REVIEW OF CAMOUFLAGE ASSESSMENT TECHNIQUES

Lex Toet & Maarten Hogervorst

OVERVIEW

- Psychophysical evaluation methods:
  - Field vs lab studies
  - Detection and recognition range
  - Search & detection performance
  - Visual conspicuity
  - Subjective blending score
  - Ranking & paired comparison
  - Eye tracking
  - Masked priming
  - Fixation locked ERPs
- Computational evaluation methods:
  - Saliency models
  - Clutter and target signature metrics
  - Search models
- New developments and Future challenges

PSYCHOPHYSICAL EVALUATION METHODS :

FIELD VS LAB STUDIES

	Field	Lab
Nr of conditions, locations, observers	Few	Many
Control over conditions	No control	Full control
Variation in performance across conditions	Large	Small
Time required	Long	Short
Effort	Labour intensive	Easy
Logistics	Complex	Simple
Costs	High	Low

But:

lab studies require validation with field data to establish link with real-world performance.

PSYCHOPHYSICAL EVALUATION METHODS :

FIELD VS LAB STUDIES

PSYCHOPHYSICAL EVALUATION METHODS :

PHOTOSIMULATION STUDIES

- Easy to study performance of targets in different backgrounds

PSYCHOPHYSICAL EVALUATION METHODS :

DETECTION AND RECOGNITION RANGE

Field

Lab

PSYCHOPHYSICAL EVALUATION METHODS :

SEARCH & DETECTION PERFORMANCE

Field trial

Lab experiment

PSYCHOPHYSICAL EVALUATION METHODS :

SEARCH & DETECTION PERFORMANCE

Field trial

Lab experiment

PSYCHOPHYSICAL EVALUATION METHODS :

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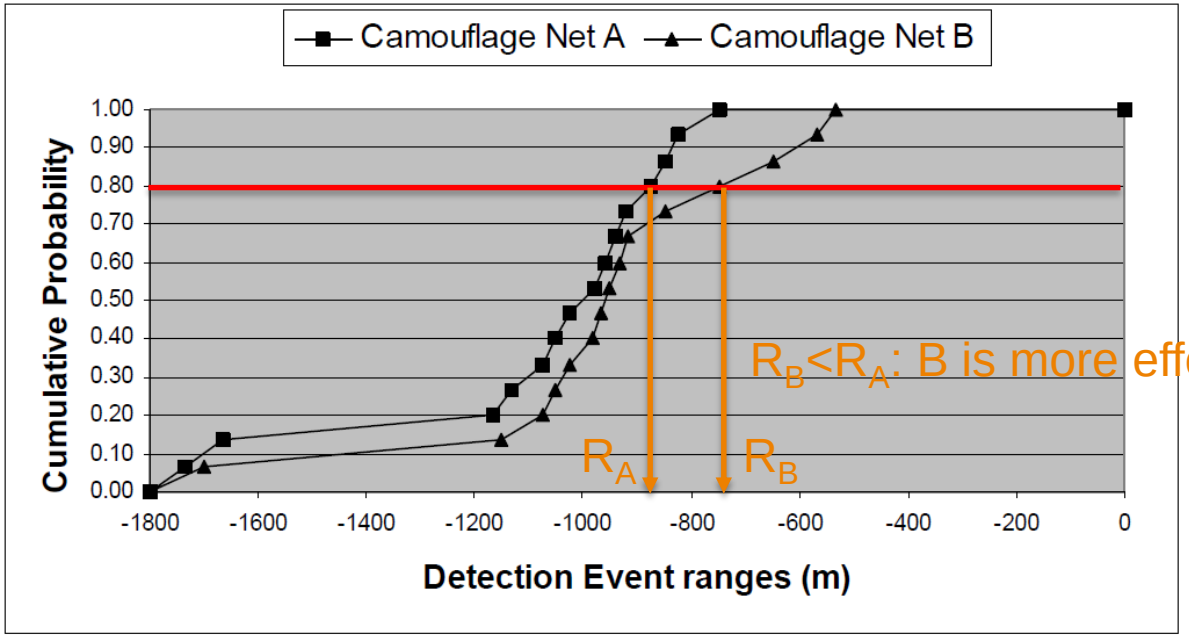
Field trial

Lab experiment

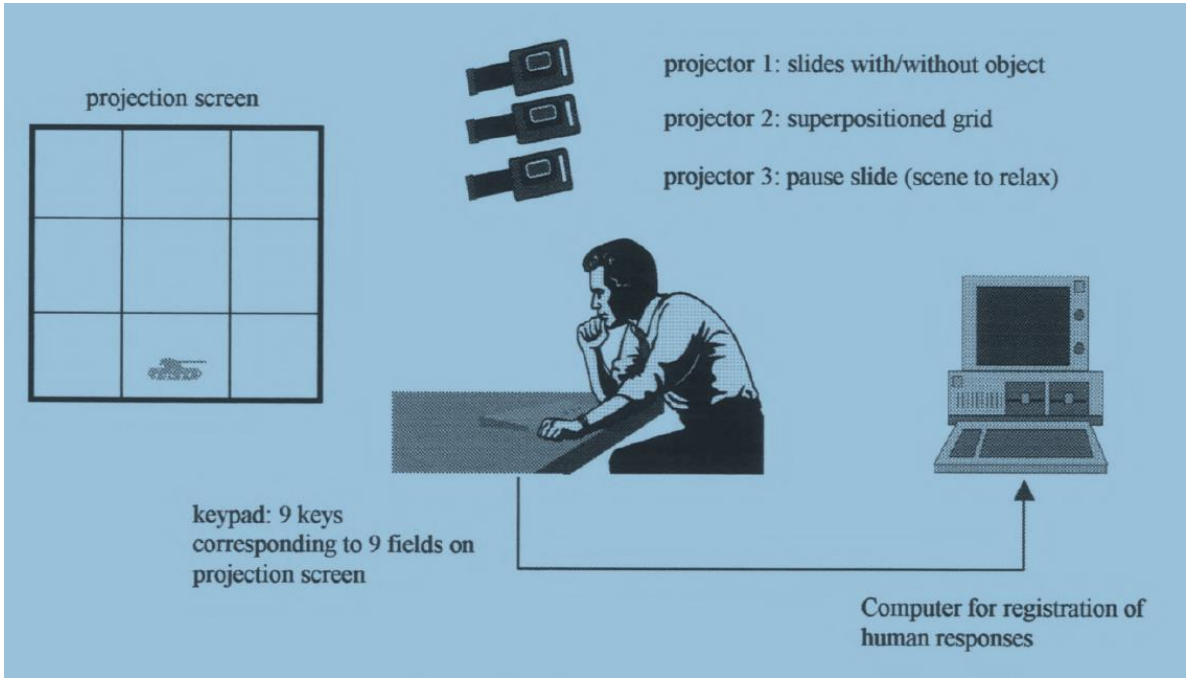
PSYCHOPHYSICAL EVALUATION METHODS :

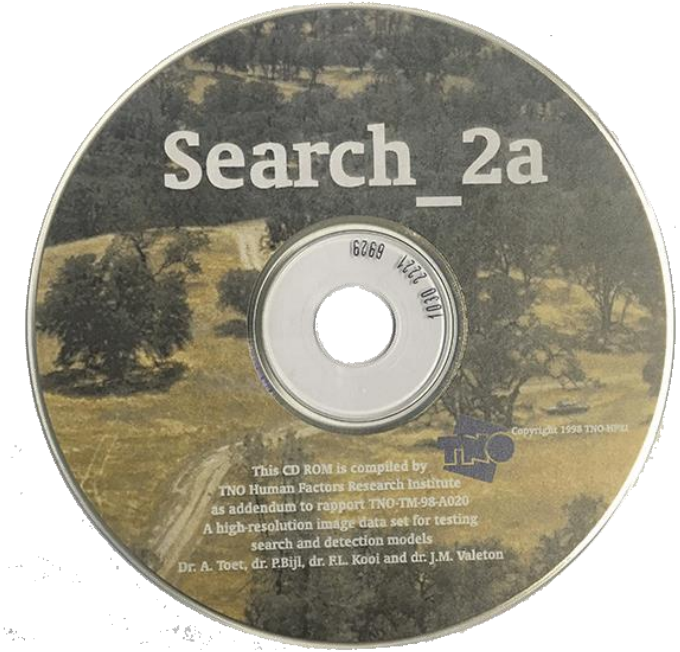
DETECTION AND RECOGNITION RANGE



PSYCHOPHYSICAL EVALUATION METHODS :

SEARCH & DETECTION





PSYCHOPHYSICAL EVALUATION METHODS :

