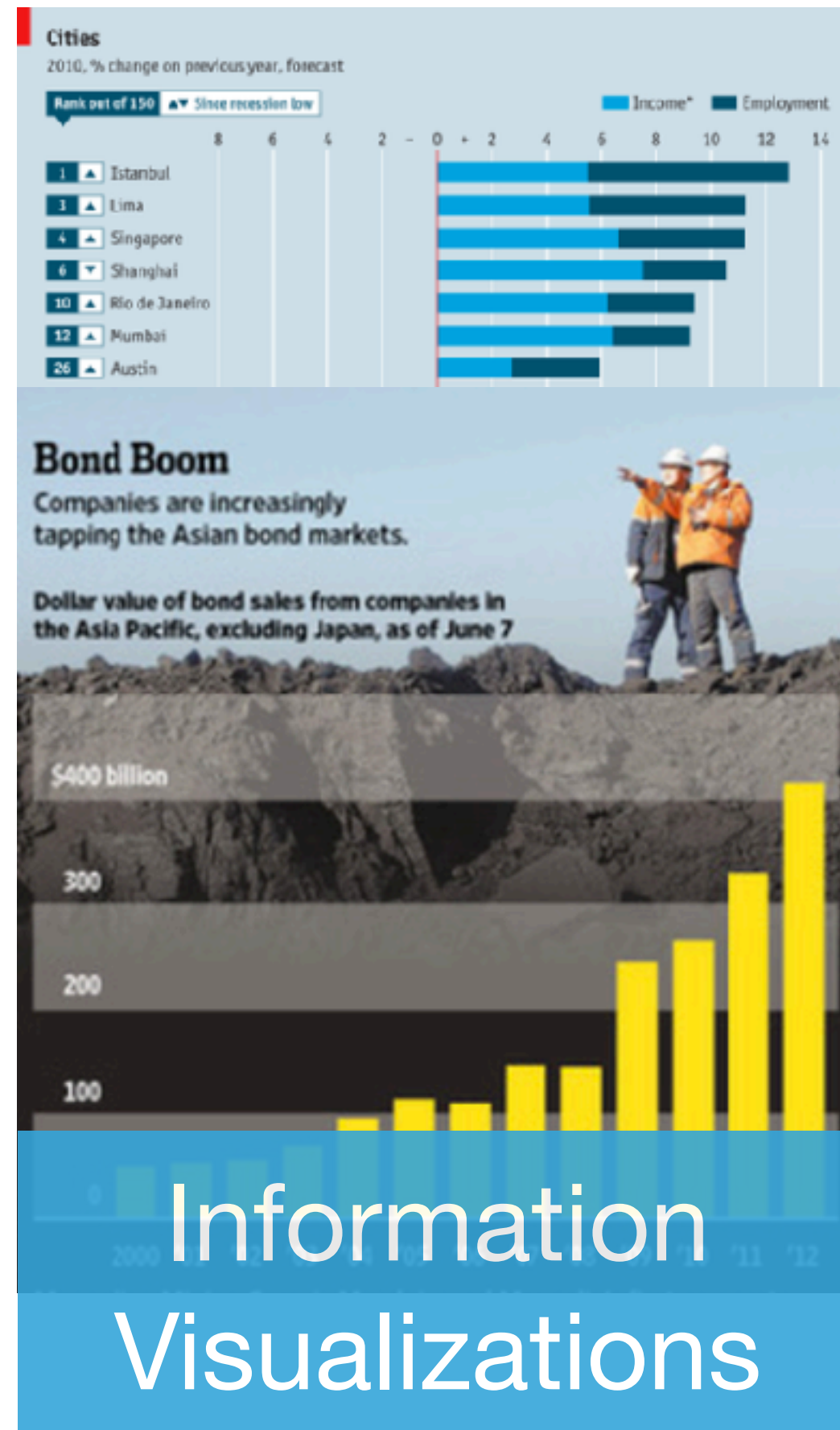


Schulte- Mecklenbeck et al. 2011



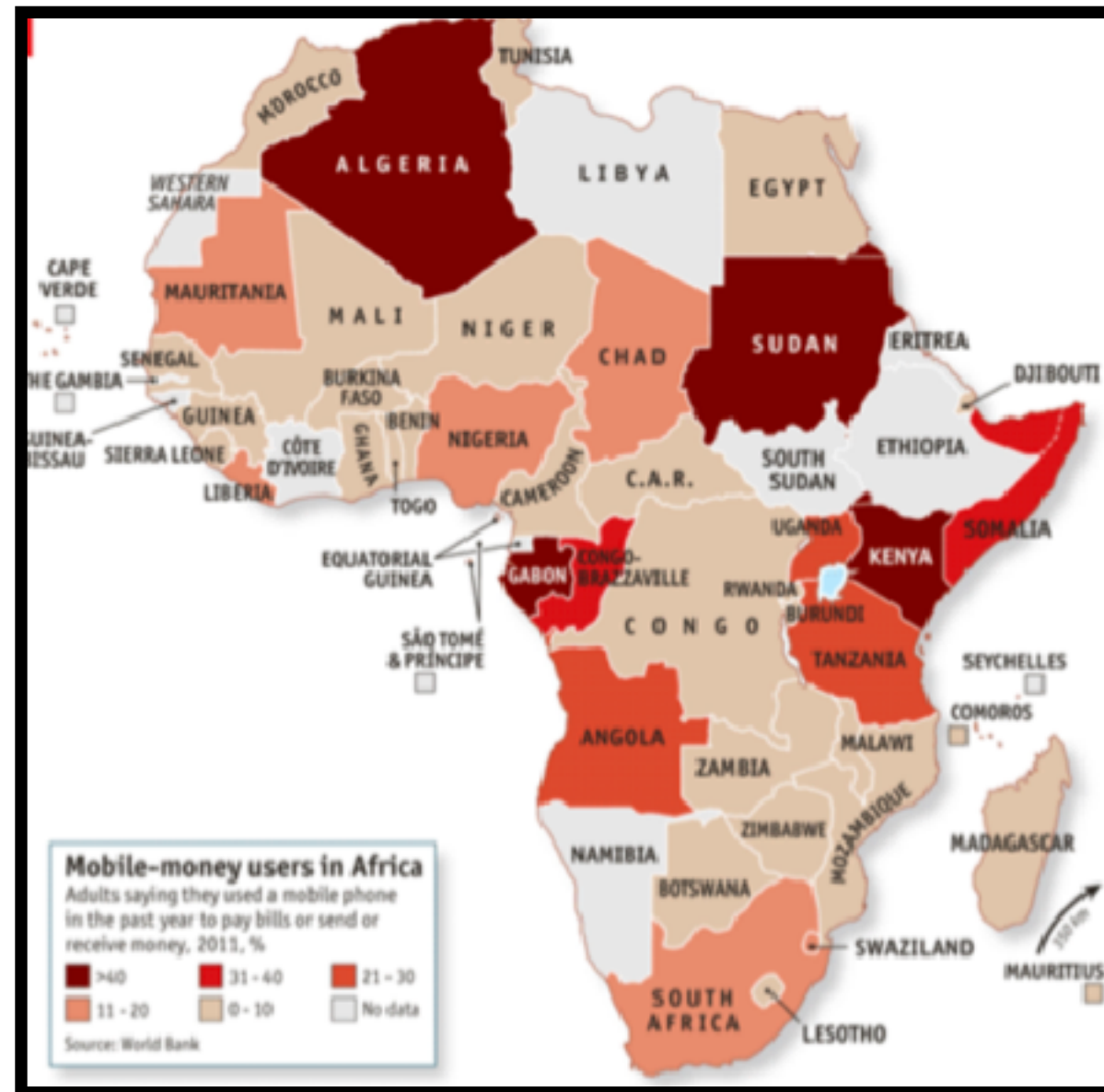
Jiang et al. 2015

EXPLORING THE BUBBLEVIEW METHODOLOGY



PERFORMANCE IS STABLE ACROSS BUBBLE SIZES

32 pix



24 pix



16 pix

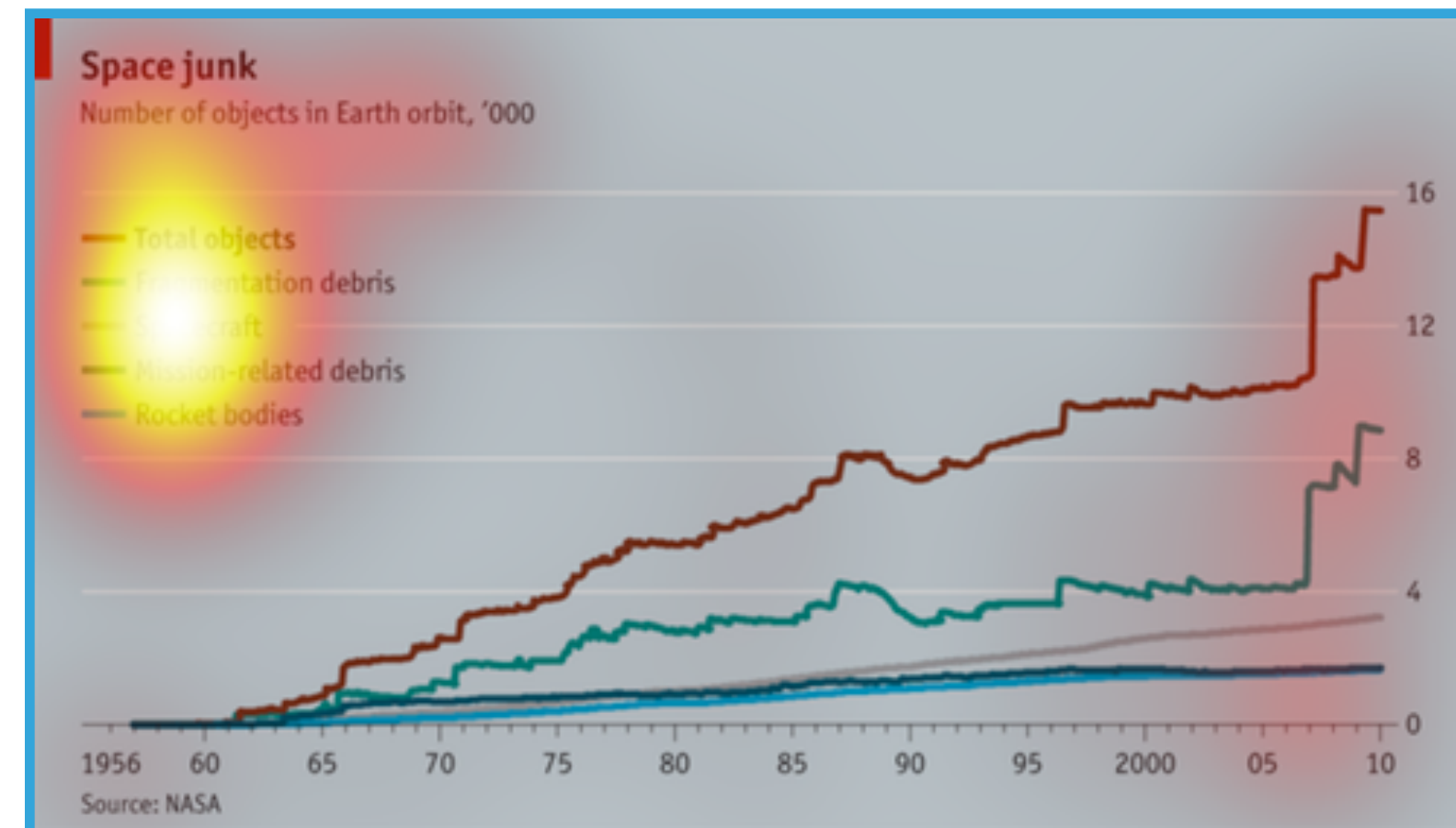
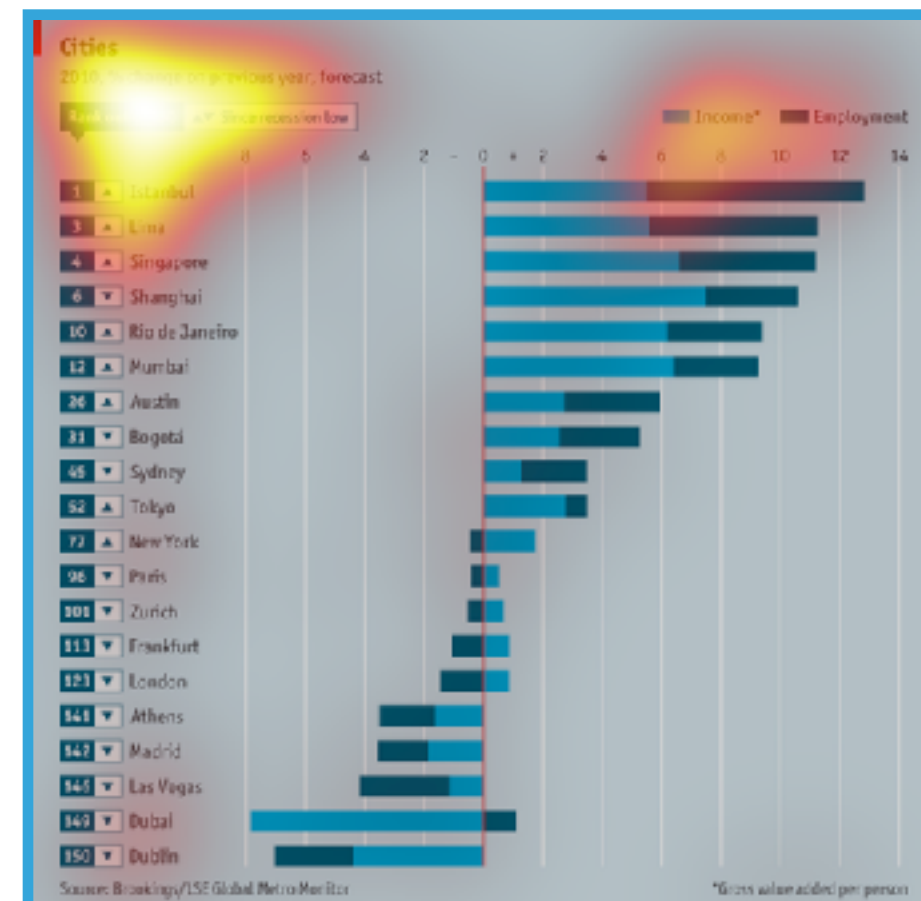


Effort

x 1.5 clicks

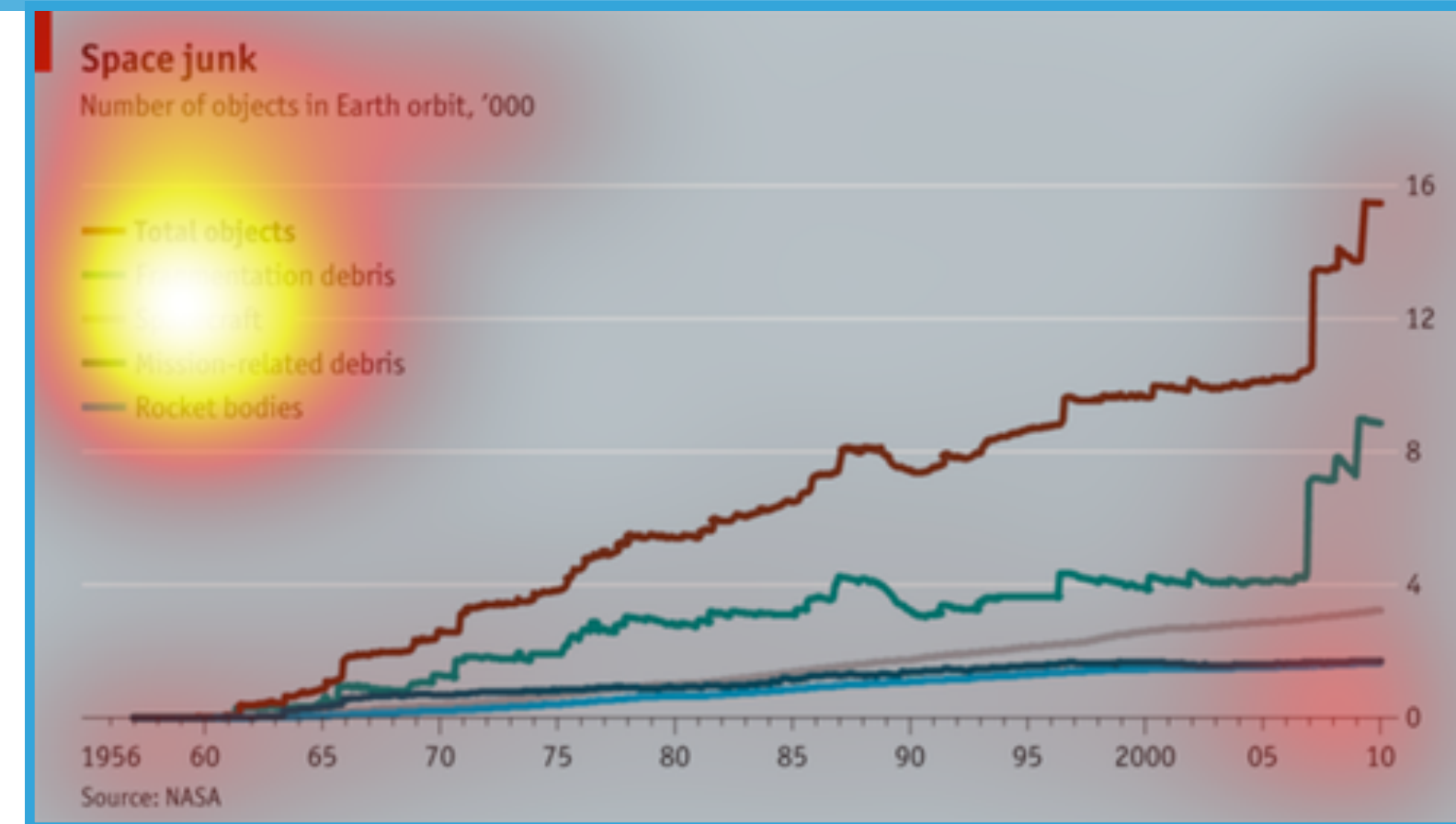
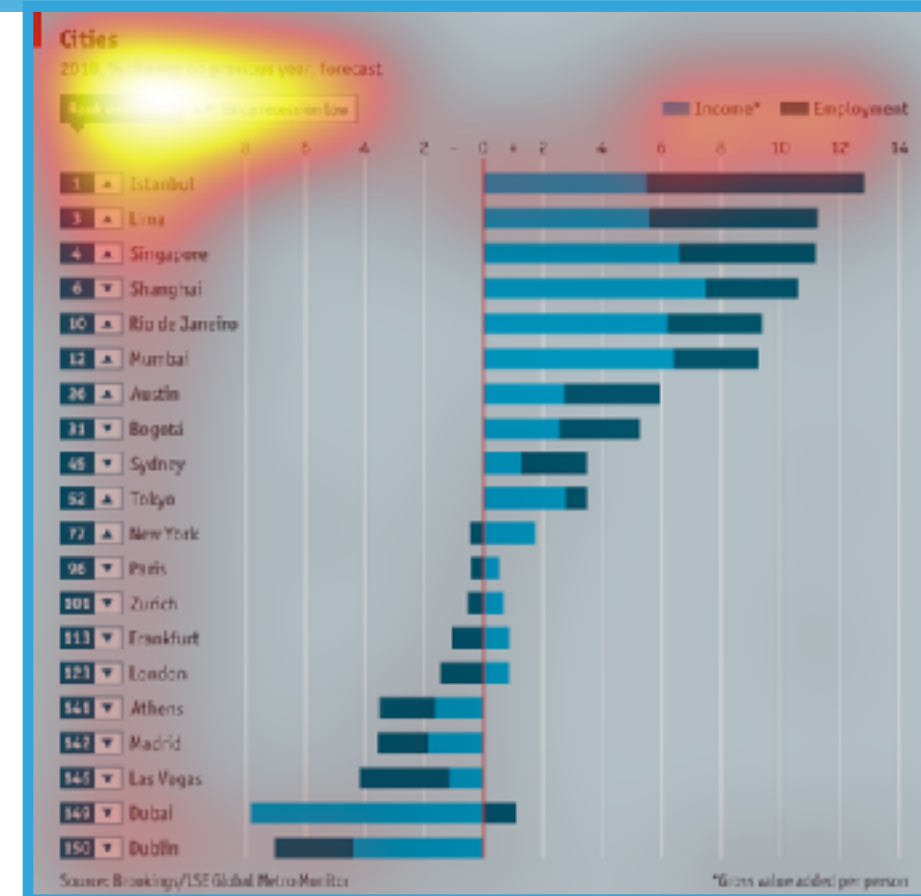
CLICKS PREDICT FIXATIONS ON VISUALIZATIONS