SEARCH & DETECTION PERFORMANCE

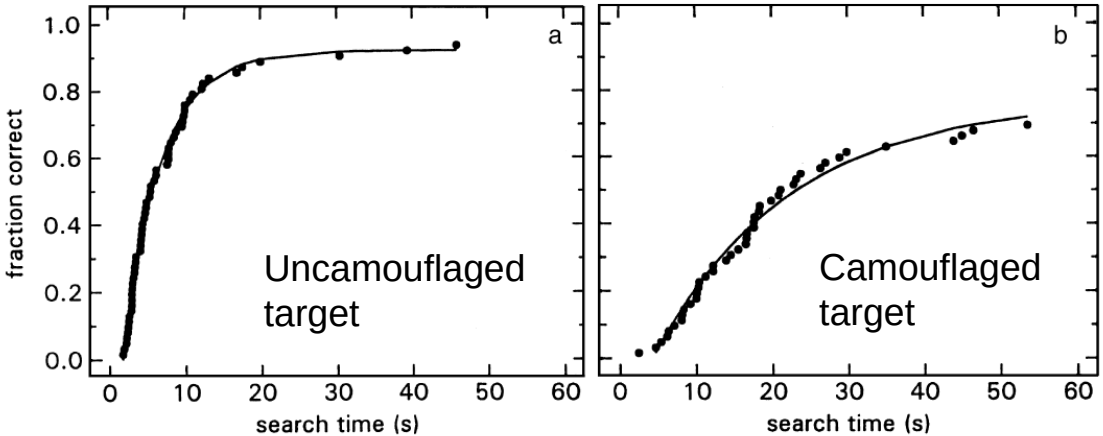
- Performance metrics:
  - Mean search time
  - Detection probability

$$P_d(t) = P_\infty \left[1 - e^{-(t - t_r)/\tau} \right]$$

P_∞ = prob. to find target given unlimited time

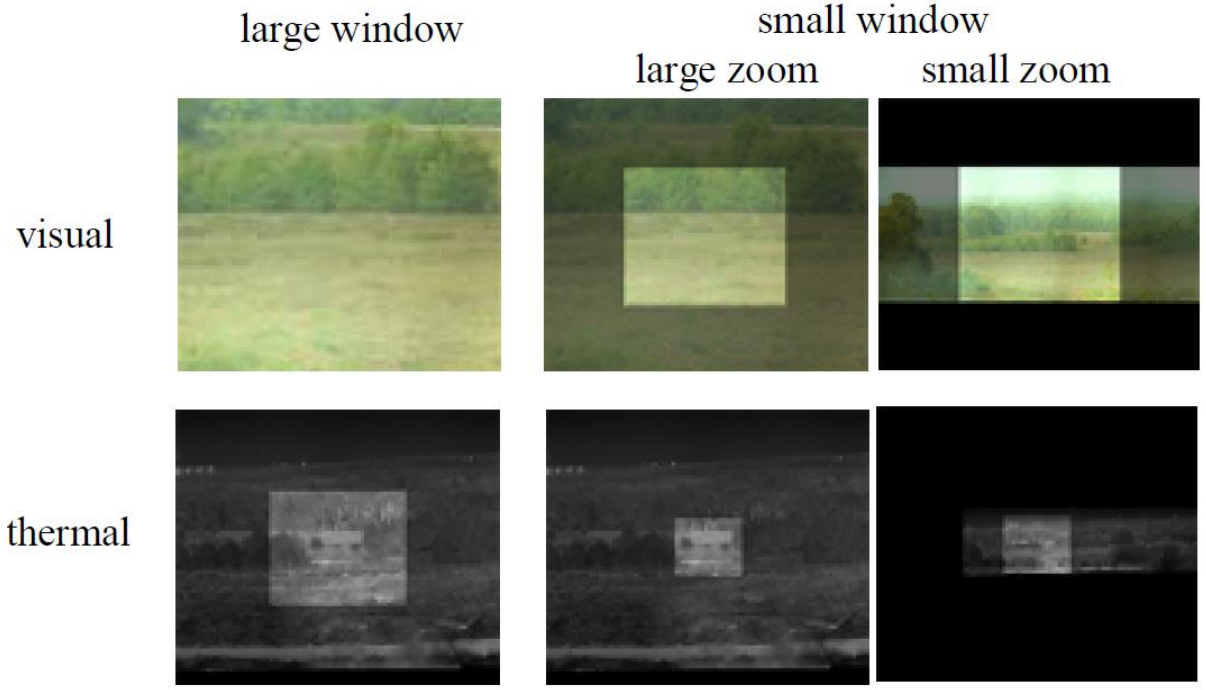
t_r = minimal response time

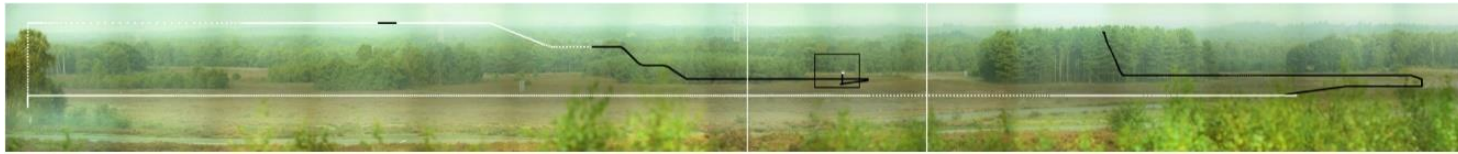
τ = mean search time



PSYCHOPHYSICAL EVALUATION METHODS :

FOV SEARCH ON PANORAMIC IMAGES

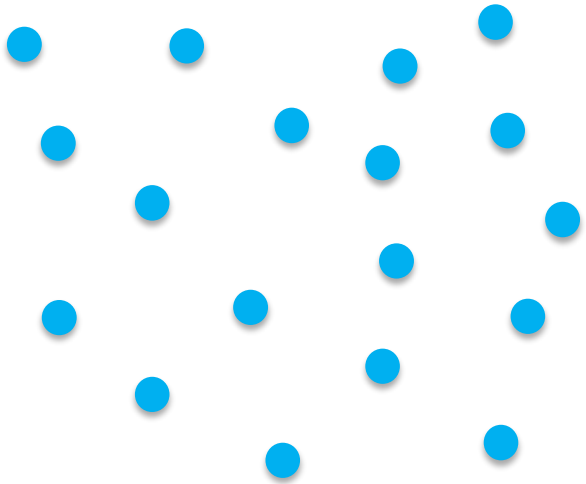




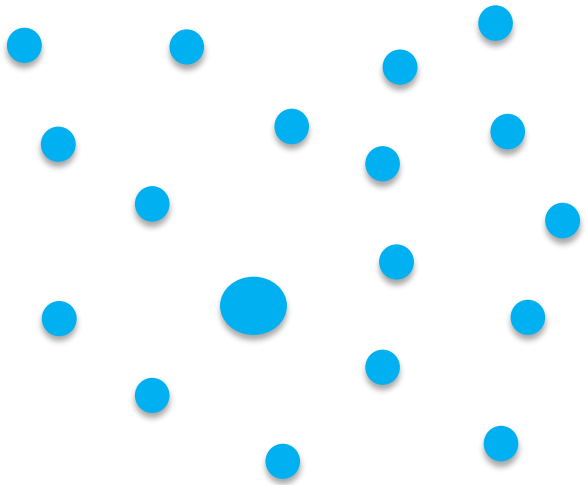
PSYCHOPHYSICAL EVALUATION METHODS :

VISUAL CONSPICUITY

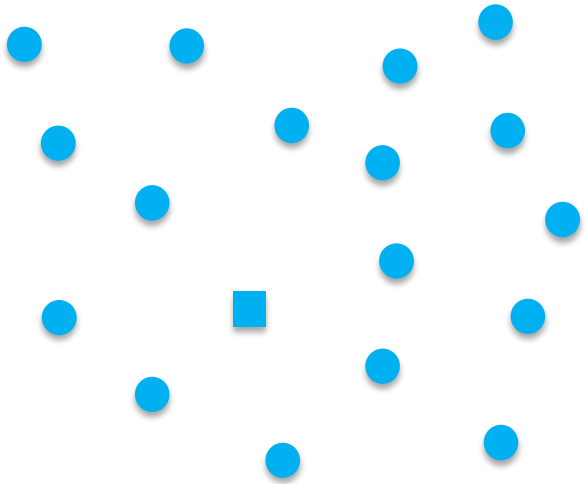
VISUAL CONSPICUITY



VISUAL CONSPICUITY



VISUAL CONSPICUITY



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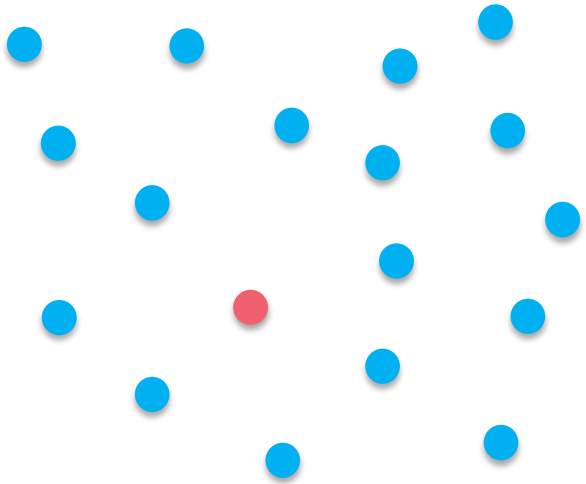

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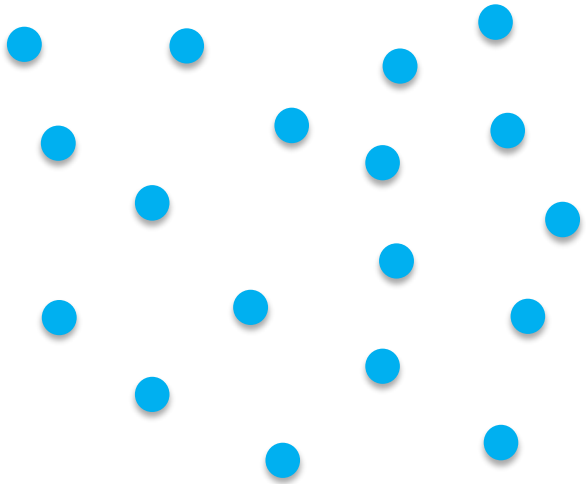

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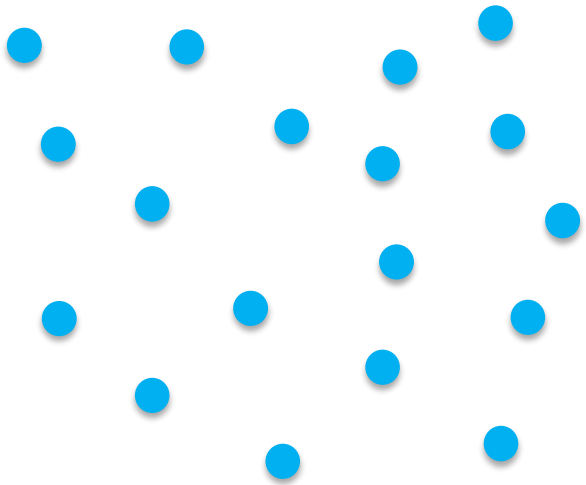