Fixations

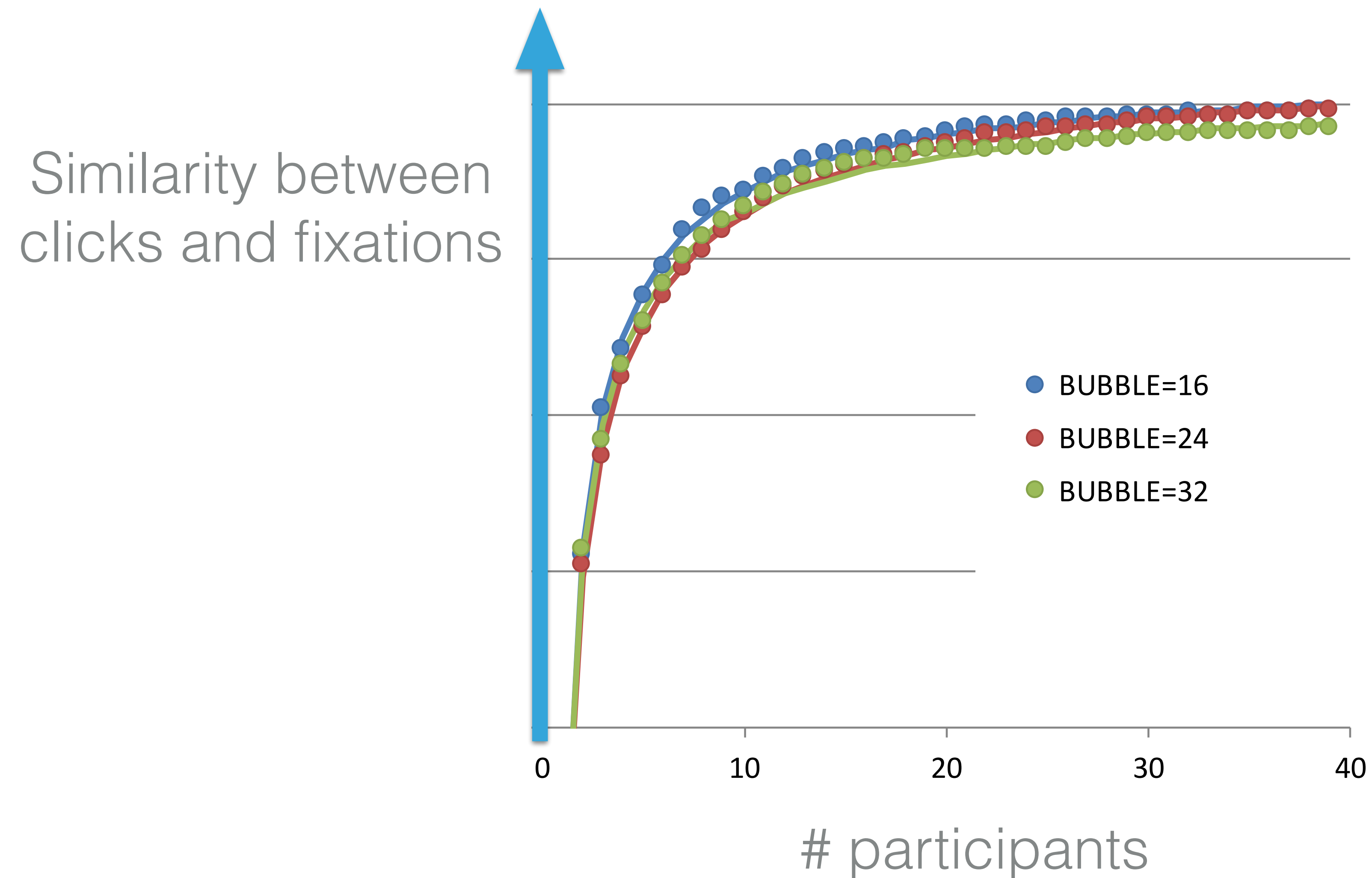


clicks of 10 participants explain 90% of fixations

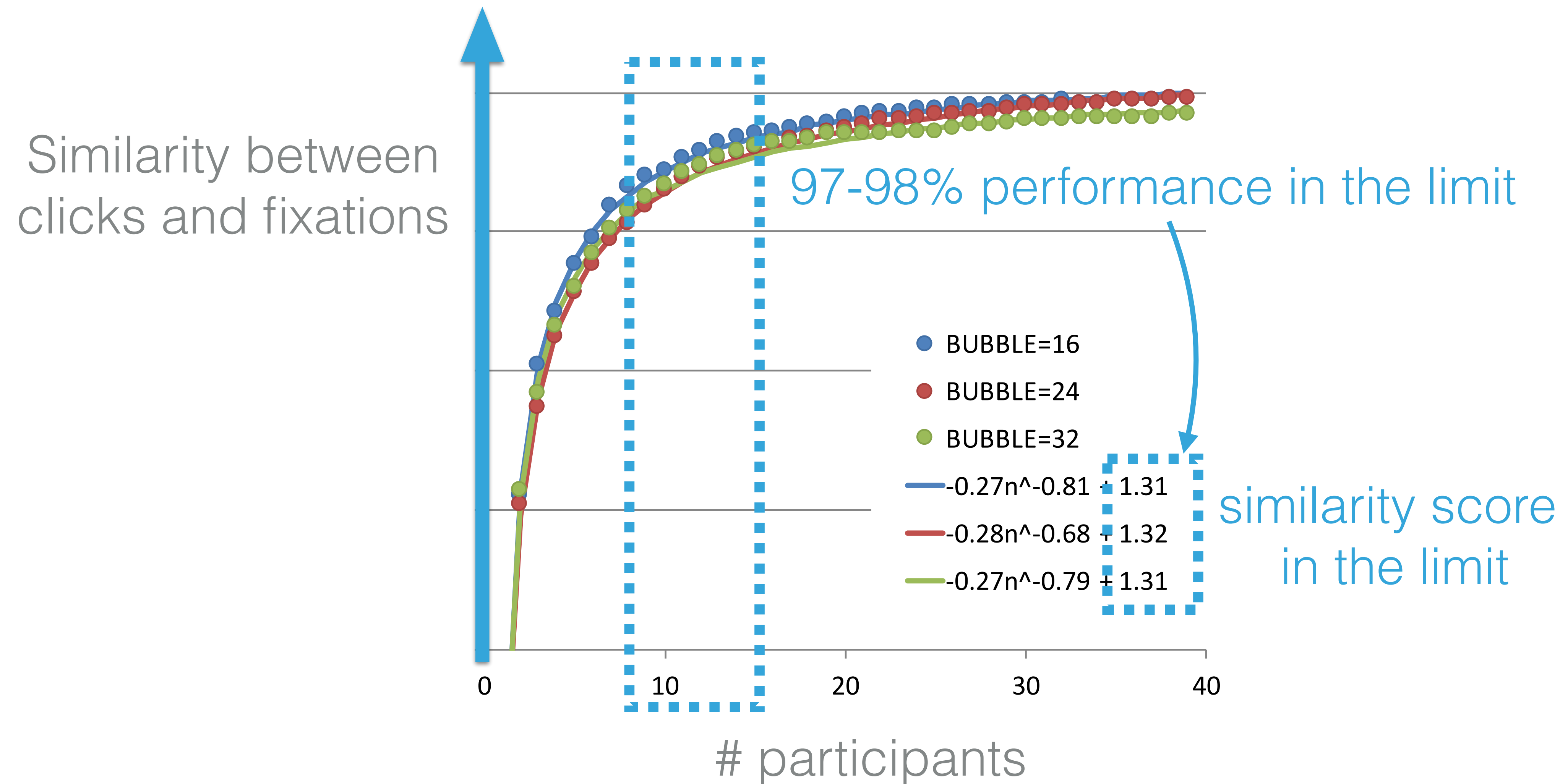
Clicks



INCREASING SIMILARITY BETWEEN CLICKS AND FIXATIONS



INCREASING SIMILARITY BETWEEN CLICKS AND FIXATIONS



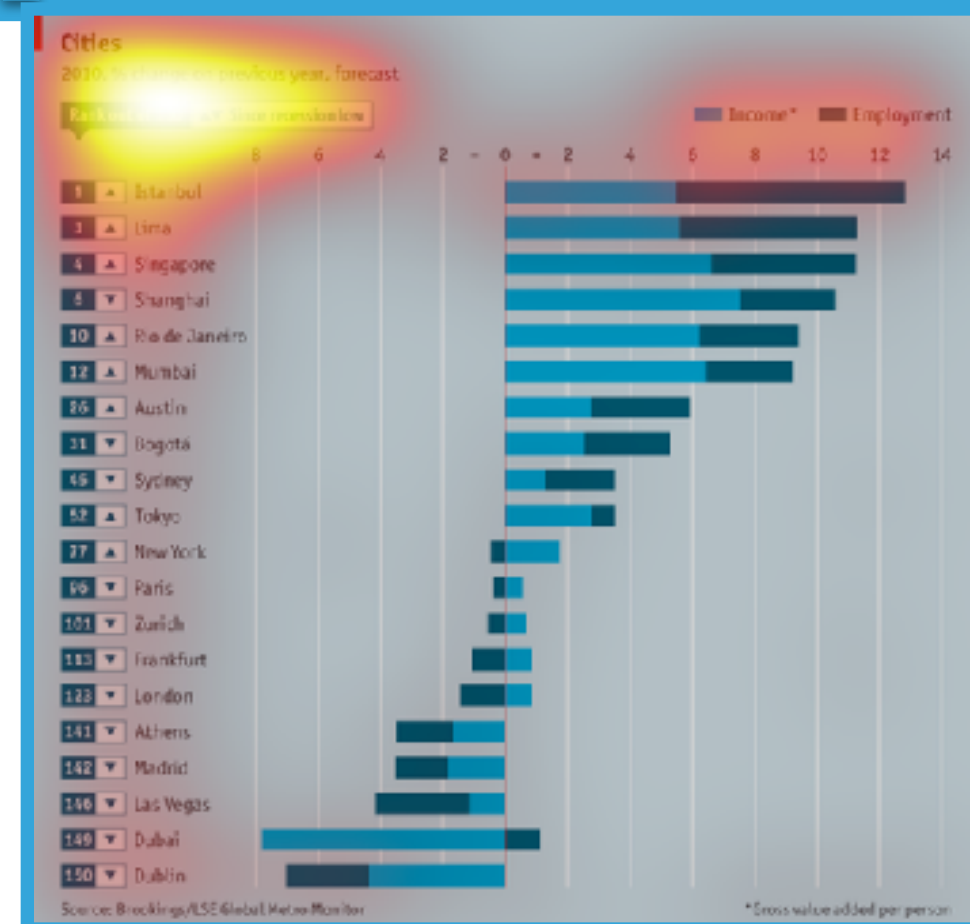
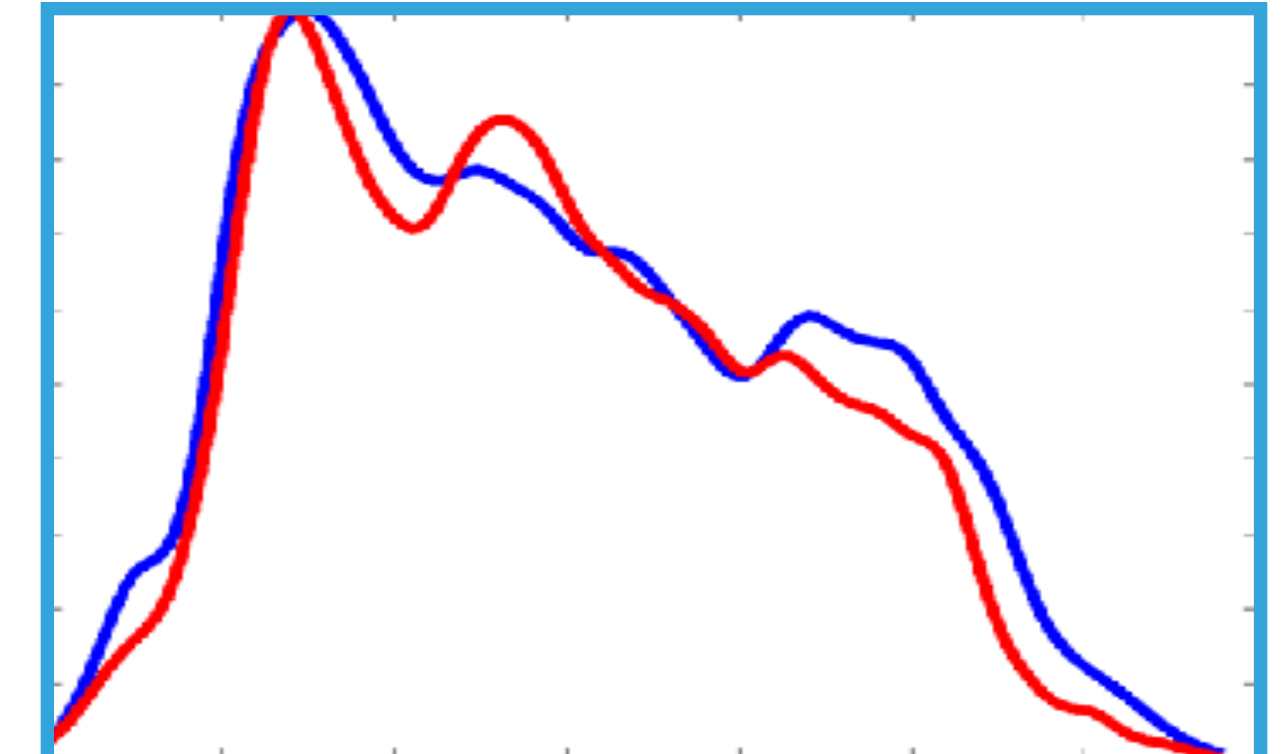
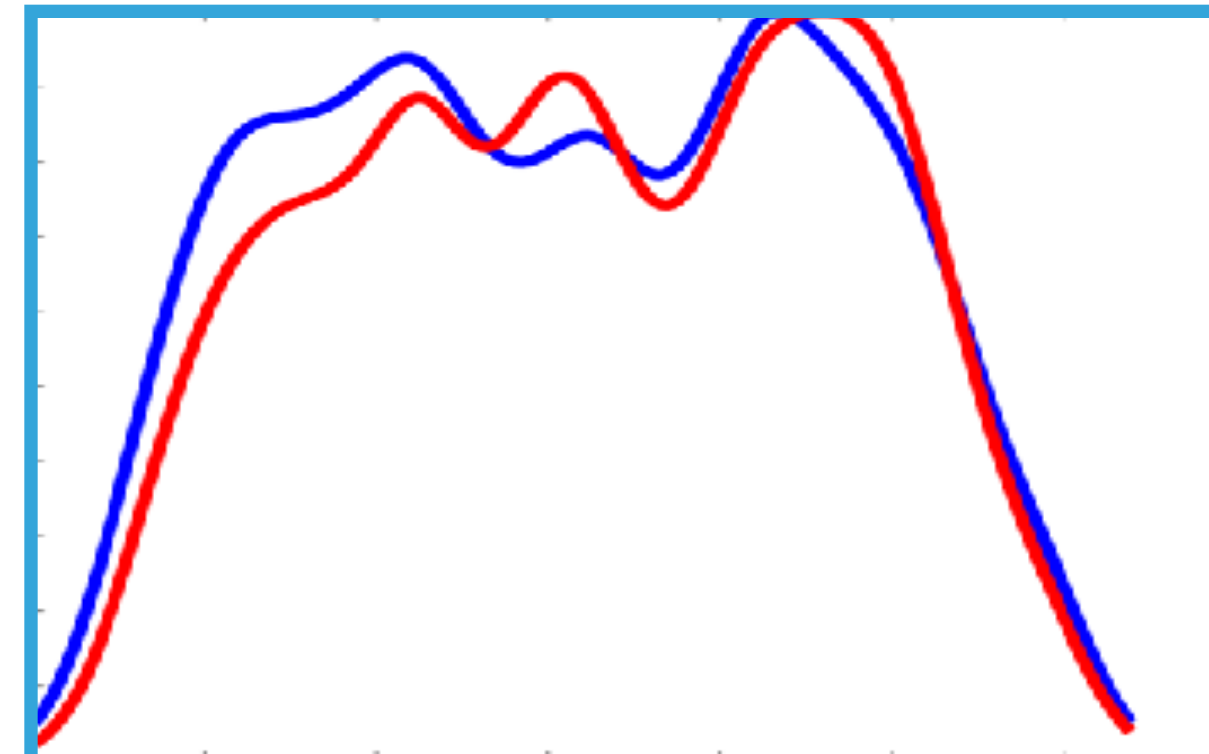
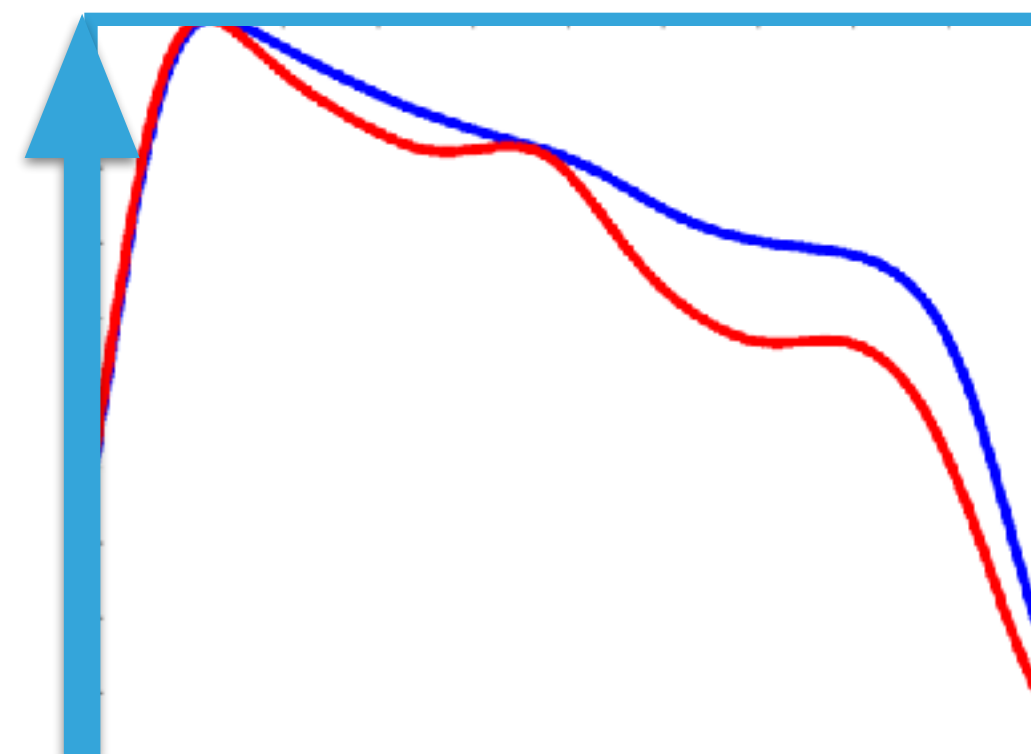
CLICK PATTERNS MATCH FIXATION PATTERNS