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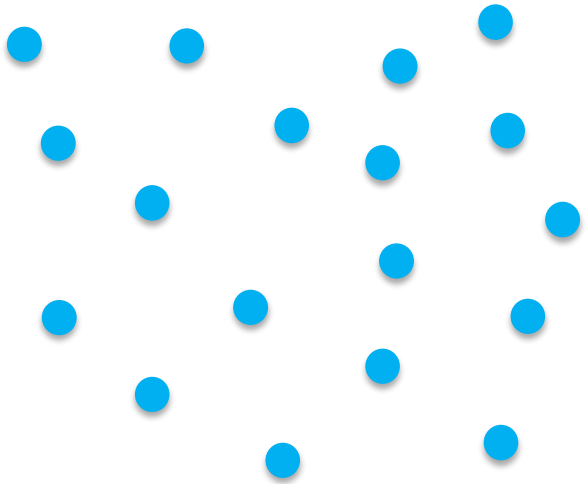

VISUAL CONSPICUITY

MOTION BREAKS CAMOUFLAGE

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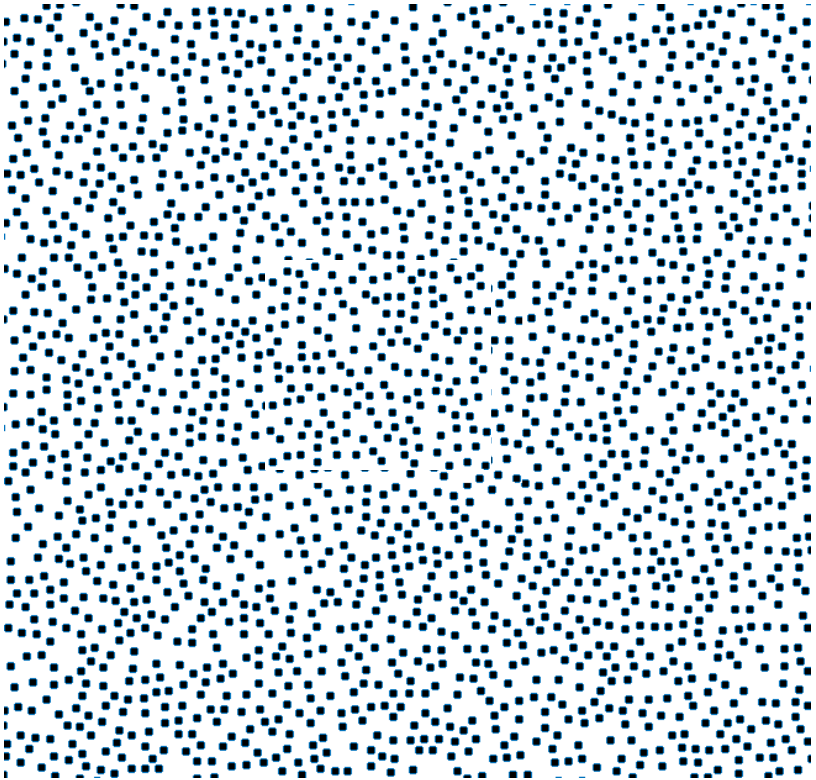

VISUAL CONSPICUITY MEASUREMENT

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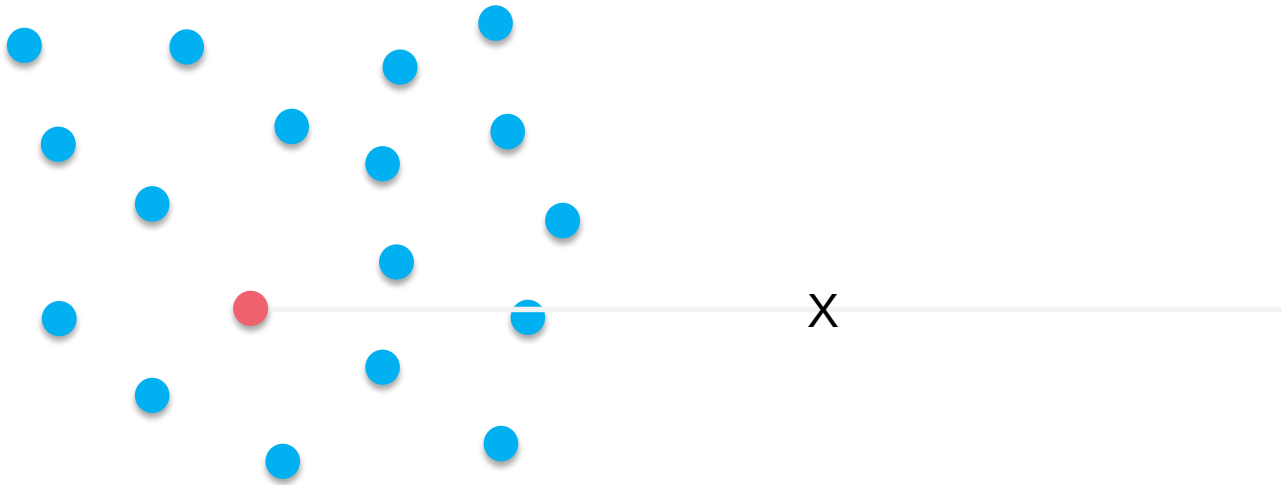

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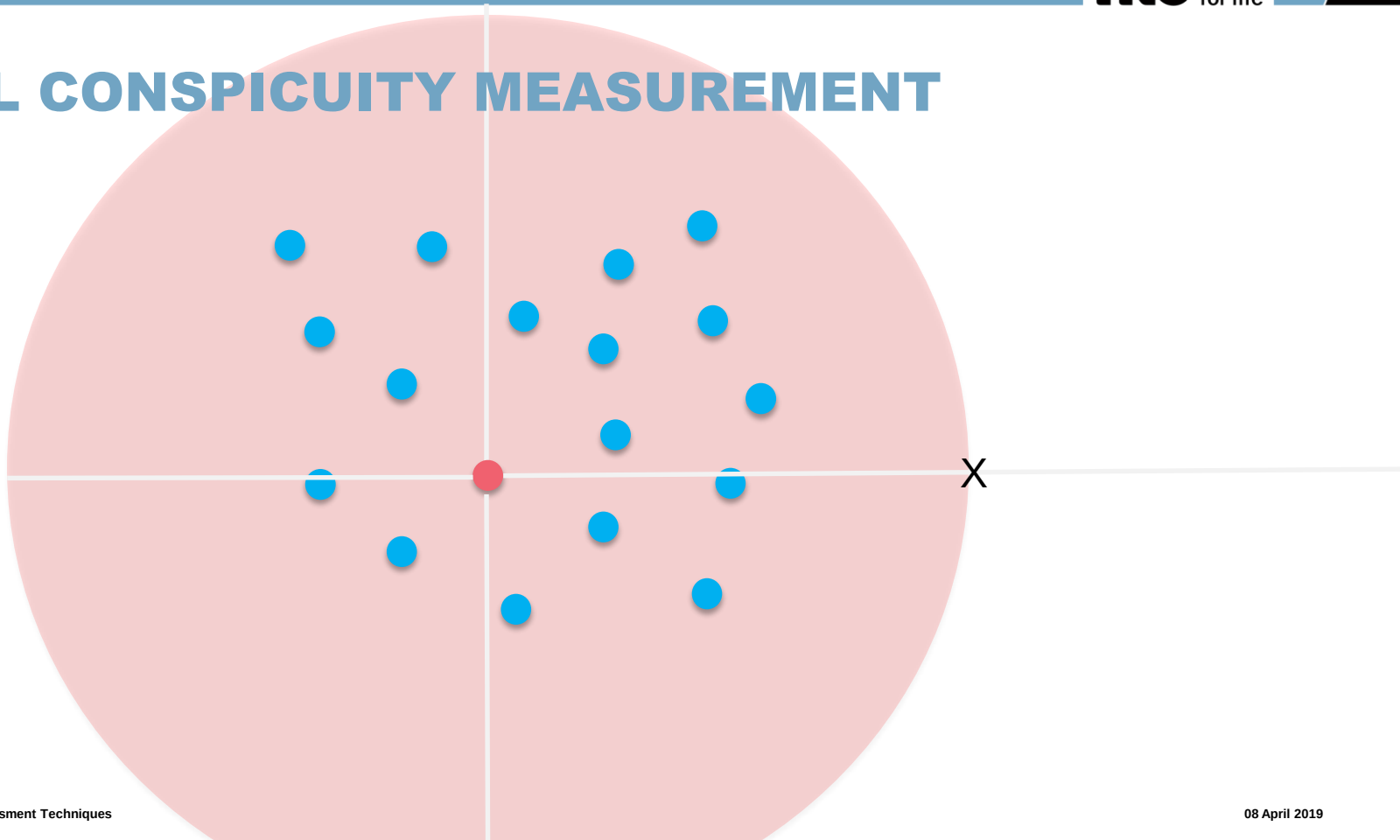

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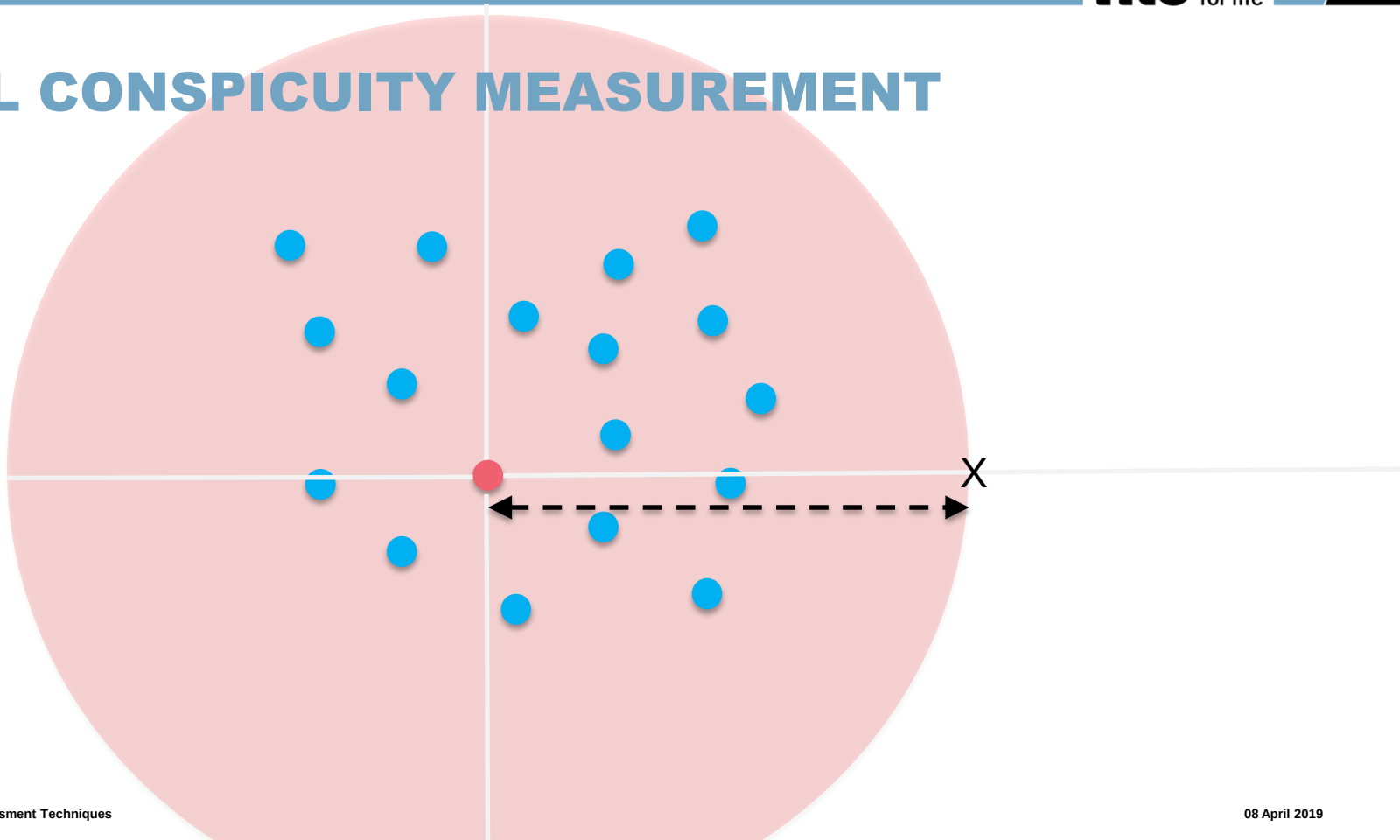
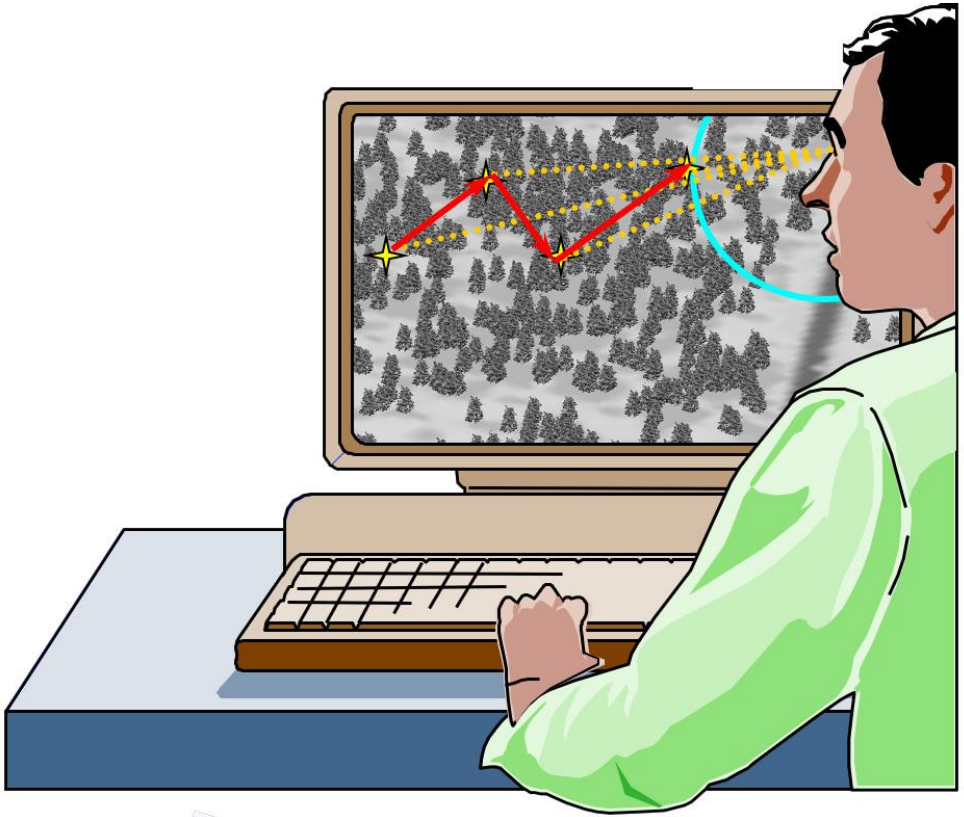
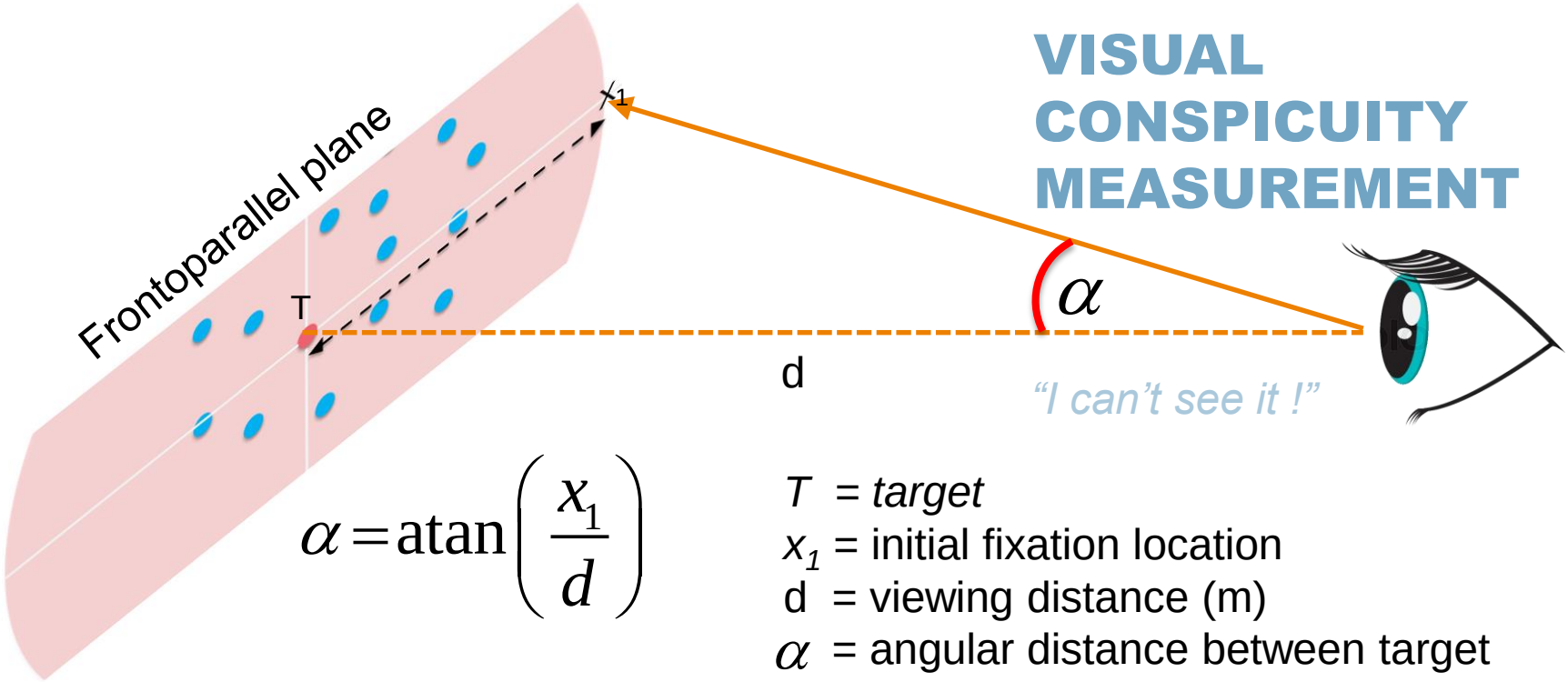