Visualizations

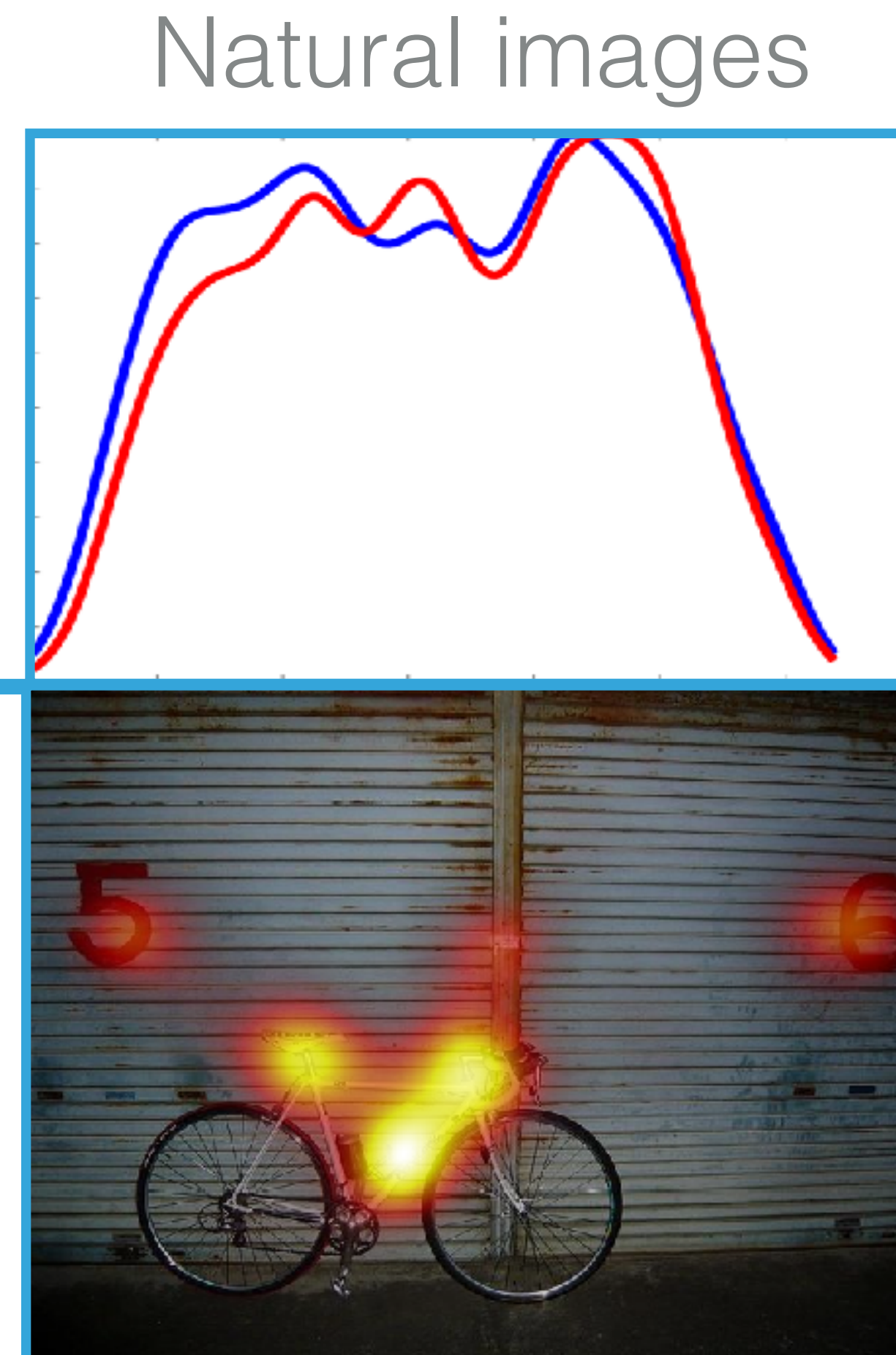
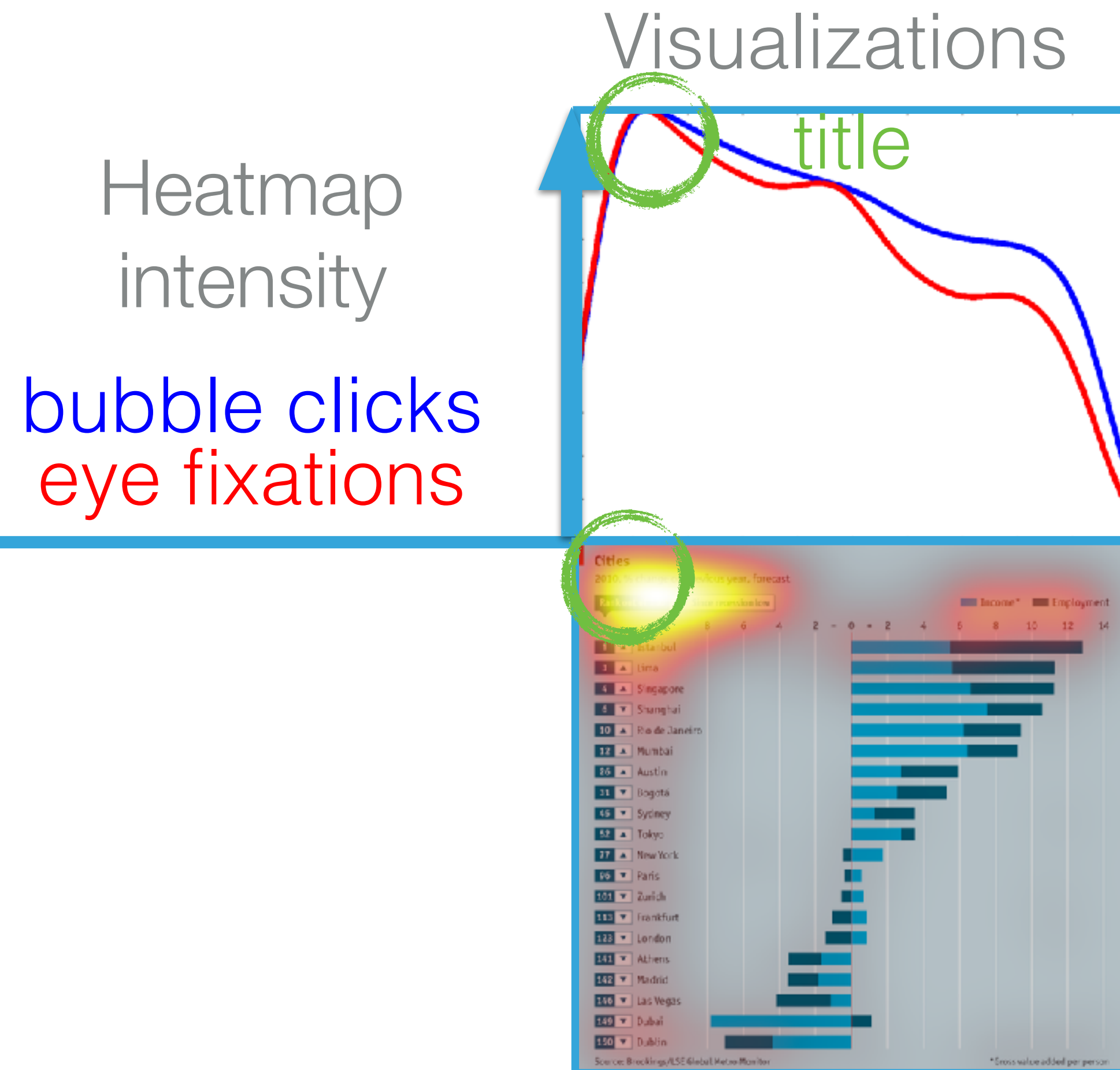
Natural images

Webpages

Heatmap
intensity
bubble clicks
eye fixations



CLICK PATTERNS MATCH FIXATION PATTERNS



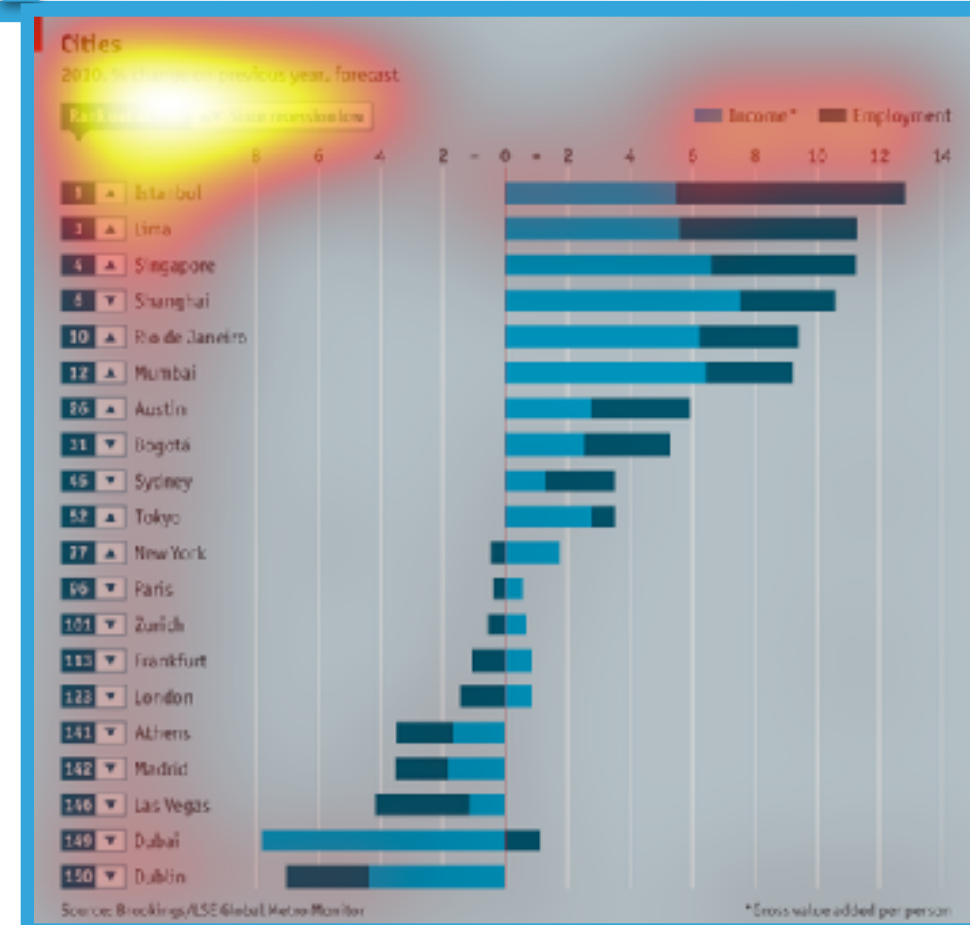
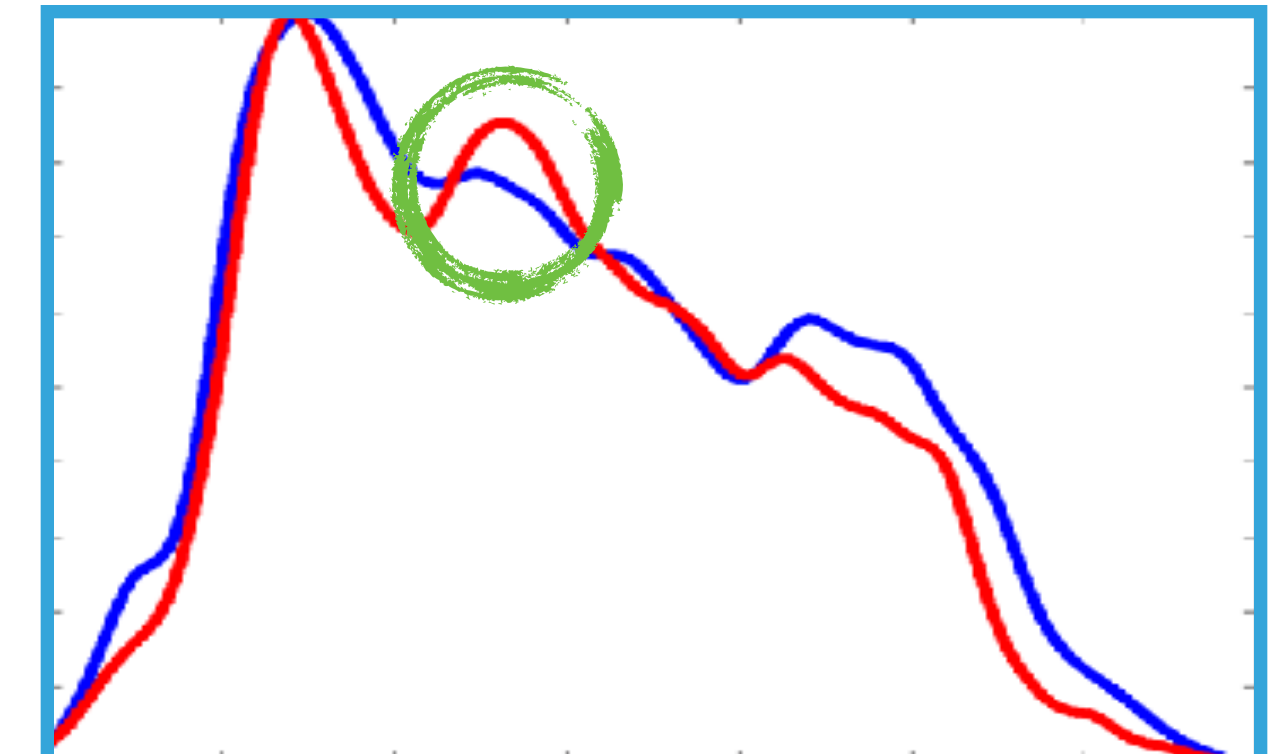
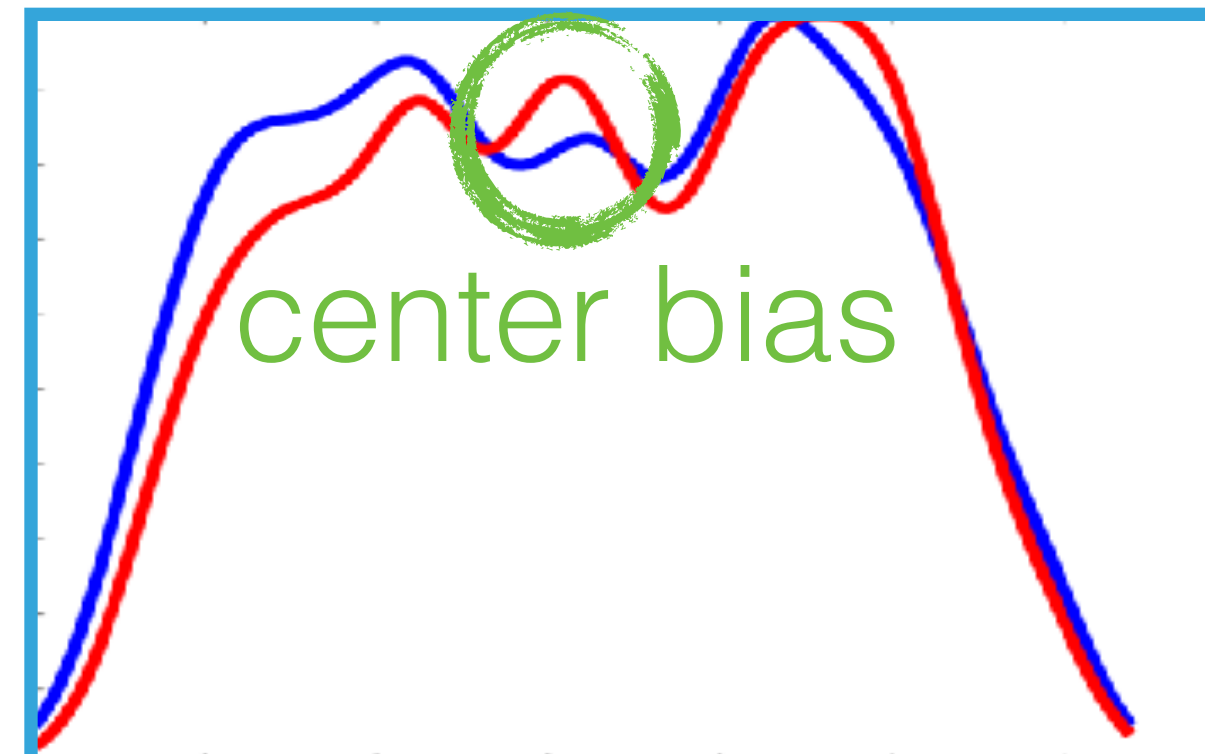
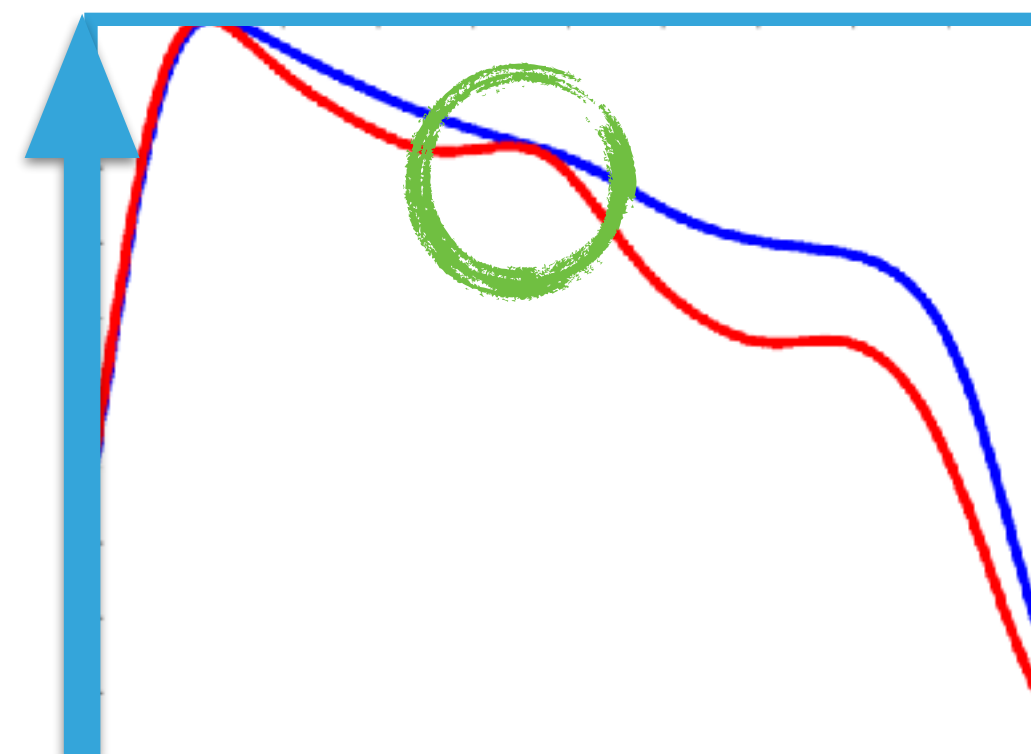
CLICK PATTERNS MATCH FIXATION PATTERNS

Visualizations

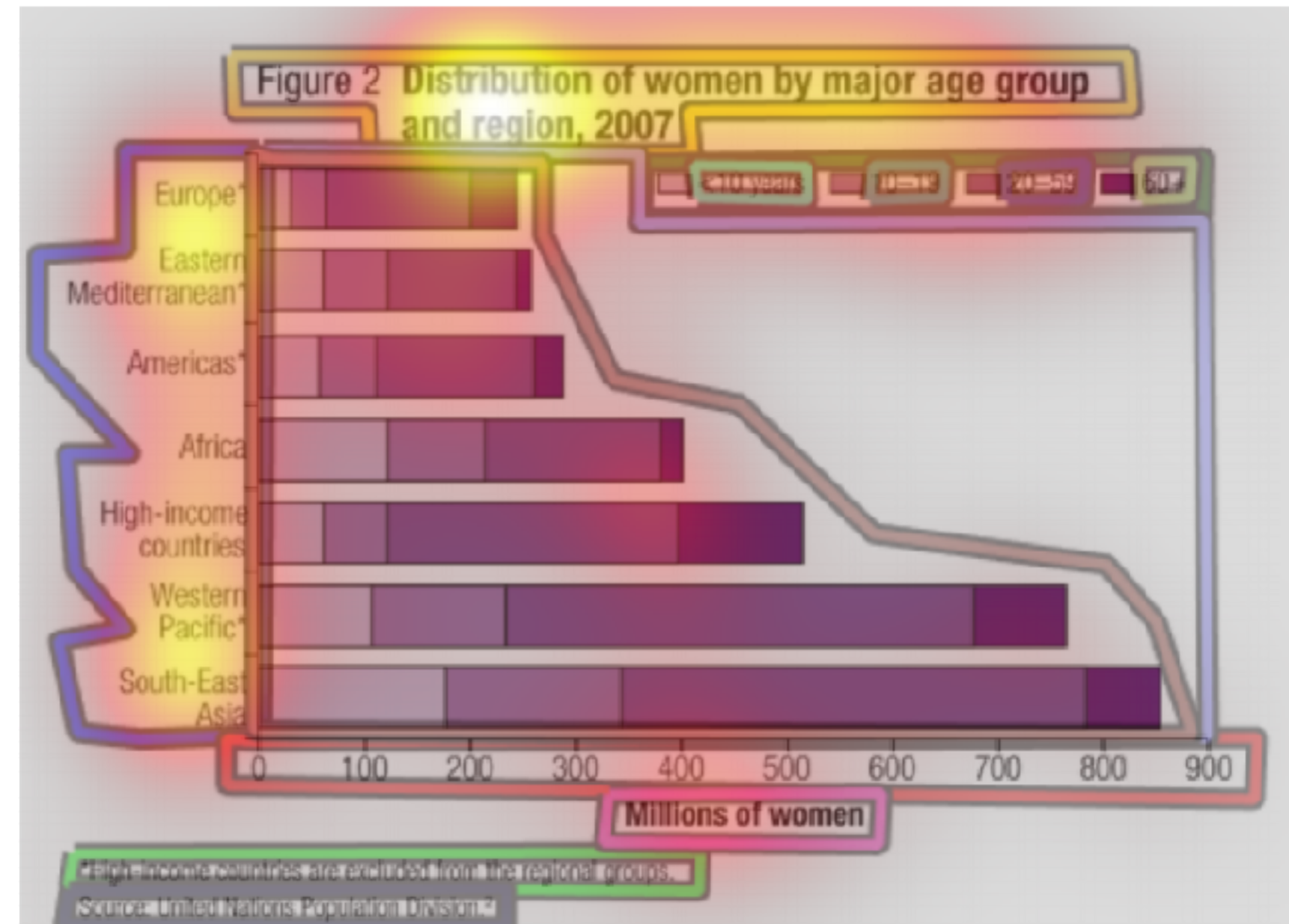
Natural images

Webpages

Heatmap
intensity
bubble clicks
eye fixations

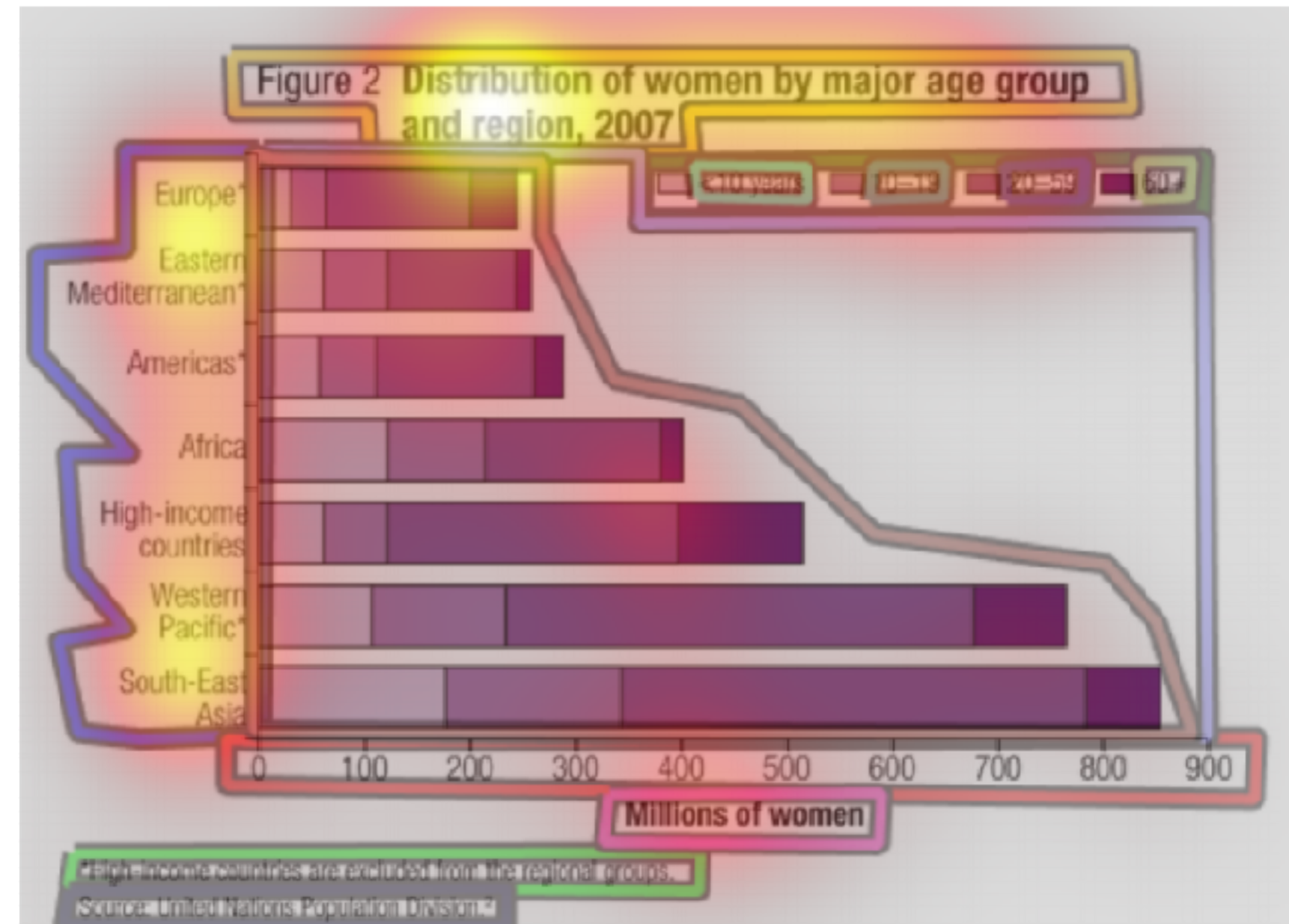


WHERE DO PEOPLE CLICK MOST?

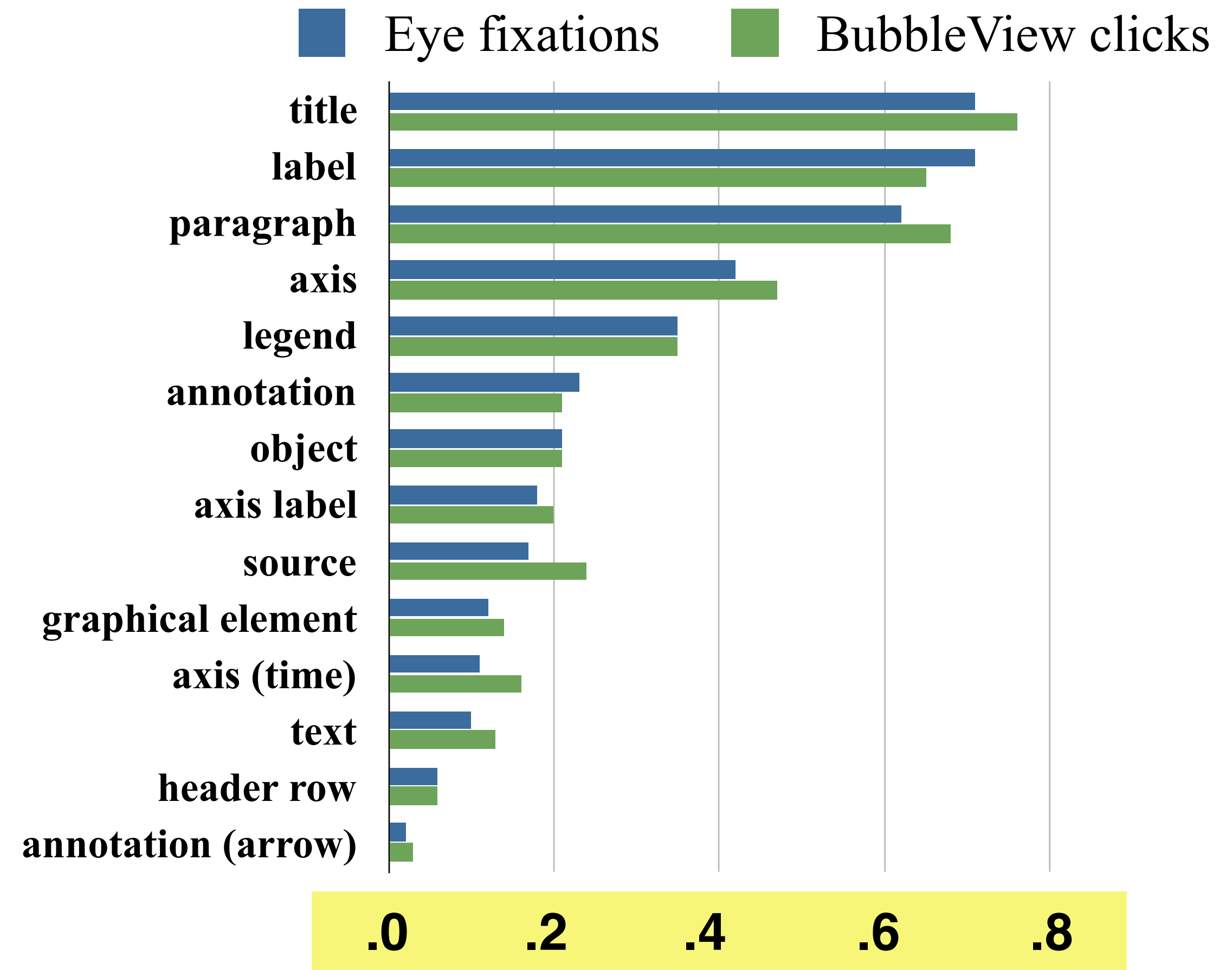


- (1) axis
- (2) axis
- (3) text (paragraph)
- (4) text (source)
- (5) text (axis label)
- (6) text (title)
- (7) legend
- (8) data
- (9) data (bars)
- (10) text (label)
- (11) text (label)
- (12) text (label)
- (13) text (label)

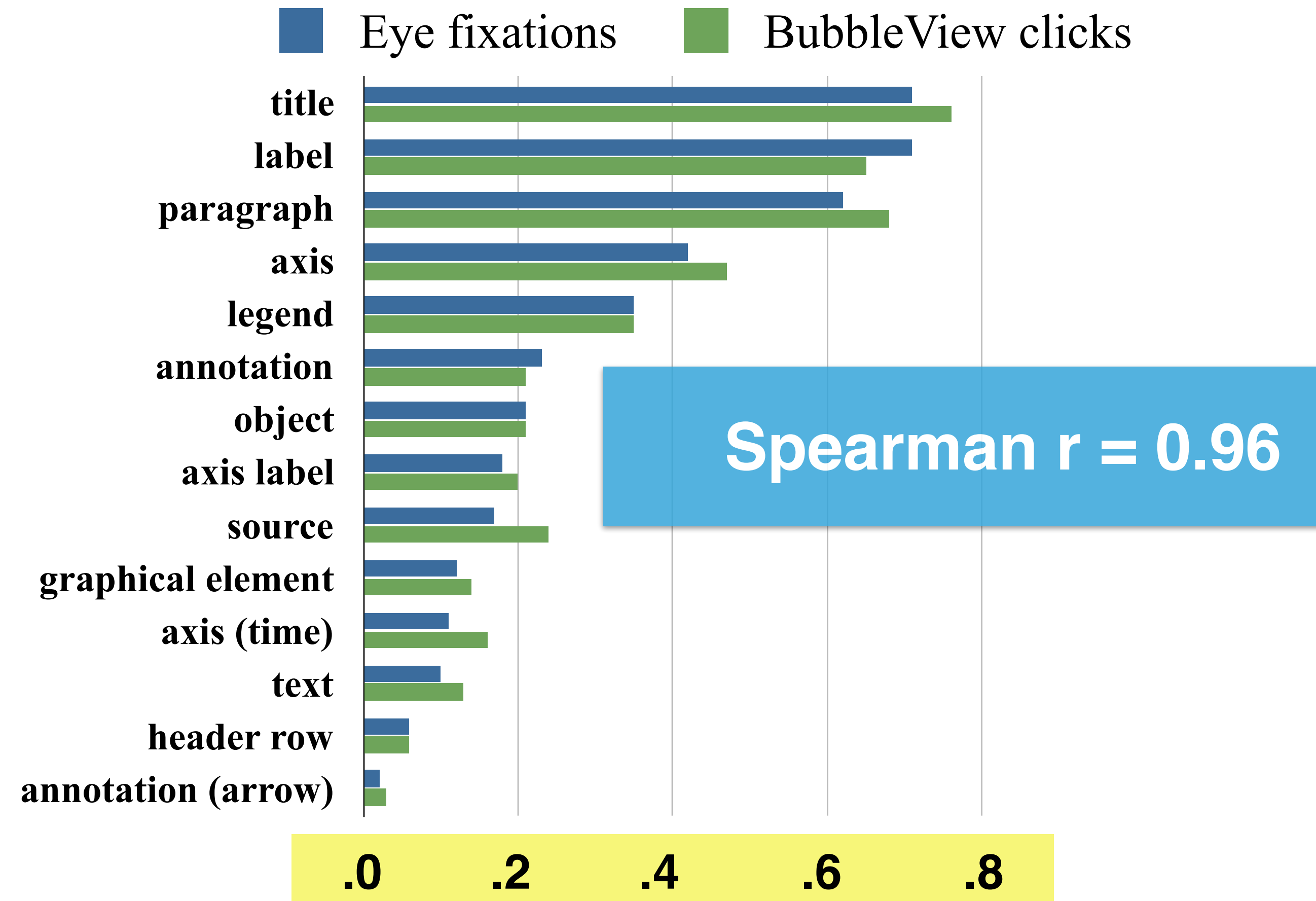
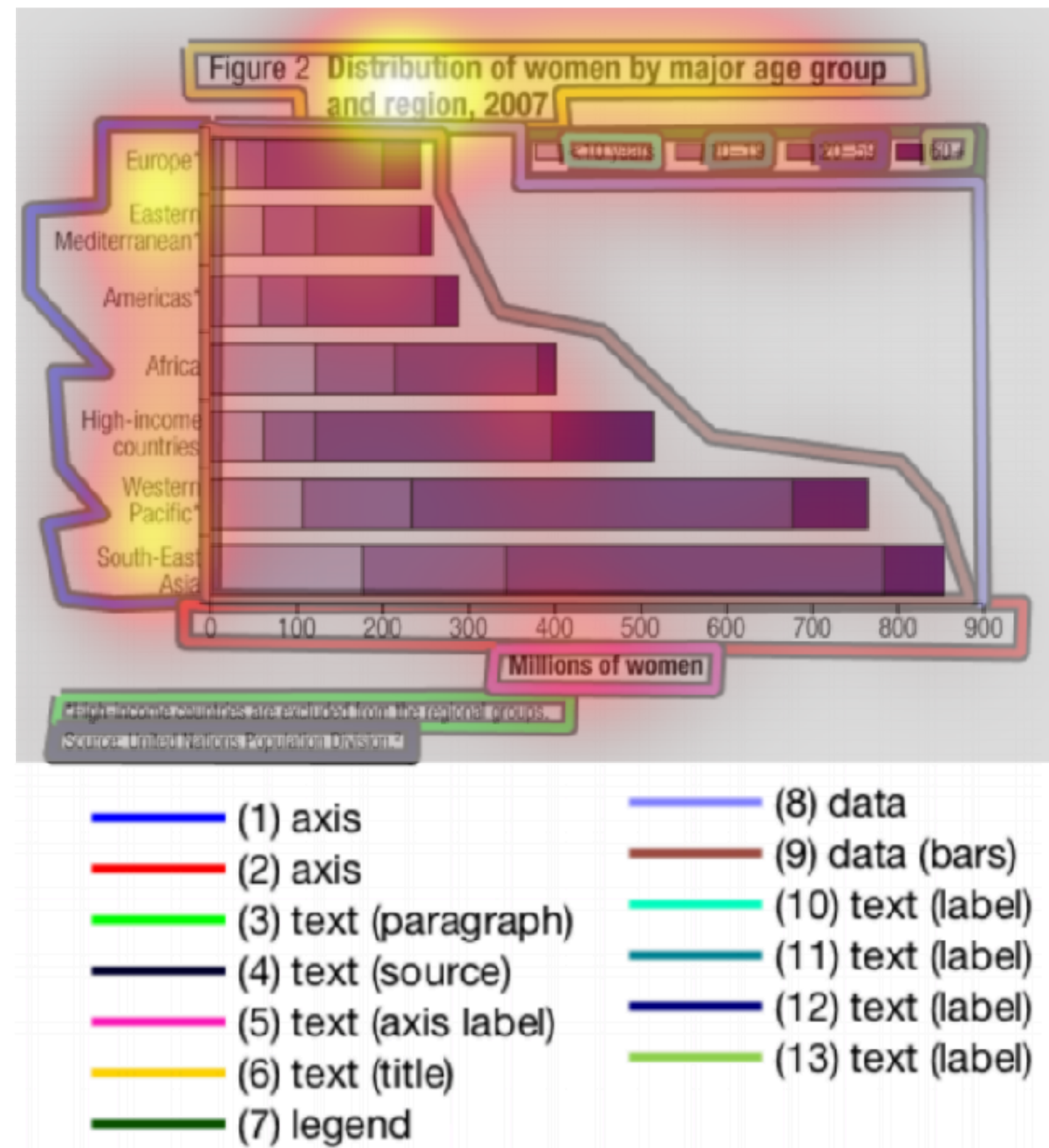
WHERE DO PEOPLE CLICK MOST?