VISUAL CONSPICUITY MEASUREMENT



VISUAL CONSPICUITY MEASUREMENT

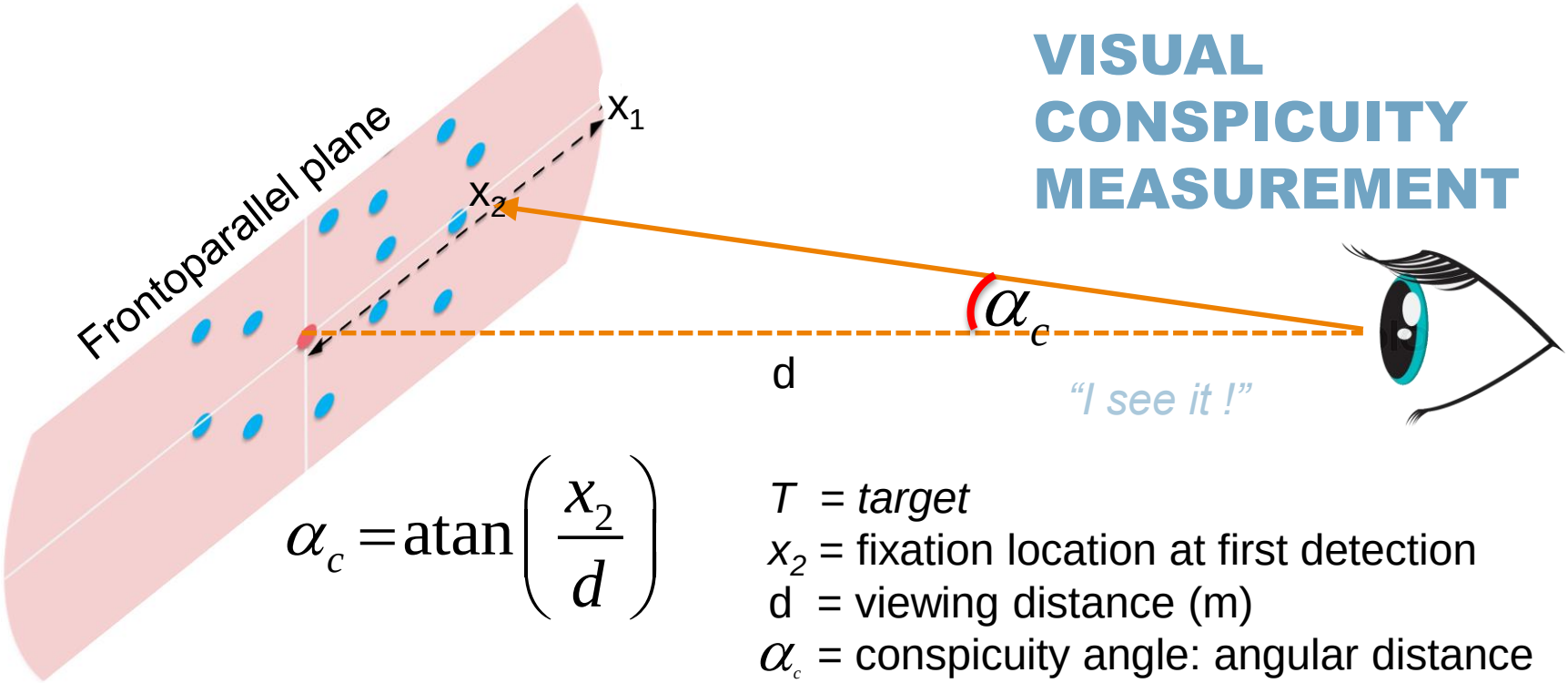


$$\alpha = \text{atan}\left(\frac{x_1}{d}\right)$$

α in deg

T = *target*
x_1 = initial fixation location
d = viewing distance (m)
α = angular distance between target and fixation (deg)

VISUAL CONSPICUITY MEASUREMENT



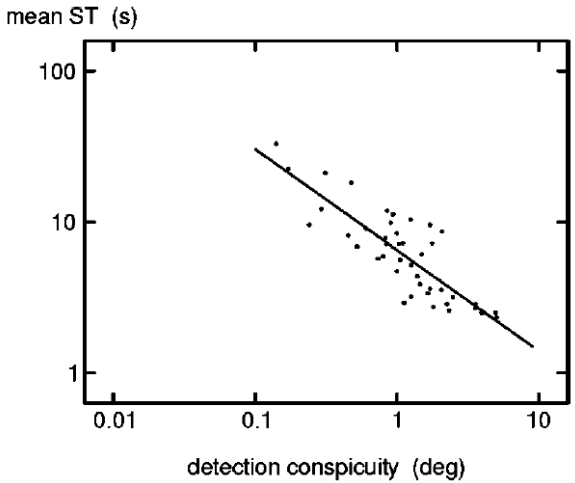
$$\alpha_c = \text{atan}\left(\frac{x_2}{d}\right)$$

α in deg

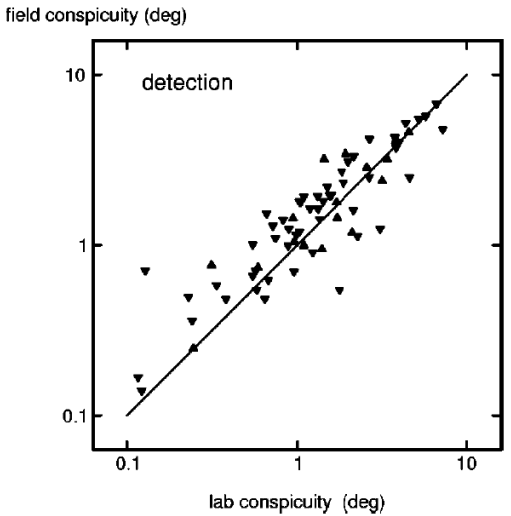
T = *target*
x_2 = fixation location at first detection
d = viewing distance (m)
α_c = conspicuity angle: angular distance between target and fixation at first detection (deg)

VISUAL CONSPICUITY MEASUREMENT

Conspicuity determines mean search time



Conspicuity measured in the lab (photosimulation) correlates with conspicuity measured in the field



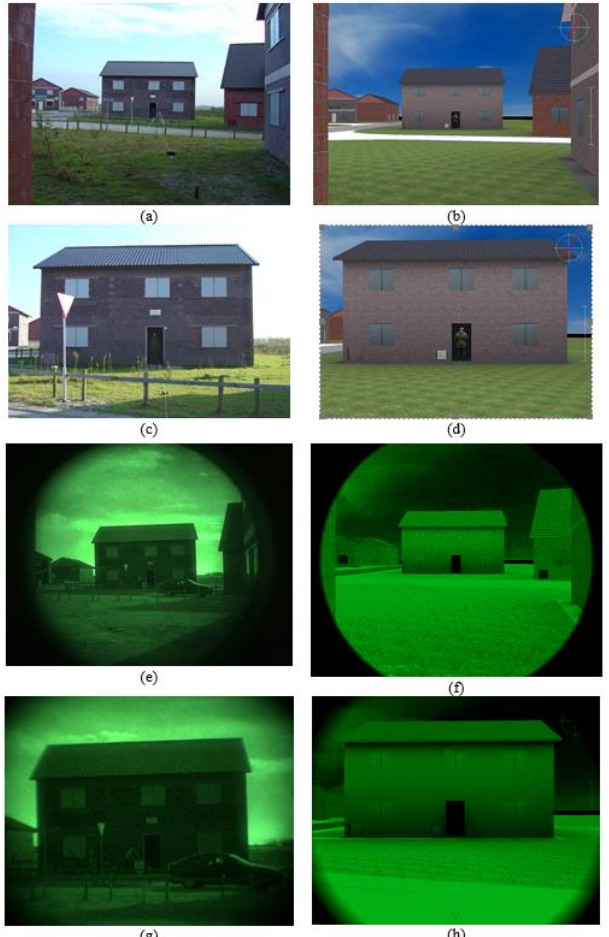
VISUAL CONSPICUITY MEASUREMENT

Field

Lab

VISUAL CONSPICUITY:

SIMULATOR CALIBRATION



PSYCHOPHYSICAL EVALUATION METHODS :

SUBJECTIVE BLENDING SCORE

- Subjective rating how well target matches background
- Can be done in the field and lab
- Easy and efficient

PSYCHOPHYSICAL EVALUATION METHODS :

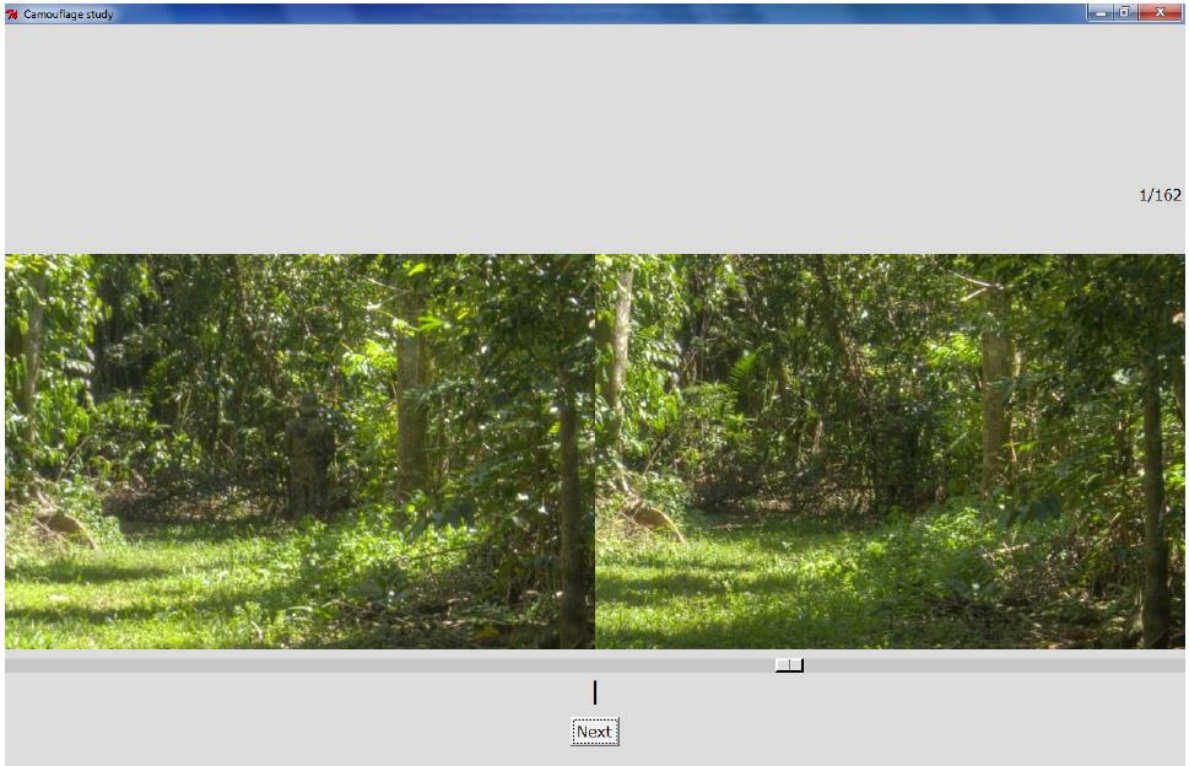
RANKING & PAIRED COMPARISON

- Ranking targets in printed images from lowest to highest conspicuity

PSYCHOPHYSICAL EVALUATION METHODS :

RANKING & PAIRED COMPARISON

- Paired comparison:
  which target is most conspicuous?



PSYCHOPHYSICAL EVALUATION METHODS :

RANKING & PAIRED COMPARISON

- NATO-RTO SCI-219: Camouflage in hot humid areas
- Overall ranking from lowest to highest conspicuity

PSYCHOPHYSICAL EVALUATION METHODS :

RANKING & PAIRED COMPARISON

- NATO-RTO SCI-219: Camouflage in hot humid areas

Figure 7-16: Best (AUS1, Left) and Worst (CAN1, Right) NIR Camouflage Performance at the Challenging High Contrast Scene Sun/Shade Recorded in the Shade on 23.07, with UKs NIR Sensor.

PSYCHOPHYSICAL EVALUATION METHODS :

RANKING & PAIRED COMPARISON

- NATO-RTO SCI-219: Camouflage in hot humid areas

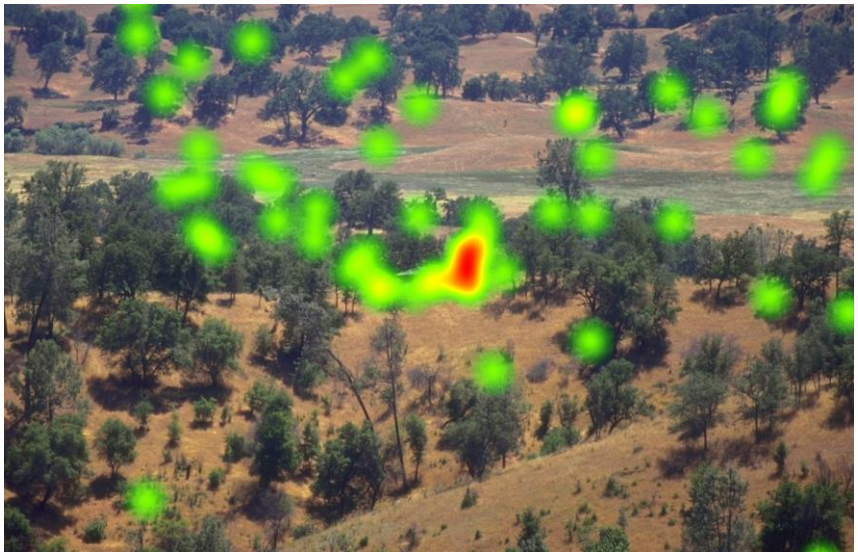
Figure 7-17: Best (CAN1, Left) and Worst (DEU2, Right) LWIR Camouflage Performance Recorded at Night of 23.07, with CAN LWIR Sensor.

PSYCHOPHYSICAL EVALUATION METHODS :

EYE TRACKING

- Scanpaths

- Heatmaps



PSYCHOPHYSICAL EVALUATION METHODS :

EYE TRACKING

- Scanpaths

- Heatmaps

PSYCHOPHYSICAL EVALUATION METHODS :

EYE TRACKING

- Scanpaths
- Over 120 different performance metrics (Holmqvist & Nystrom, Eye Tracking, Oxford Univ. Press, 2011)
- Most relevant measures:
  - Fixation locations
  - Fixation durations (duration increases with clutter)
  - Pupil size (pupils dilate with increasing cognitive workload)
  - Scan path similarity (fixation order, saccadic length)

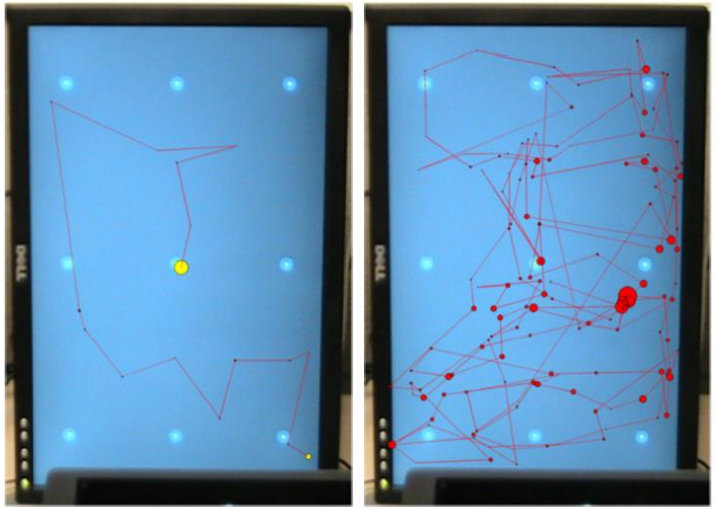
PSYCHOPHYSICAL EVALUATION METHODS :

EYE TRACKING

General findings:

- Increasing clutter leads to :
  - Longer fixation times (increasing nr of target-similar features)
  - Shorter saccades
- Fixation duration :
  - Longer for targets than non-targets
  - Longer for hits than for misses
- Pupil size :
  - Larger for targets than for non-targets
  - Larger for misses than for hits

scanpaths

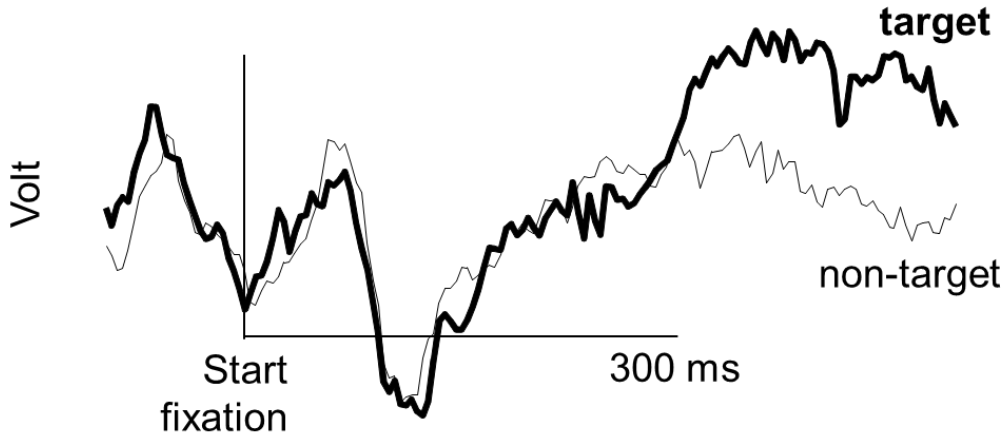


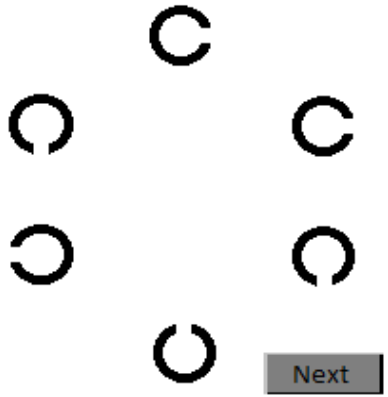
Low clutter High clutter

PSYCHOPHYSICAL EVALUATION METHODS :

FIXATION RELATED ERPS - ATTENTION

- Distinguishing targets from non-targets: Fixation Event Related Potentials (FRPs)
- FRPs eliminate the need for subjective (cognitively biased) reports





Brouwer, Reuderink, Vincent, van Gerven & van Erp (2013). Distinguishing between target and nontarget fixations in a visual search task using fixation-related potentials. *Journal of Vision*, 13(3):17, 1–10.

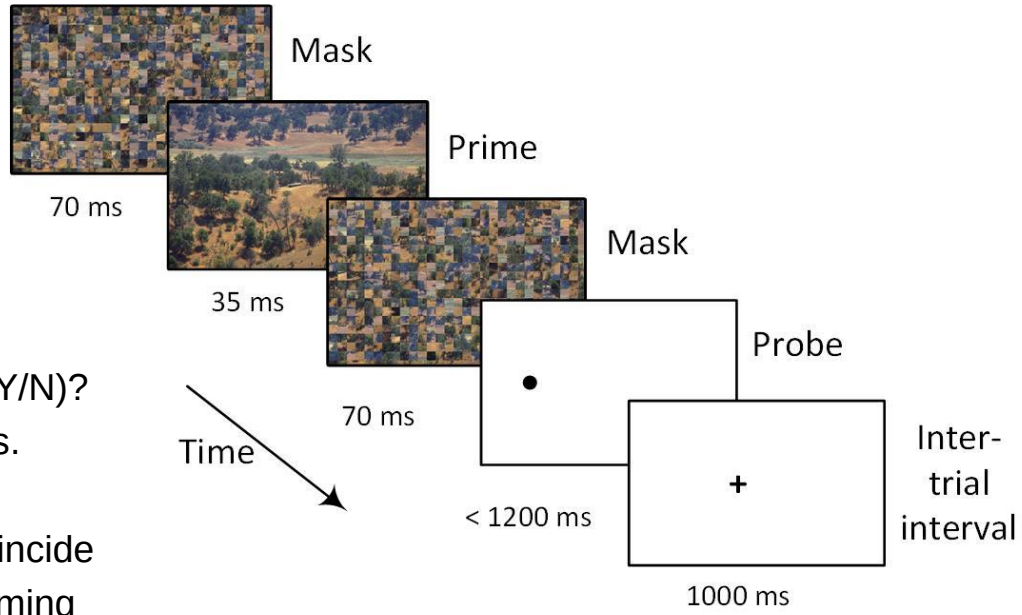
Brouwer, Hogervorst, Oudejans, Ries, Touryan (2017) EEG and Eye Tracking Signatures of Target Encoding during Structured Visual Search. Front. Hum. Neurosci. 11:264

PSYCHOPHYSICAL EVALUATION METHODS :

MASKED PRIMING

- Procedure :
  - Forward mask (preceding the prime),
  - Brief prime (stimulus) presentation,
  - Backward mask (following the prime),
  - Dot probe,
  - Question : target present at dot location (Y/N)?
  - Measures: error rates and response times.