- (1) axis
- (2) axis
- (3) text (paragraph)
- (4) text (source)
- (5) text (axis label)
- (6) text (title)
- (7) legend
- (8) data
- (9) data (bars)
- (10) text (label)
- (11) text (label)
- (12) text (label)
- (13) text (label)



WHERE DO PEOPLE CLICK MOST?



BUBBLEVIEW MEASURES IMPORTANCE

Fixations



with free-viewing

Clicks



with free-viewing

Clicks



with description

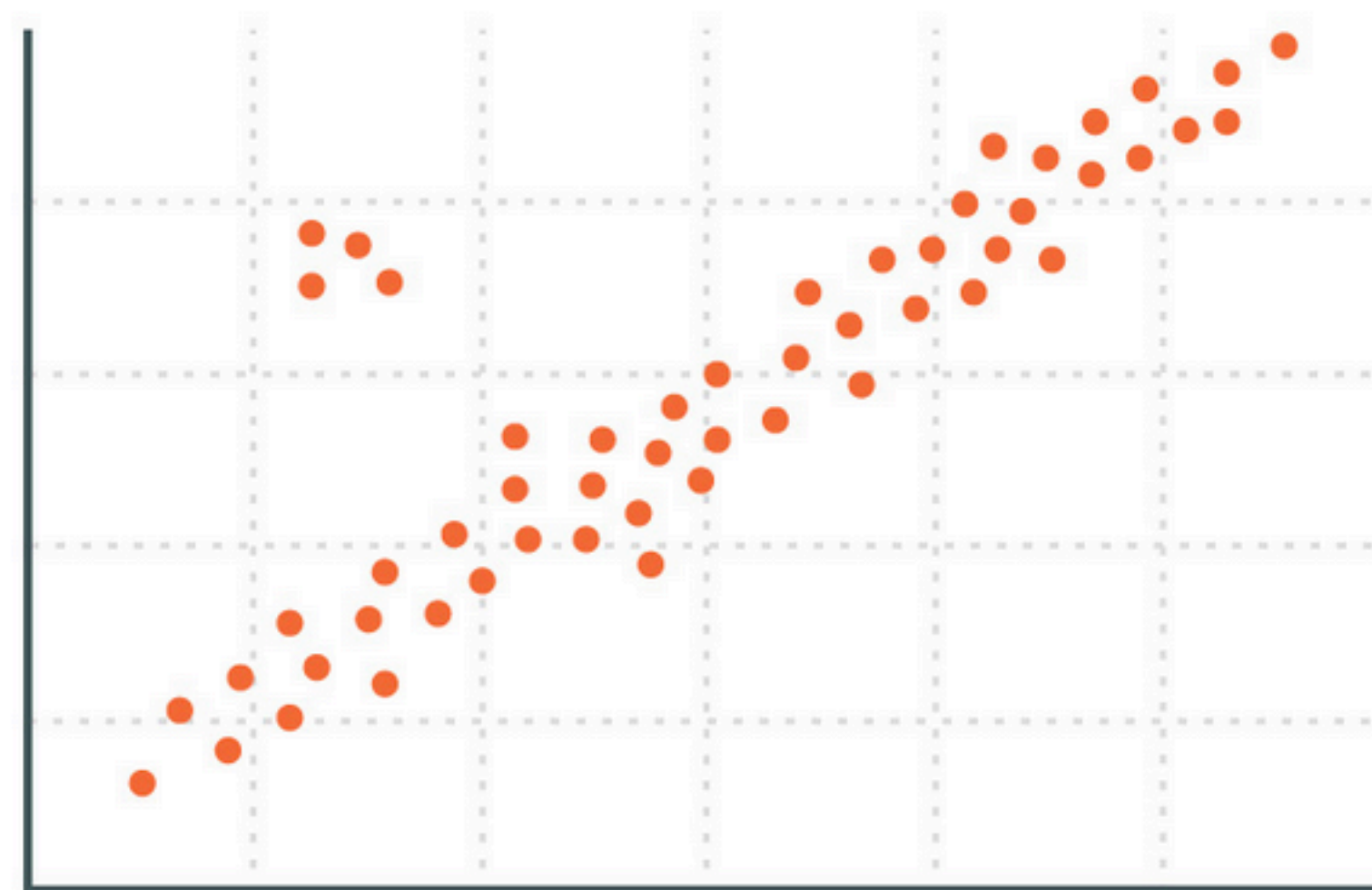
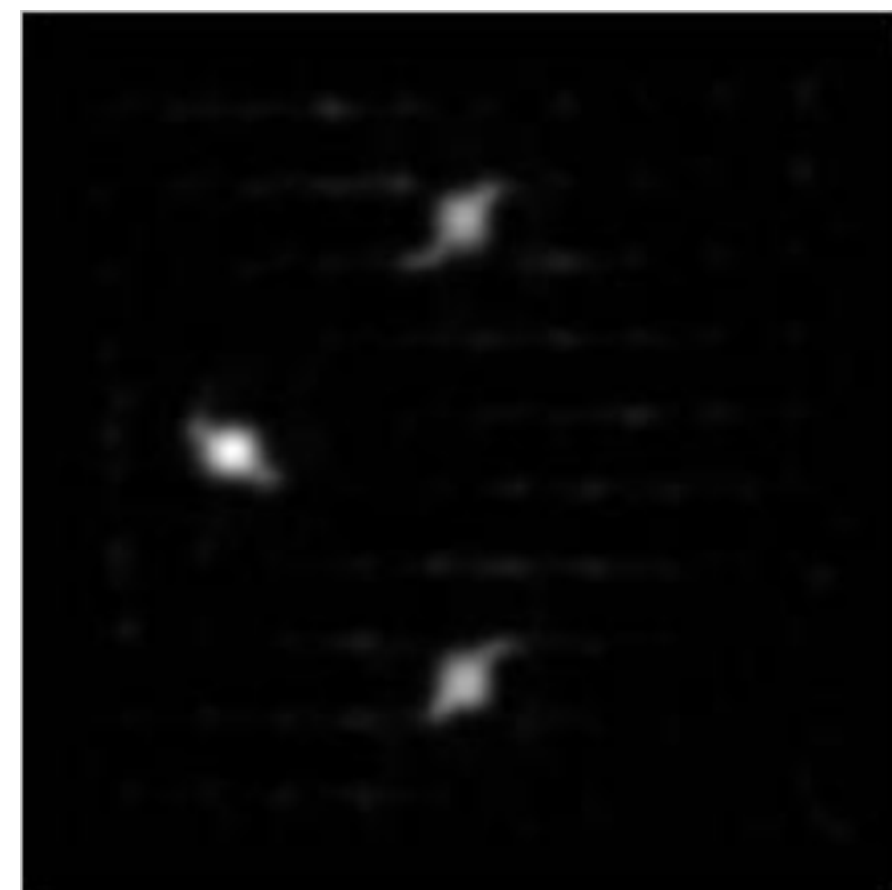
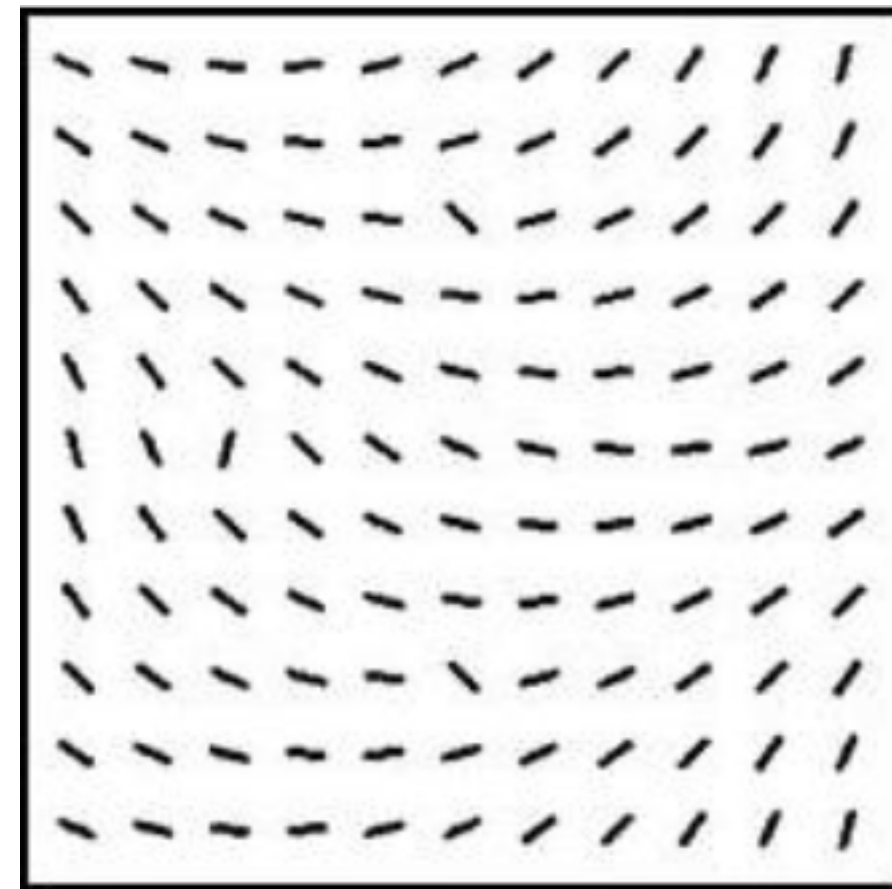
“Saliency”

Intentionality

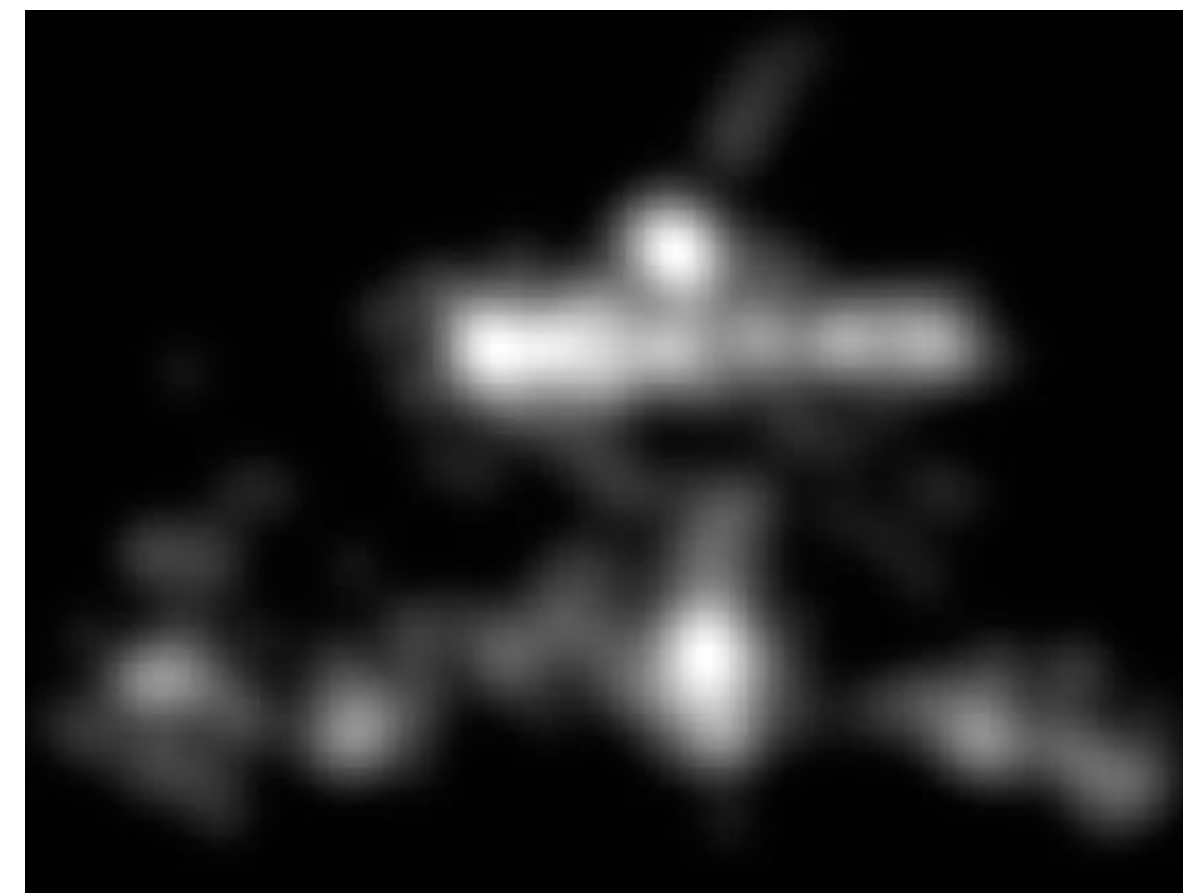
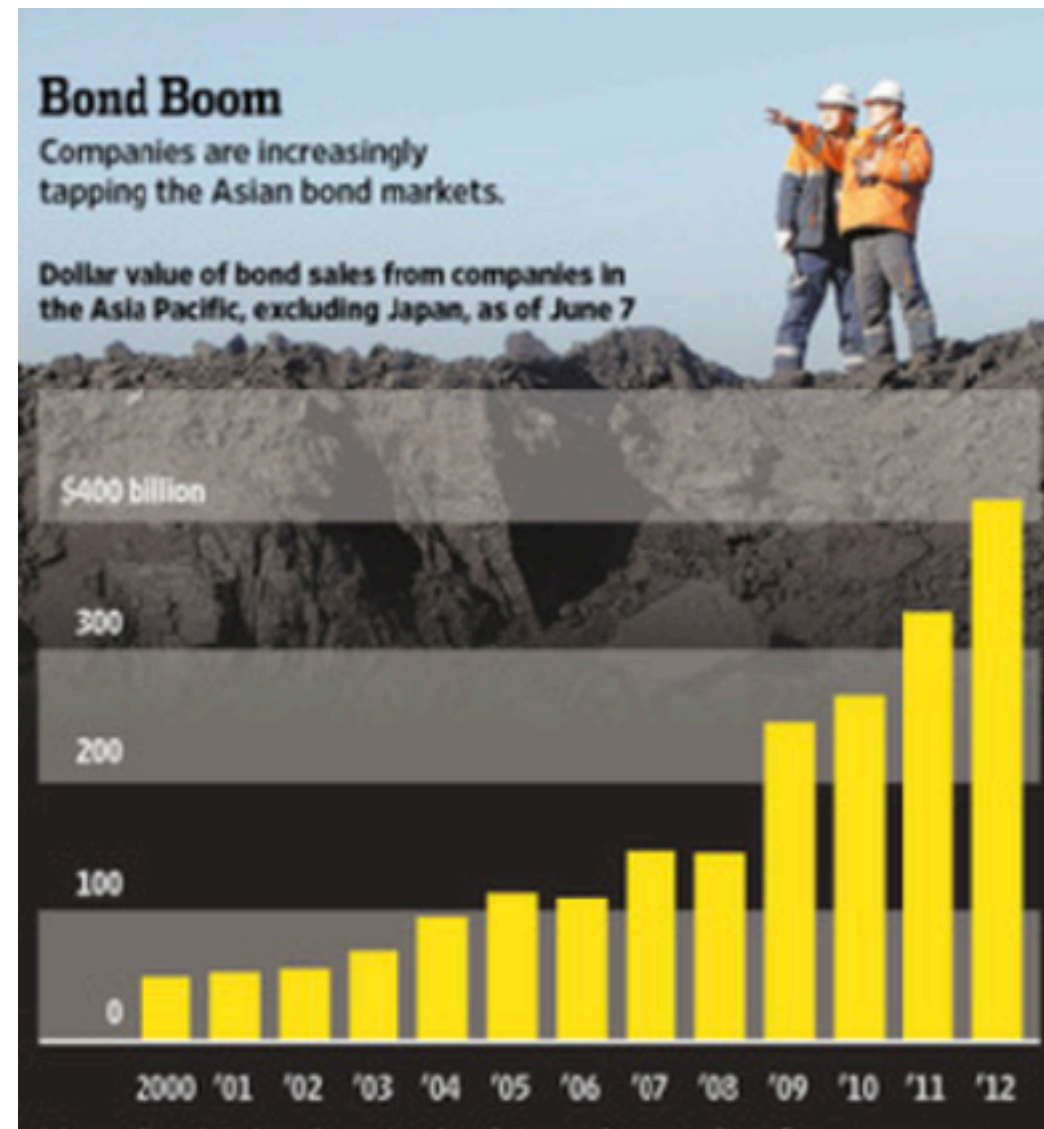
“Importance”