- Shorter response time when dot and prime coincide
- Stimulus presentation time needed to elicit priming effects inversely related to conspicuity



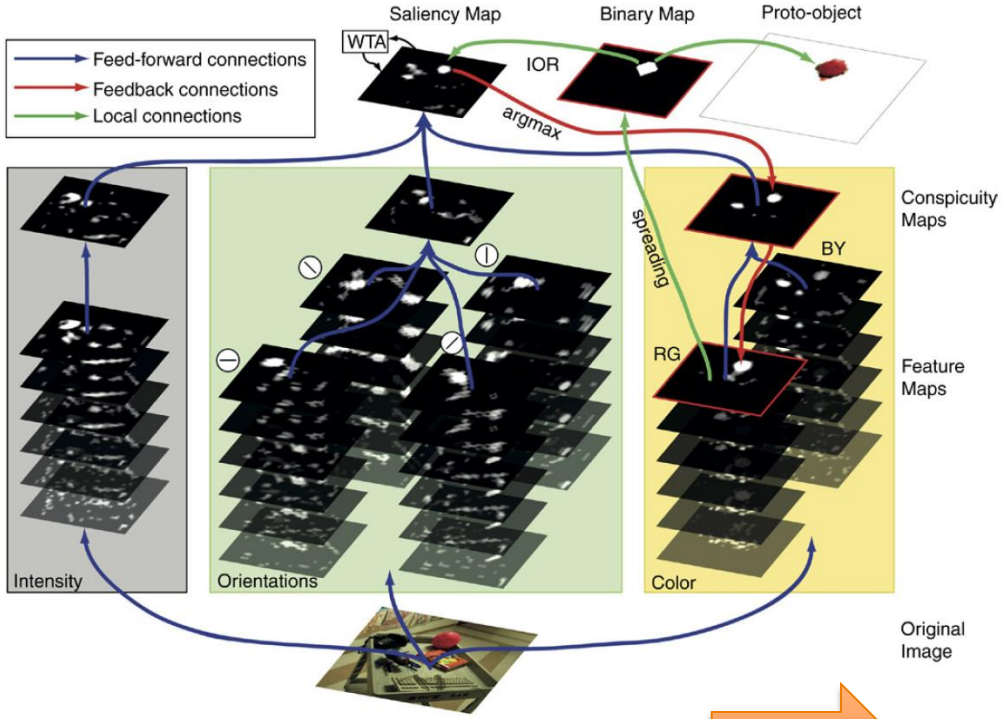
COMPUTATIONAL EVALUATION METHODS :

SALIENCY MODELS

- Compute target distinctness relative to background (conspicuity)
- Accounting for many different features (e.g., color, texture, shape, edge strength, orientation, etc.)

EXAMPLE: SALIENCY TOOLBOX (WALTHER, KOCH, ITTI)

D. Walther, C. Koch / Neural Networks 19 (2006) 1395–1407

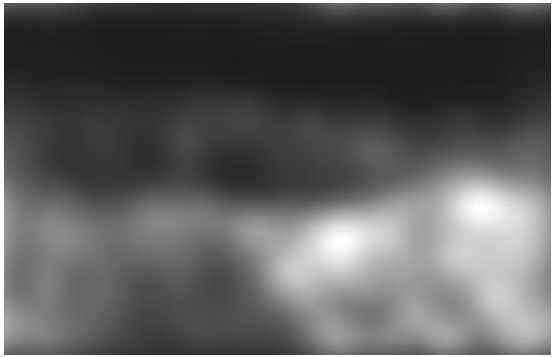


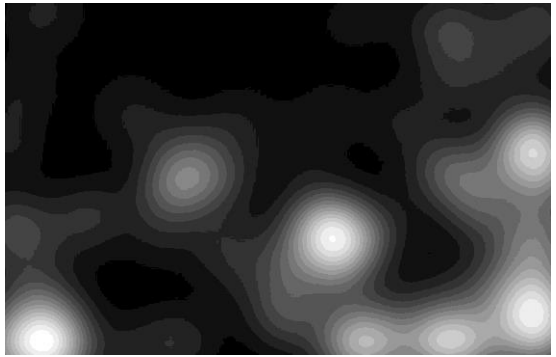
Multiple levels of resolution

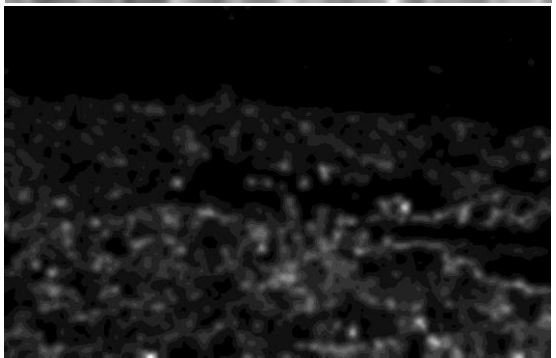
Multiple feature maps

COMPUTATIONAL SALIENCY

Different algorithms yield different maps







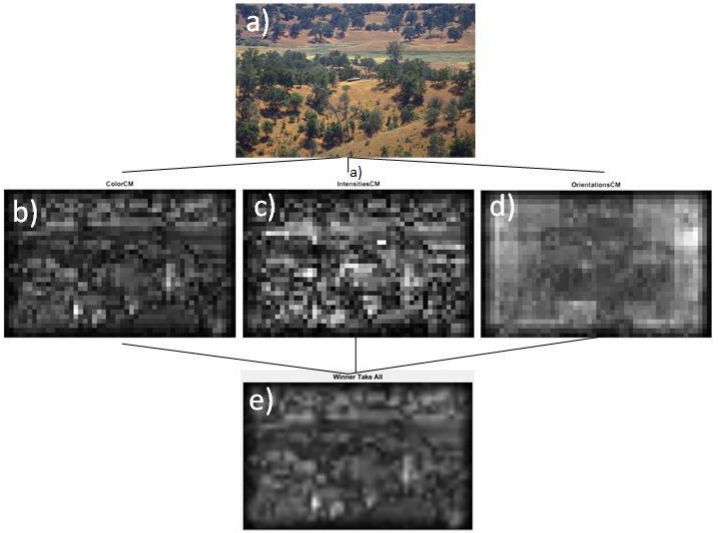
COMPUTATIONAL SALIENCY

COMPUTATIONAL SALIENCY

COMPUTATIONAL SALIENCY

FIXATION PREDICTION FROM SALIENCY MAPS

Saliency Toolbox
Walther, Koch & Itti, 2006



Color + intensity + orientation >

intensity (+ orientation) >

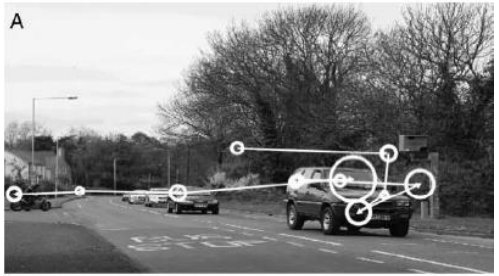
SALIENCY BASED SIMULATED FIXATION BEHAVIOR

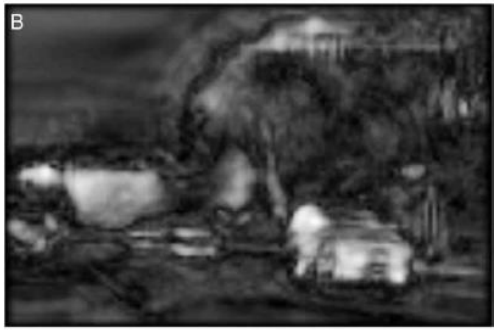
Saliency Toolbox
Walther, Koch & Itti, 2006

SALIENCY BASED SIMULATED FIXATION BEHAVIOR

- Not successful:
  - Observer scan patterns no correlation with those predicted by (Itti) saliency map models

Foulsham & Underwood, 2008 ;
Underwood, Foulsham & Humphrey, 2009





BOTTOM-UP VS TOP-DOWN SALIENCY

- Bottom-Up (BU) saliency: regular CS filters
- Top-down (TD) saliency: correlation of BU saliency map with target template filter
- TD map predicts human fixation behaviour better than bottom-up (BU)