Effort, task time, consistency

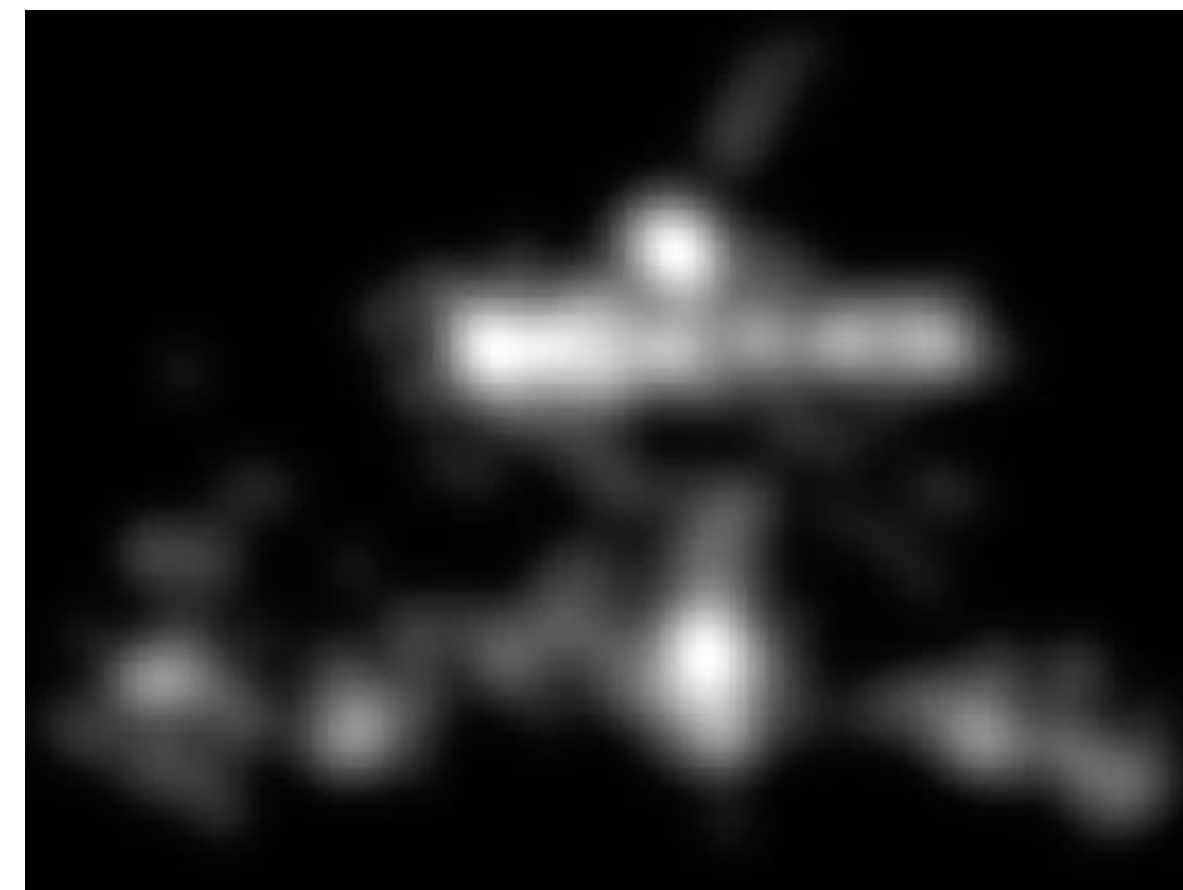
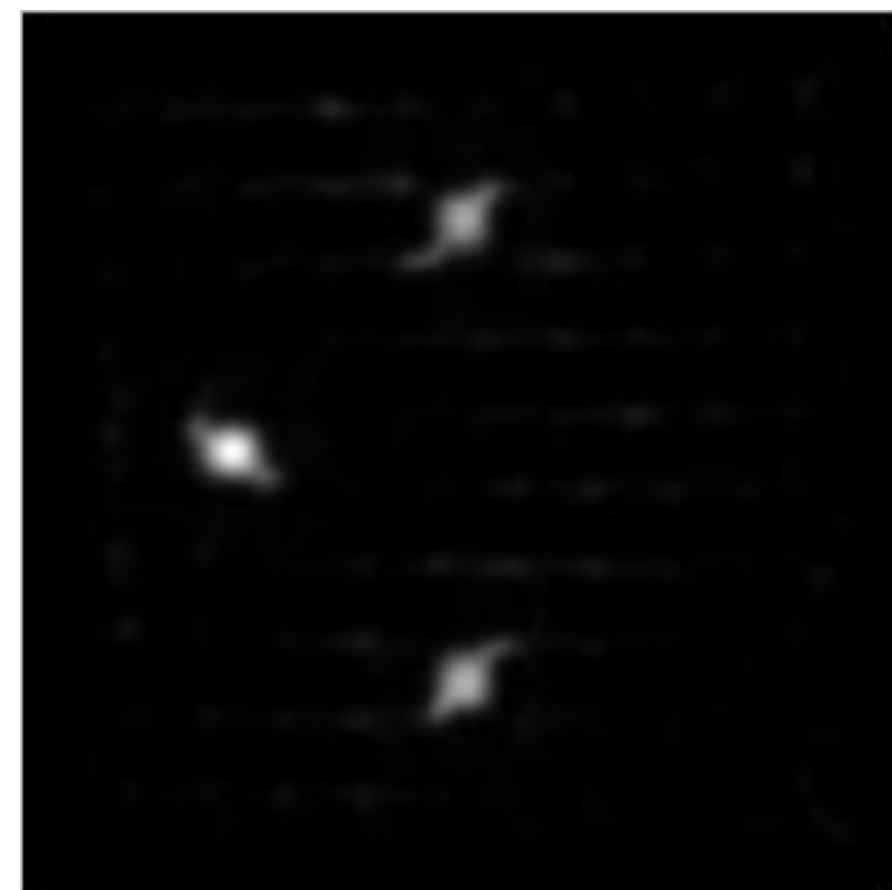
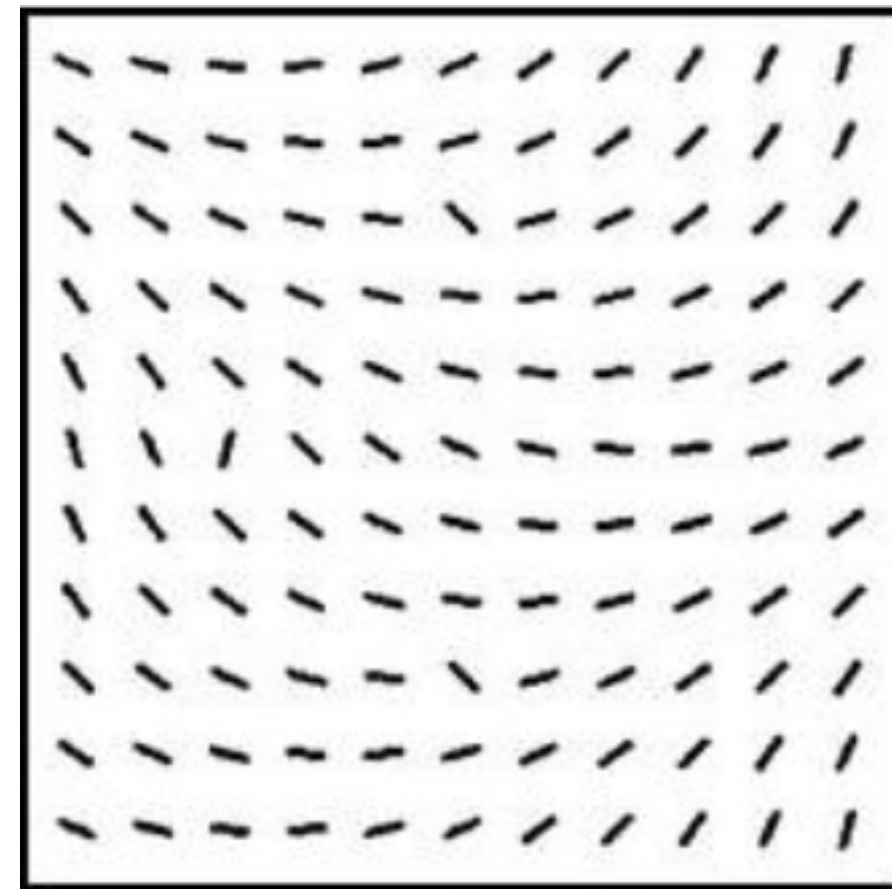
SALIENCY: BOTTOM-UP OR TOP-DOWN?



SALIENCY: BOTTOM-UP OR TOP-DOWN?

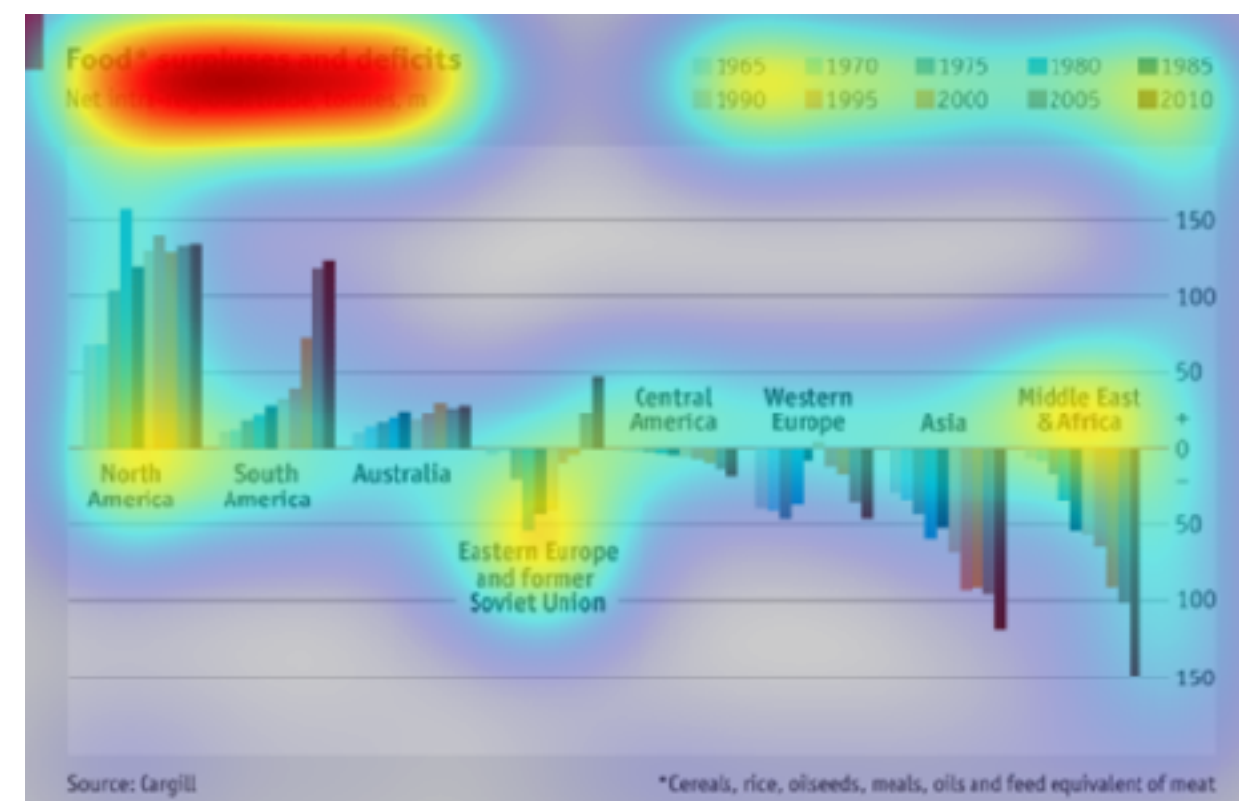


SALIENCY: BOTTOM-UP OR TOP-DOWN?

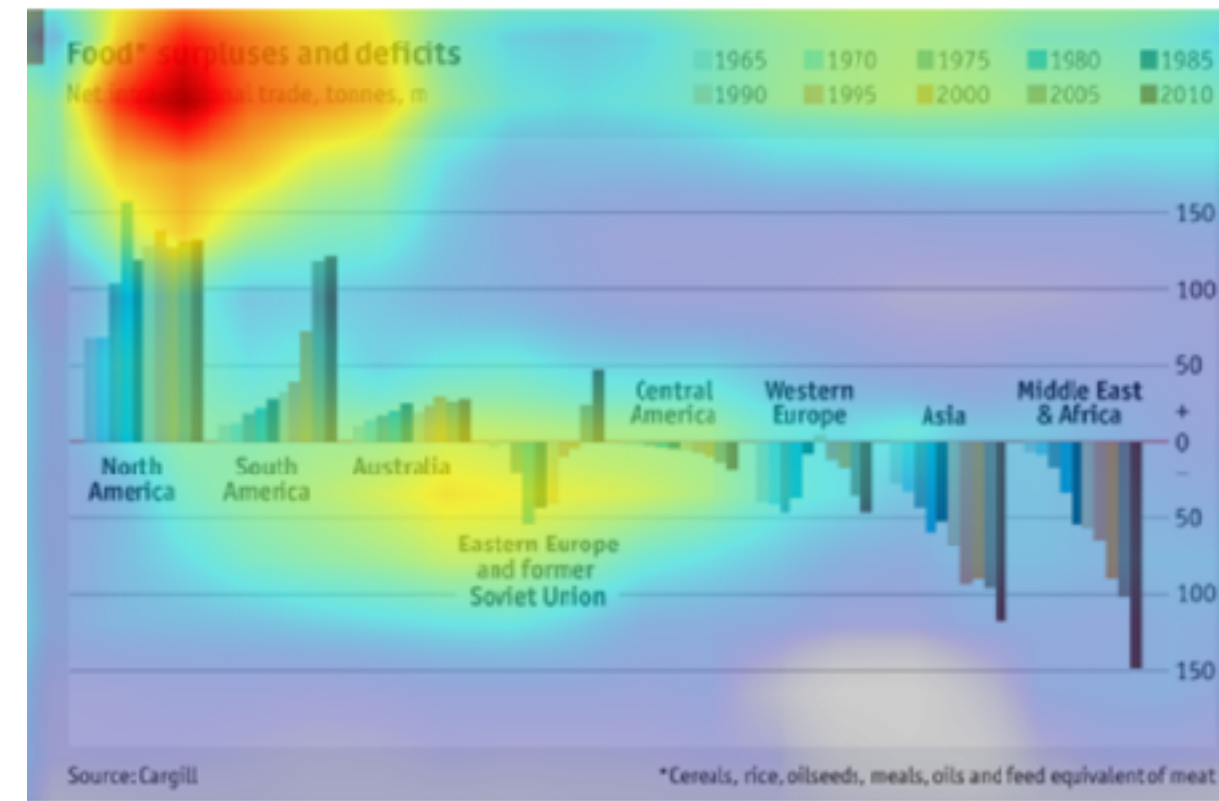


SALIENCY IS NOT ENOUGH

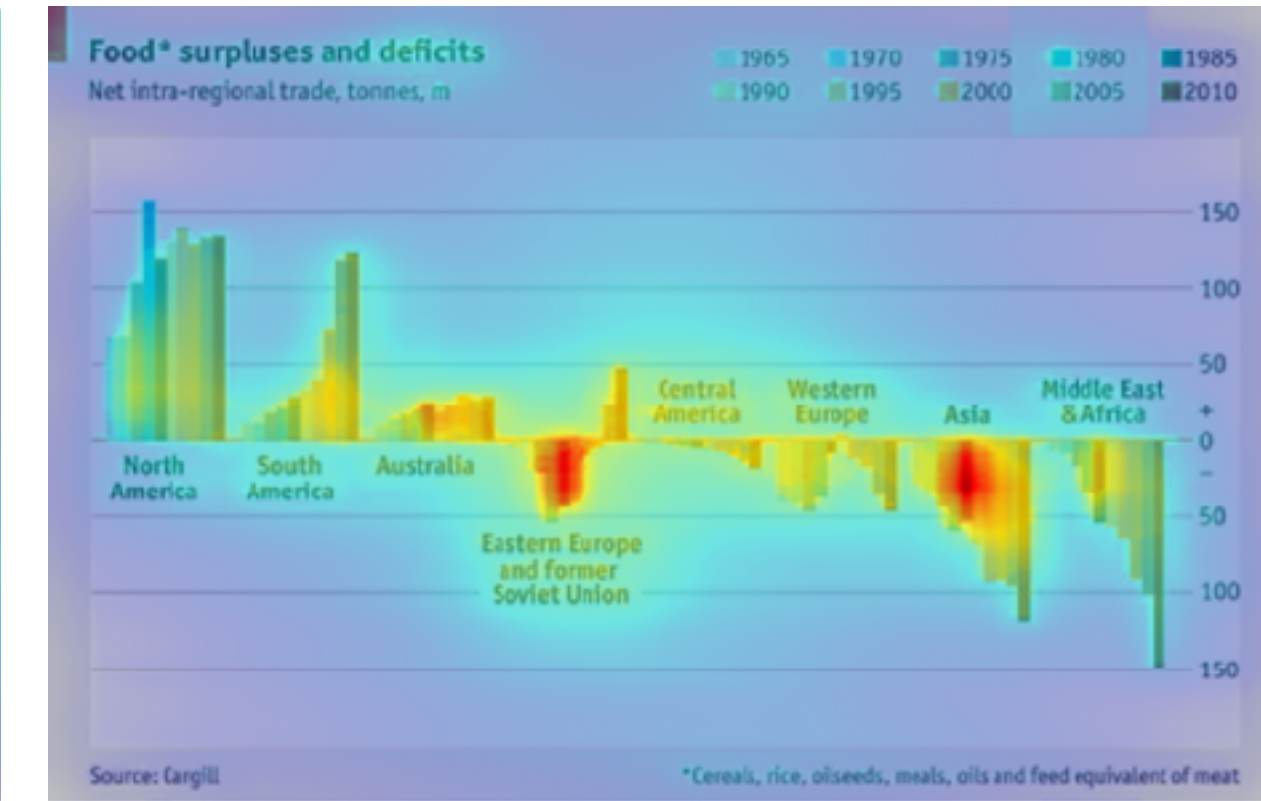
Ground truth



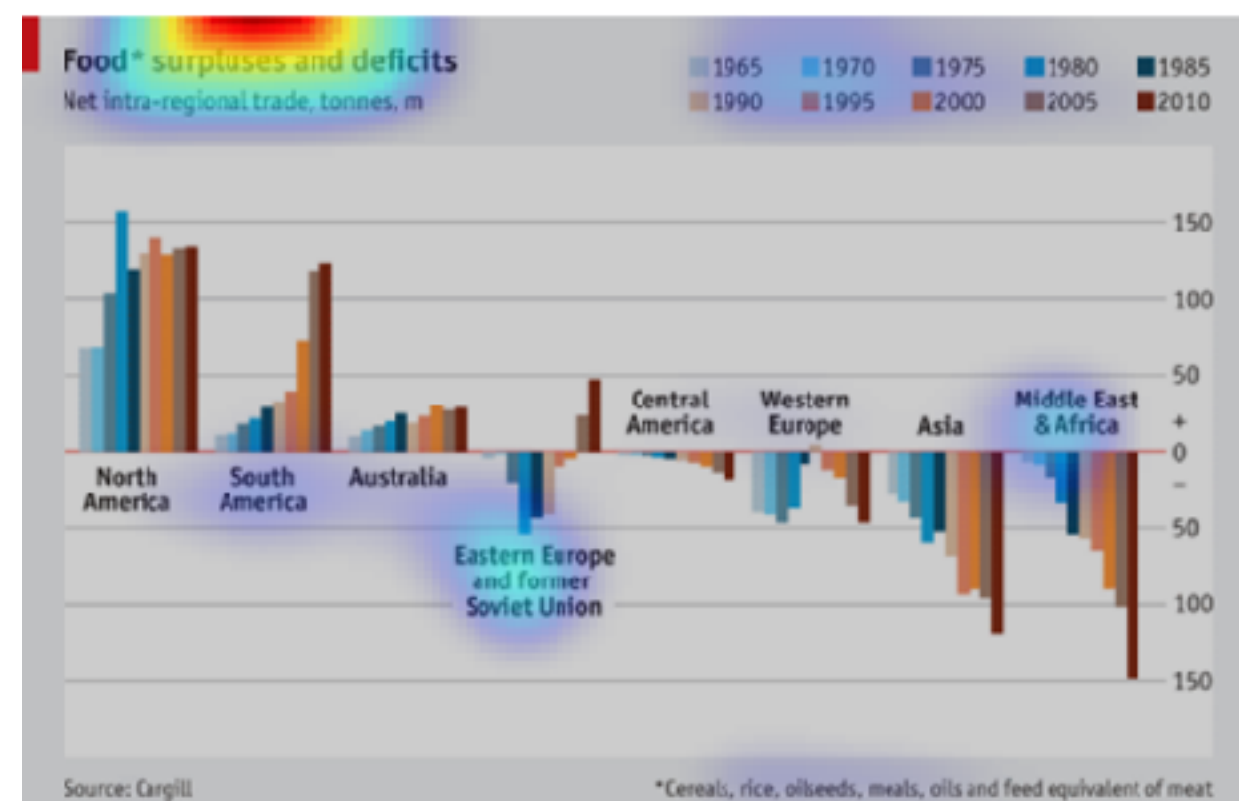
Our model



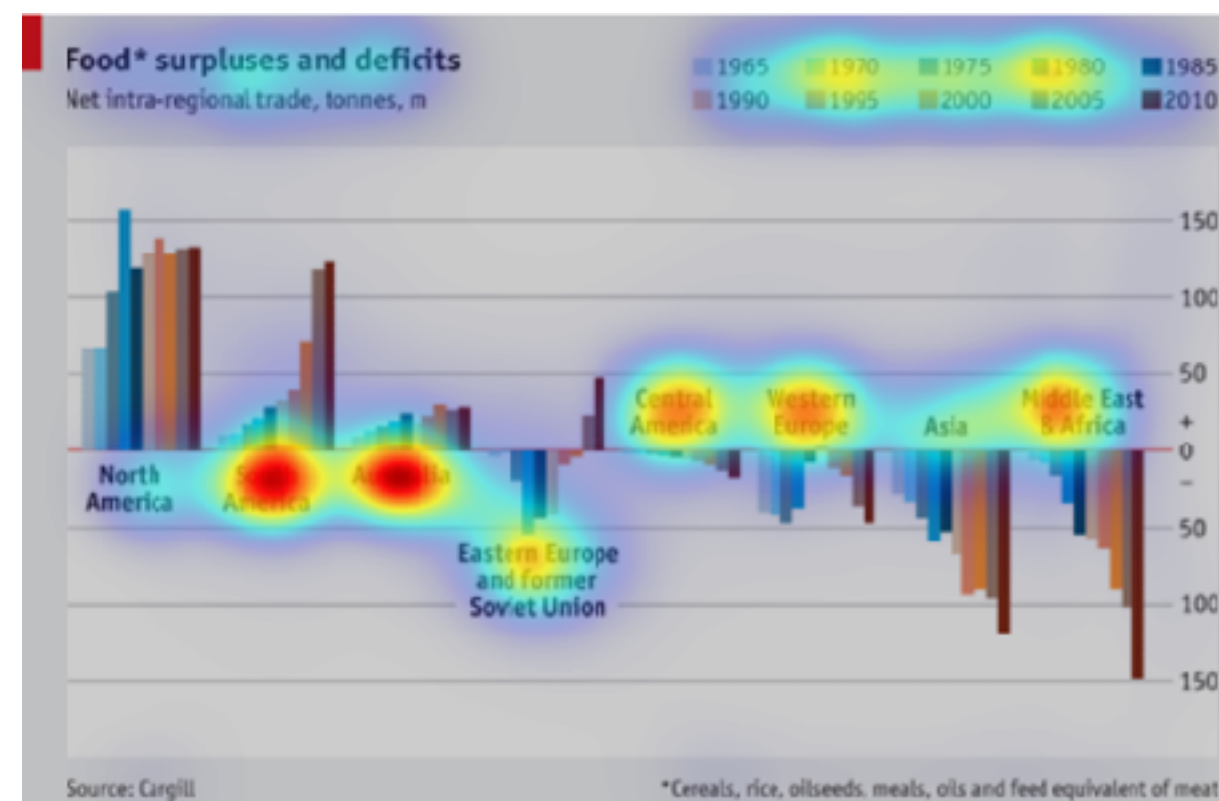
Judd



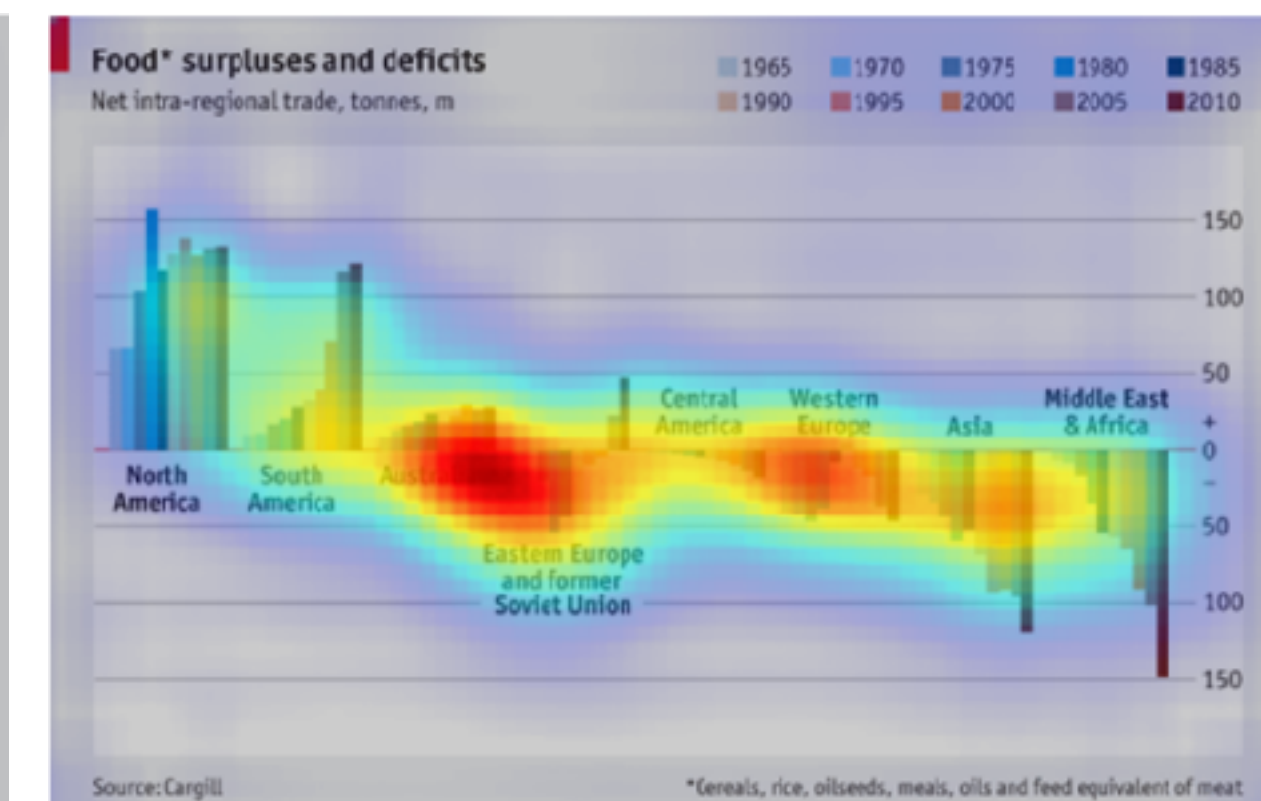
DeepGaze



SalNet



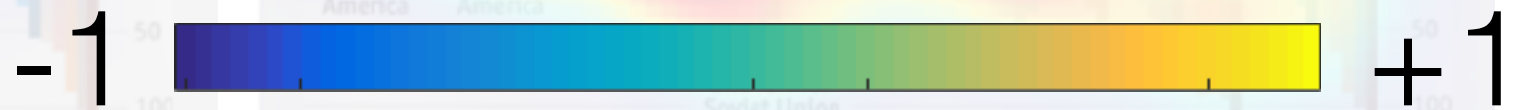
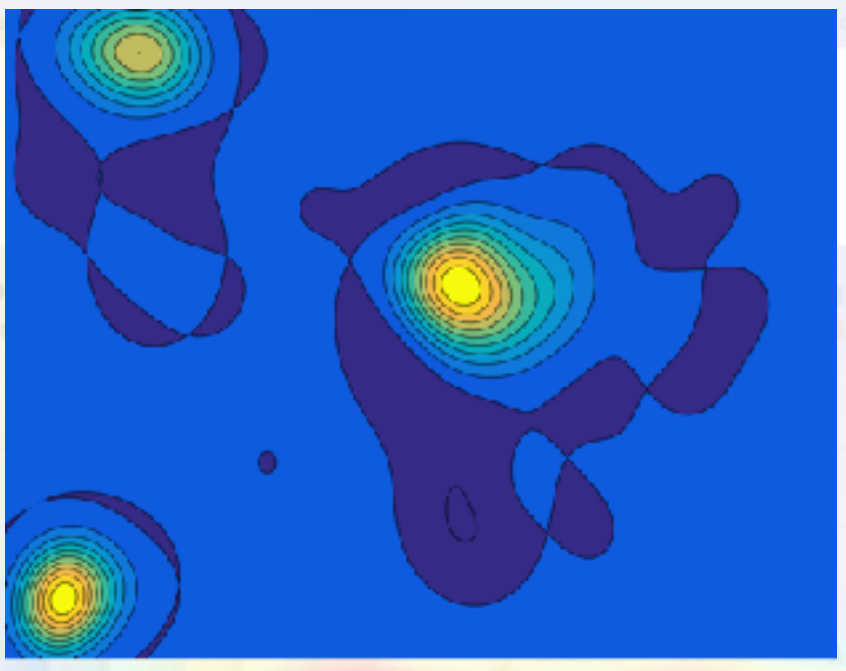
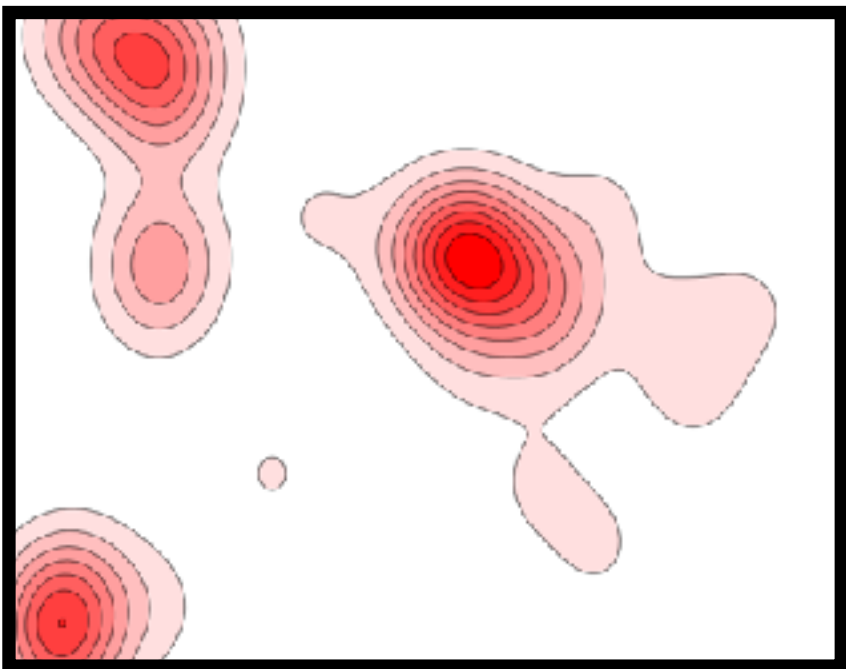
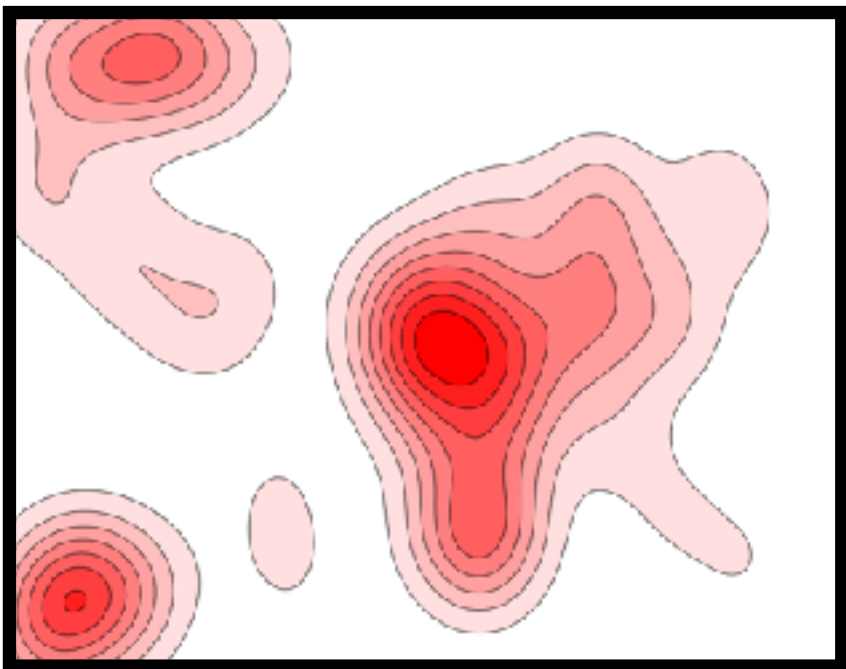
SALICON



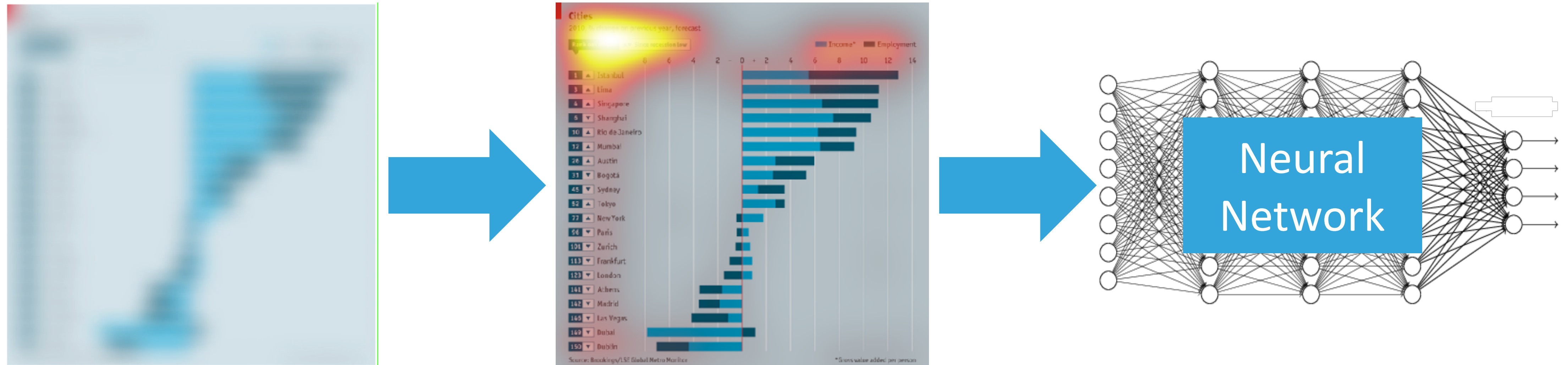
SALIENCY IS NOT ENOUGH

Pearson's Correlation Coefficient (CC) Metric

	CC↑
Judd	0.11
SalNet	0.24
SALICON	0.54
DeepGaze2	0.54
DeepGaze	0.57
Our model	0.69

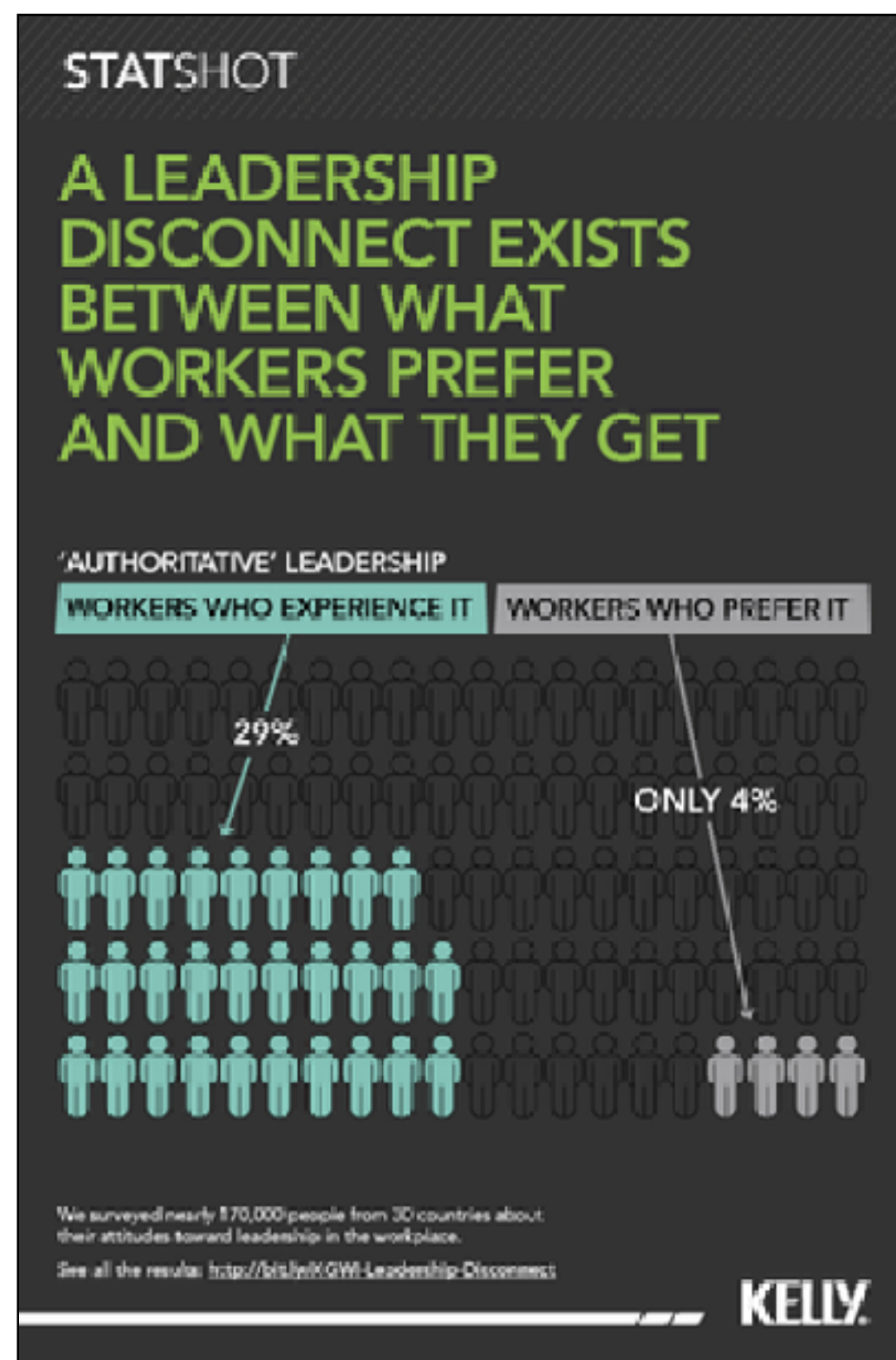


TRAINING AN ATTENTION MODEL



APPLICATION: THUMBNAILING

Input



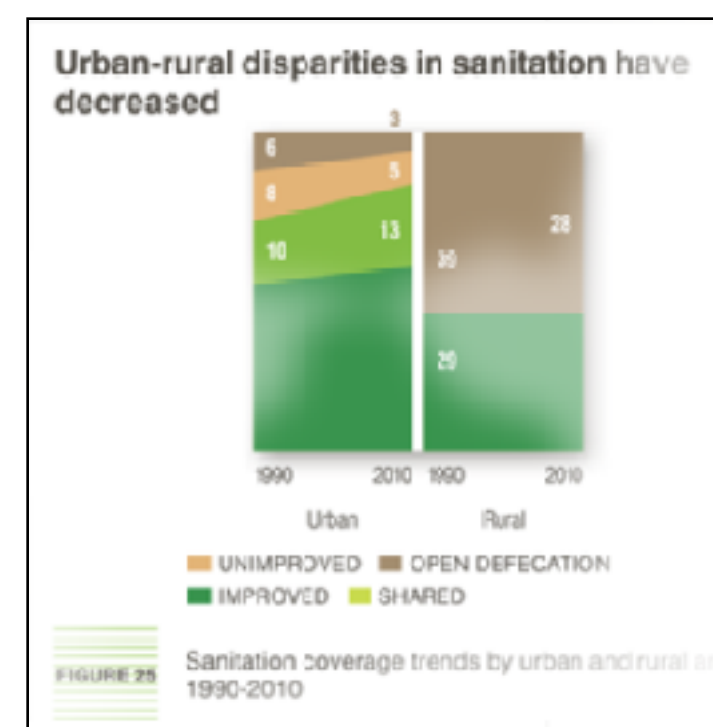
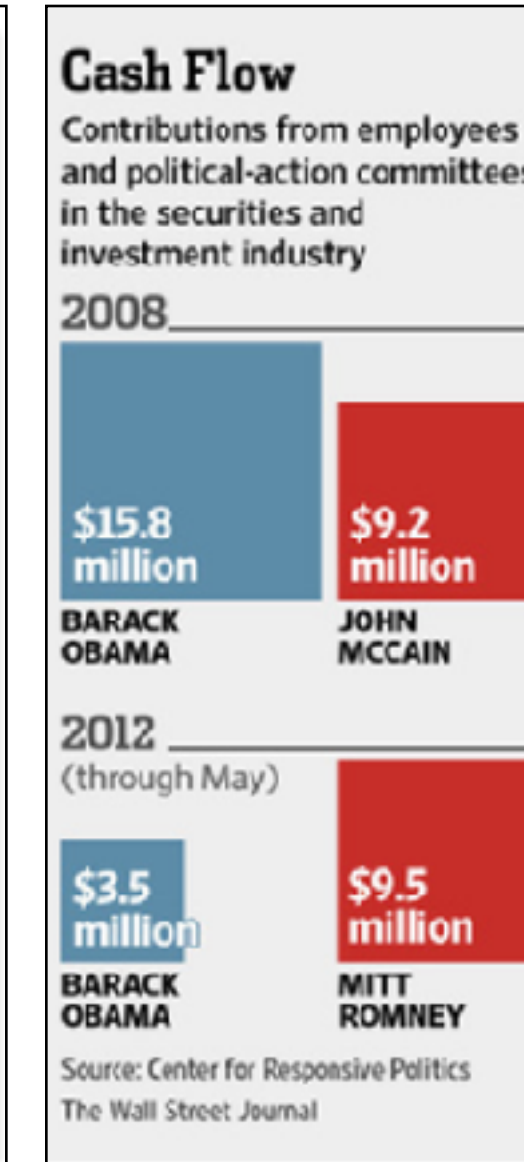
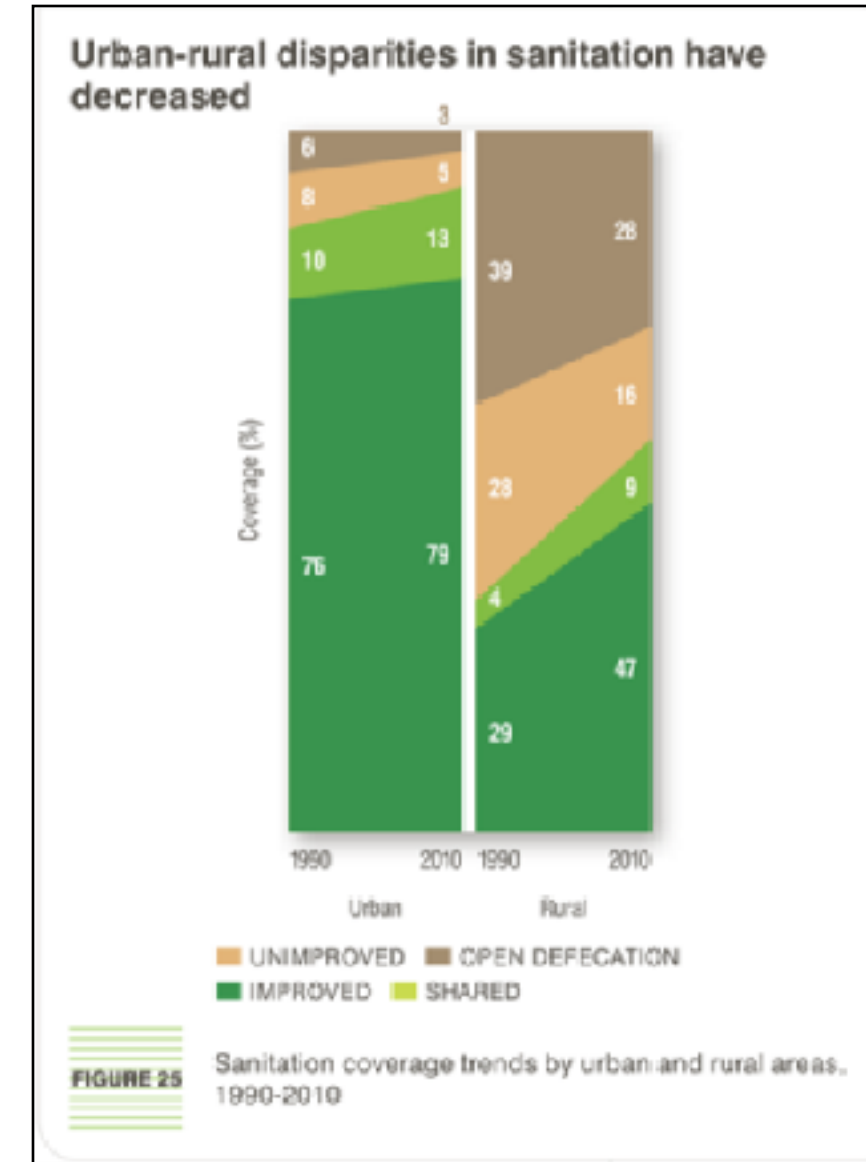
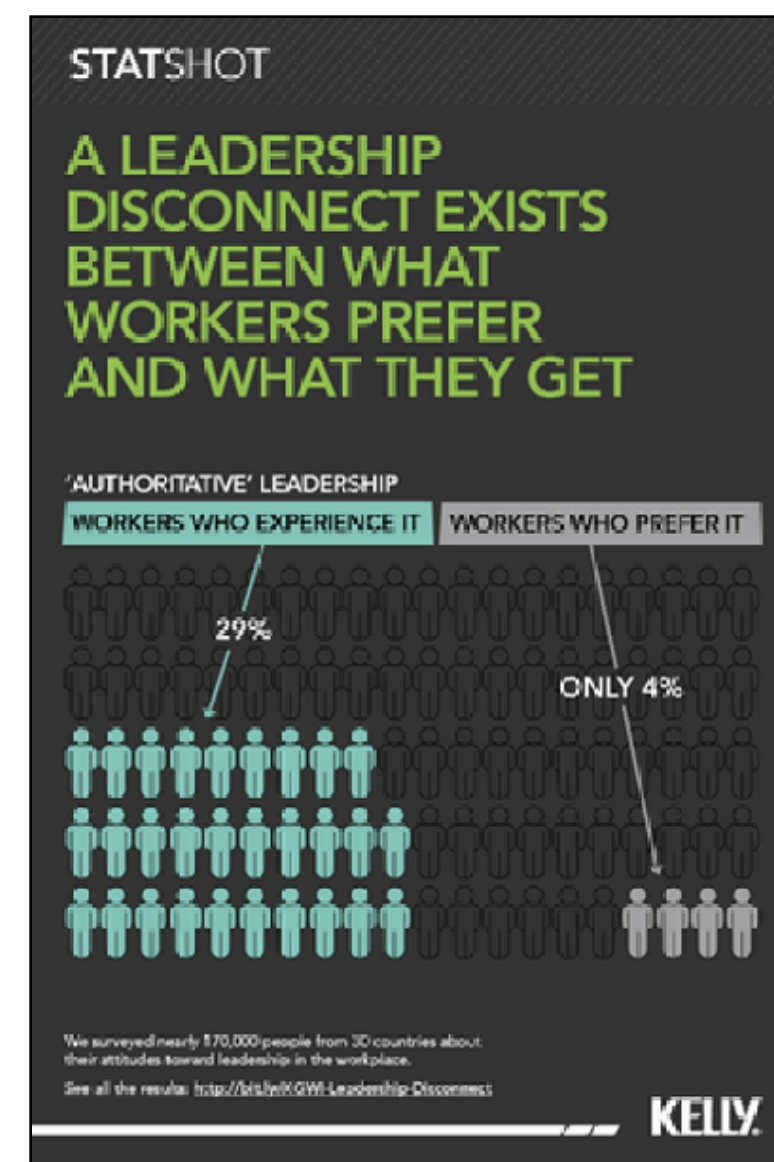
Importance heatmap



Thumbnail



APPLICATION: THUMBNAILING



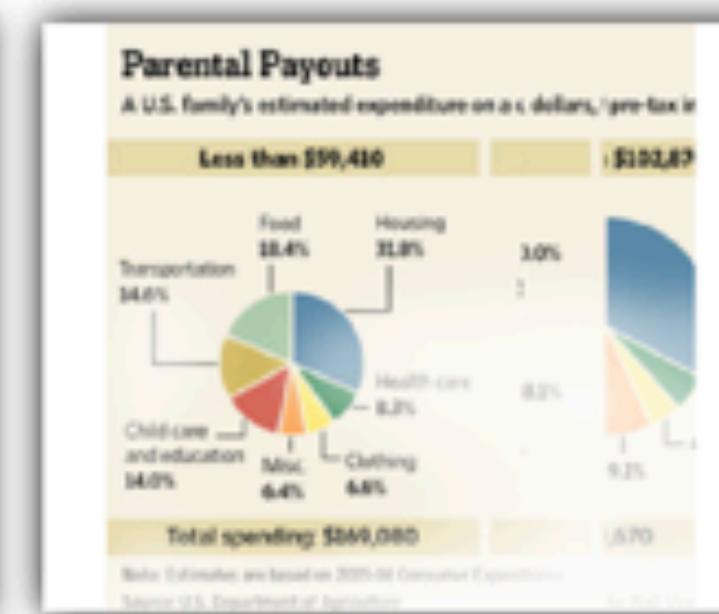
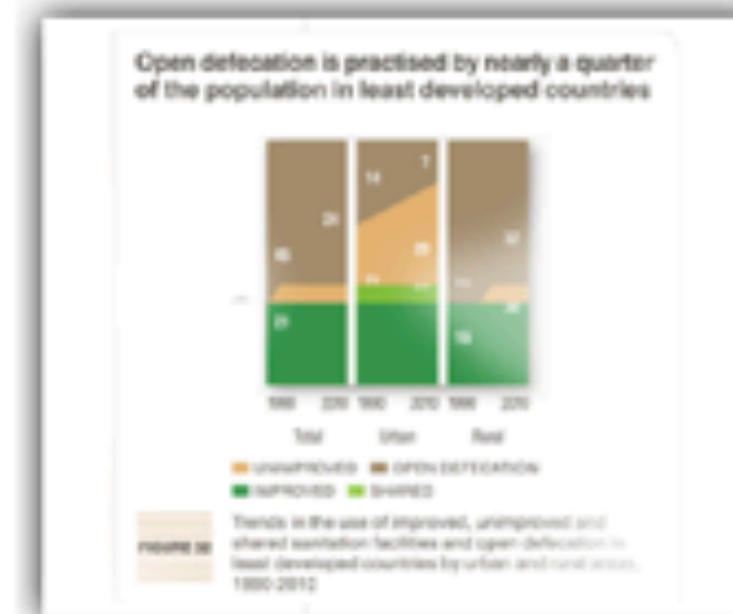
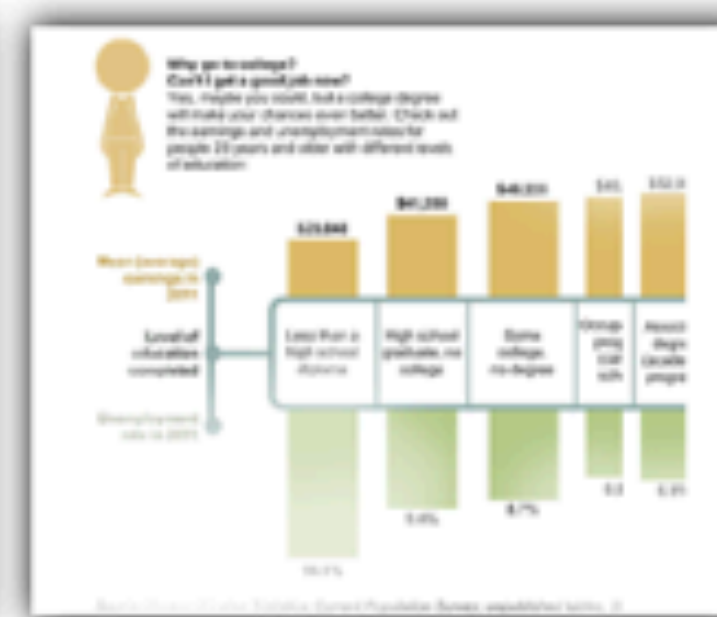
APPLICATION: THUMBAILING

Find a graphic image that matches the caption provided.

Submit

Image Caption

This graph shows that workers don't get what they prefer. There is a disconnect between leadership and workers.



APPLICATION: THUMBAILING

Find a graphic image that matches the caption provided.

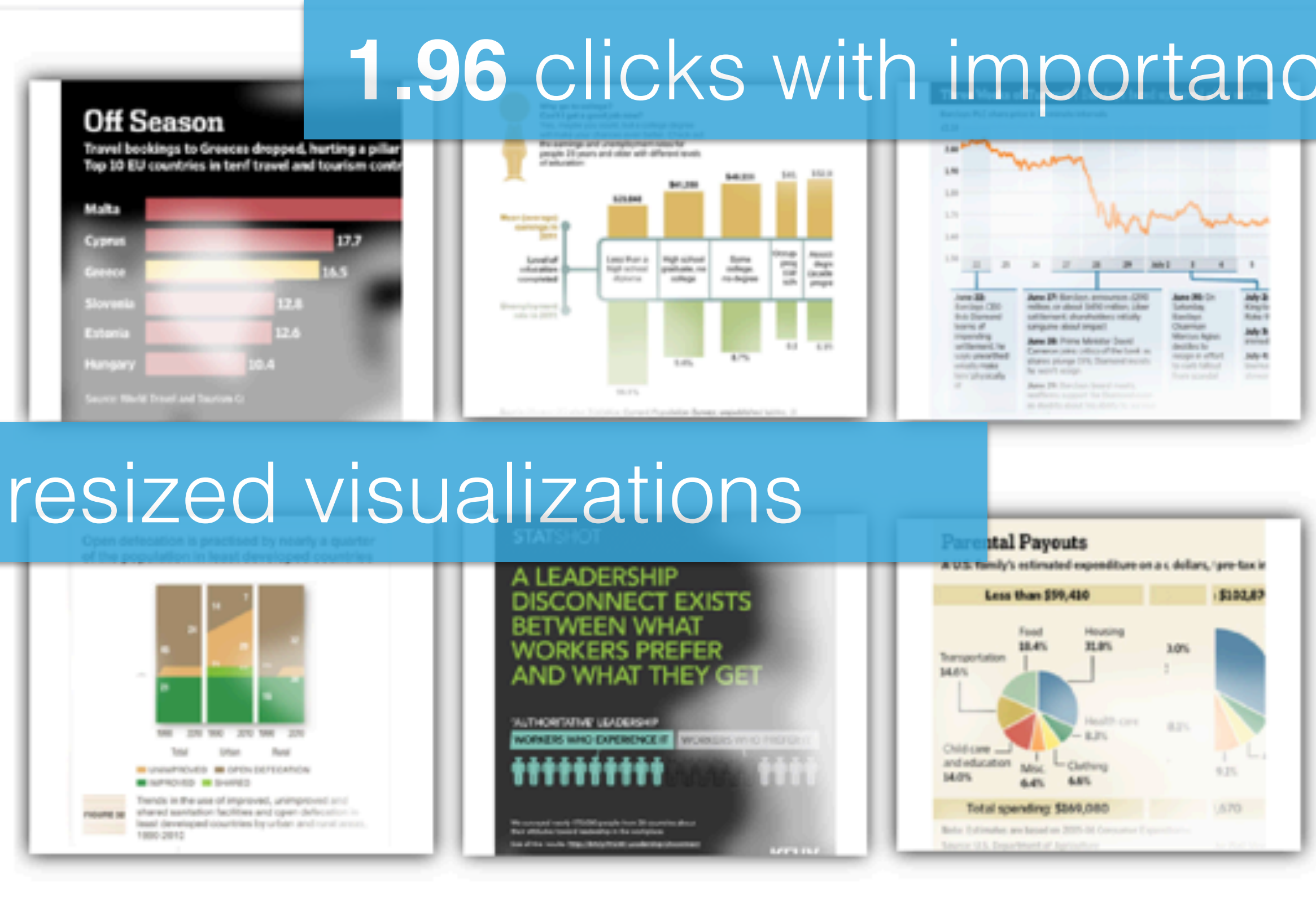
Submit

Image Caption

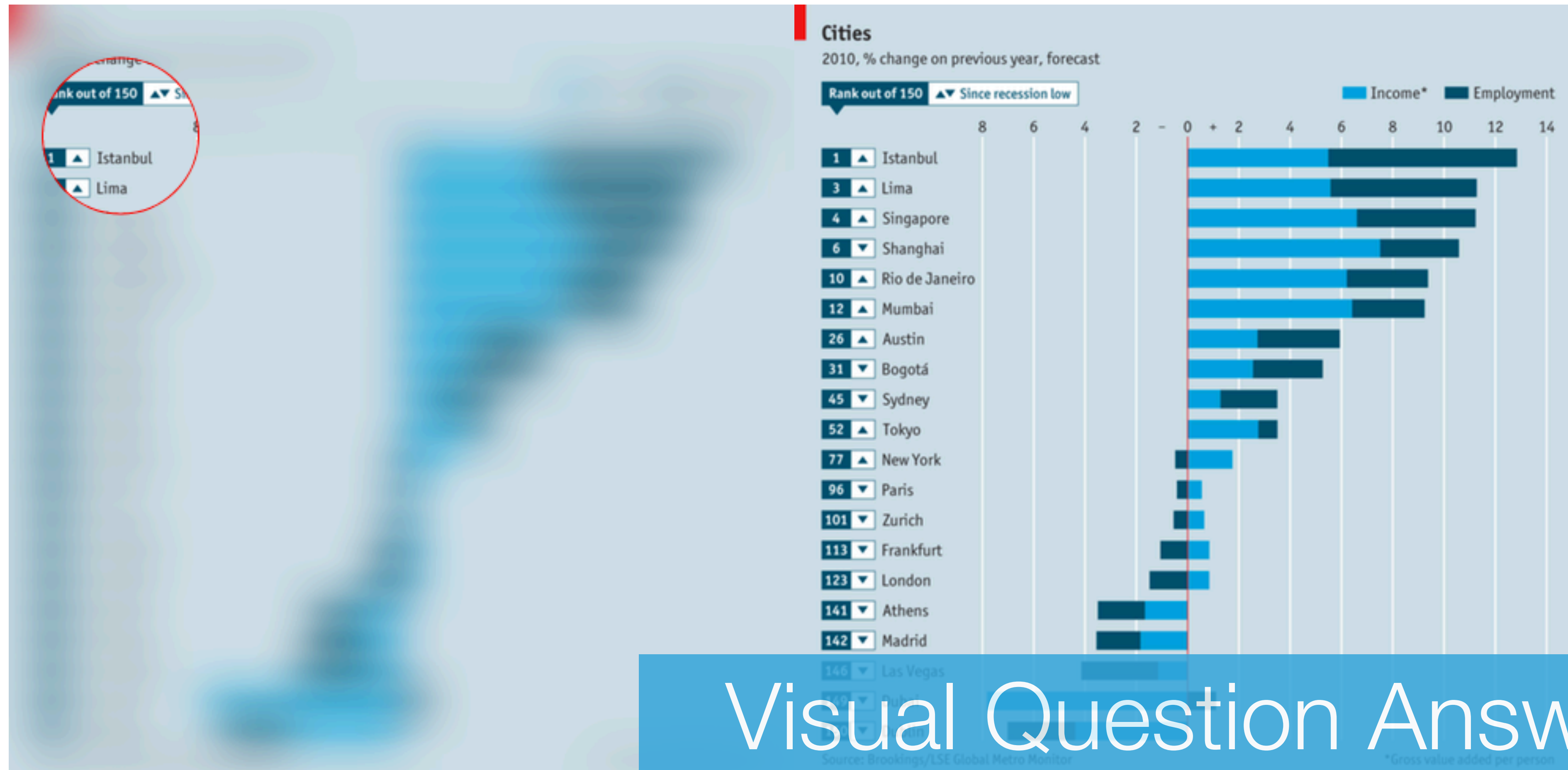
This graph shows that workers don't get what they prefer. There is a disconnect between leadership and workers.

1.96 clicks with importance-based thumbnails

3.25 clicks with resized visualizations



APPLICATION: TASK-BASED ATTENTIONAL DATA



Visual Question Answering

NEXT STEPS

- ▶ Task-based predictions
 - ▶ Description, question answering, visual search
- ▶ Personalized predictions
 - ▶ Expert versus novice
- ▶ Larger datasets & more powerful models

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