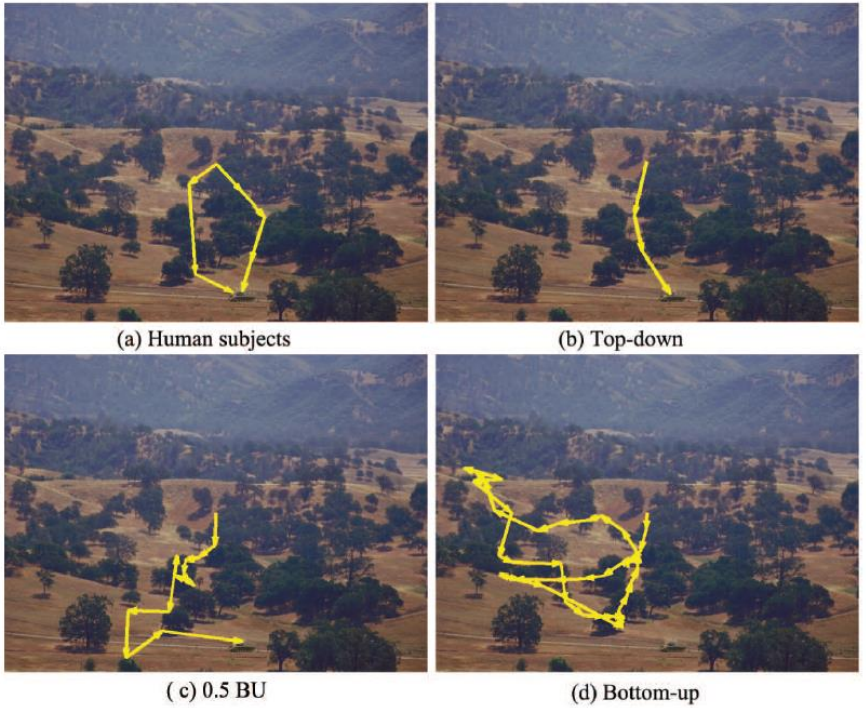
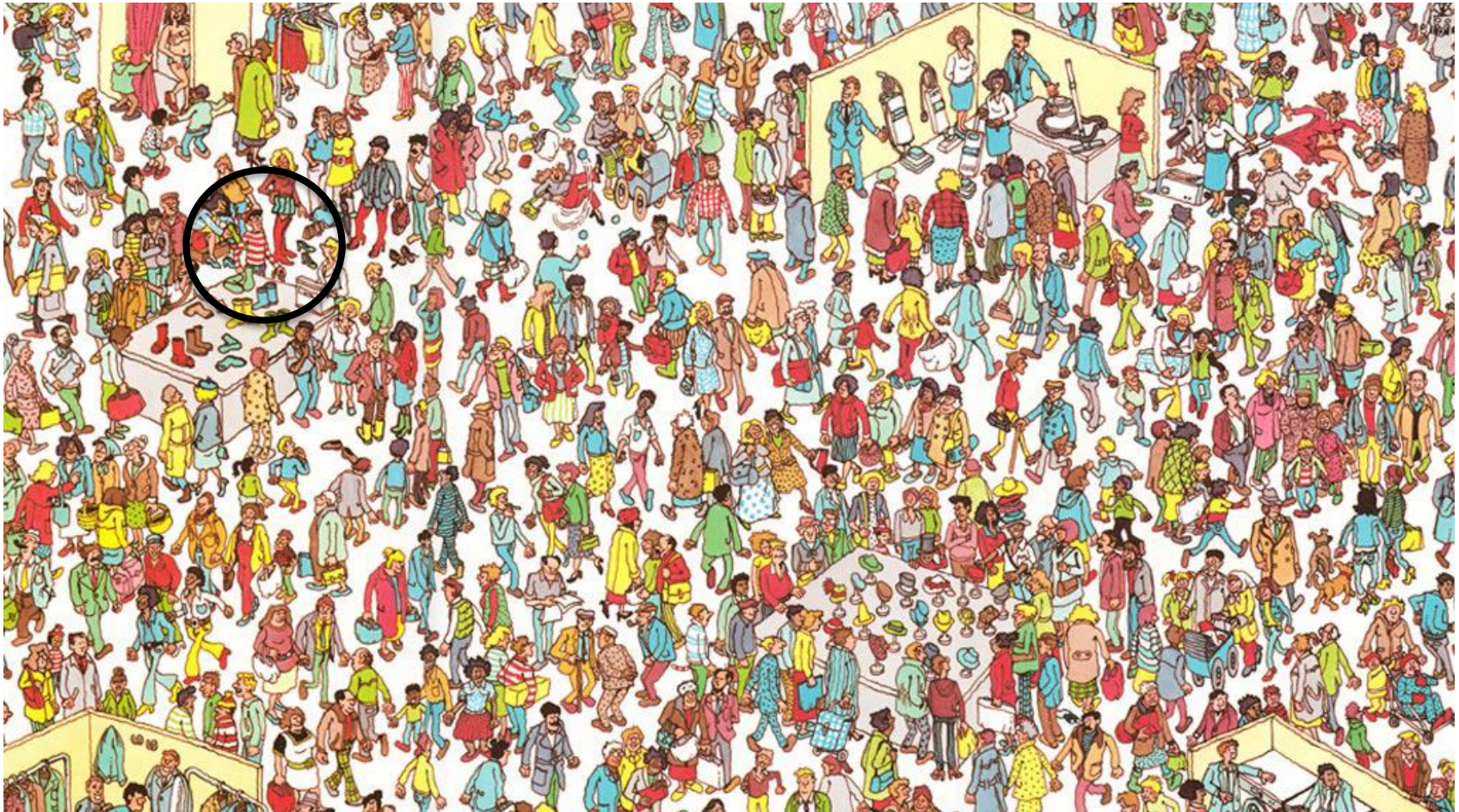


Figure 2: Comparison of human and model scanpaths at different TD/BU weight

CLUTTER AND TARGET SIGNATURE METRICS



Where's Waldo?

COMPUTATIONAL EVALUATION METHODS :

CLUTTER AND TARGET SIGNATURE METRICS

- Static targets:
  - Edge detection
  - Texture metrics (e.g. CAMAELEON)
  - Contrast energy detection
- Dynamic targets
  - Correlation
  - Gradient
  - Energy

COMPUTATIONAL EVALUATION METHODS :

CLUTTER AND TARGET SIGNATURE METRICS

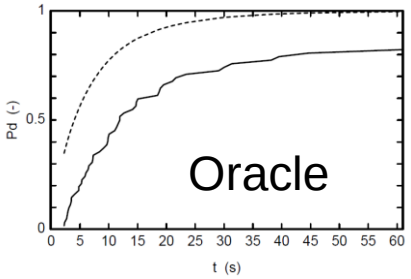


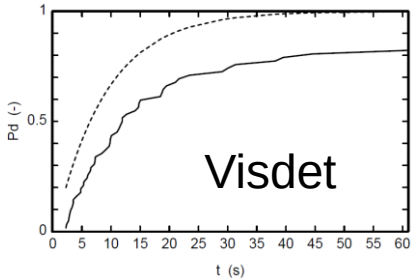
- CAMAELEON
- Target-background contrast in terms of
  - local energy
  - local spatial frequency
  - local orientation


COMPUTATIONAL EVALUATION METHODS :

SEARCH MODELS

- **Input parameters e.g. :**
  - Luminance:
    - target
    - local background
    - overall scene
  - Dimensions:
    - target
    - FOV
    - FOR
- **Output:**
  - Mean search time
  - $P_d(t)$



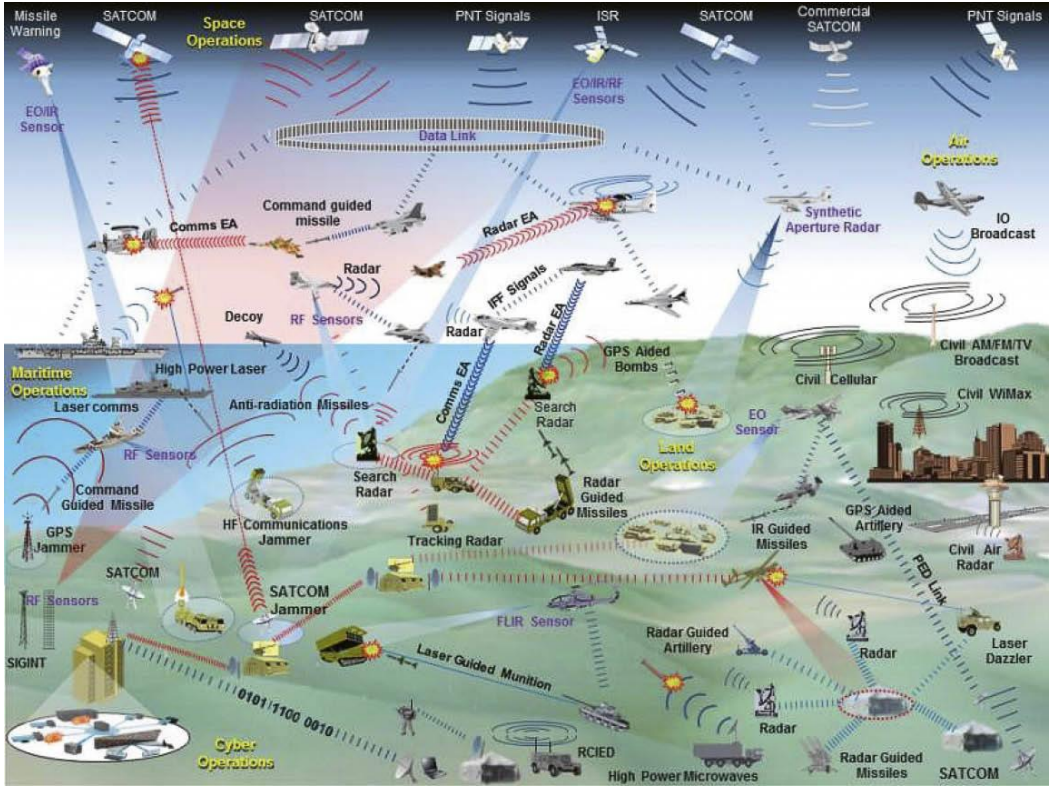


FUTURE CHALLENGES

- Camouflage
  - can one hide on the modern battlefield?

or

- Deception
  - can we spoof modern sensors?



ACTIVE CAMOUFLAGE

- Yehudi lights:
  lamps of automatically-controlled brightness placed on the front and leading edges of an aircraft to raise its luminance to the average sky brighten

Developed by US Navy from 1943 onwards.

Increased interest due to stealth technology.

ACTIVE CAMOUFLAGE

- Yehudi lights:
  lamps of automatically-controlled brightness placed on the front and leading edges of an aircraft to raise its luminance to the average sky brighten

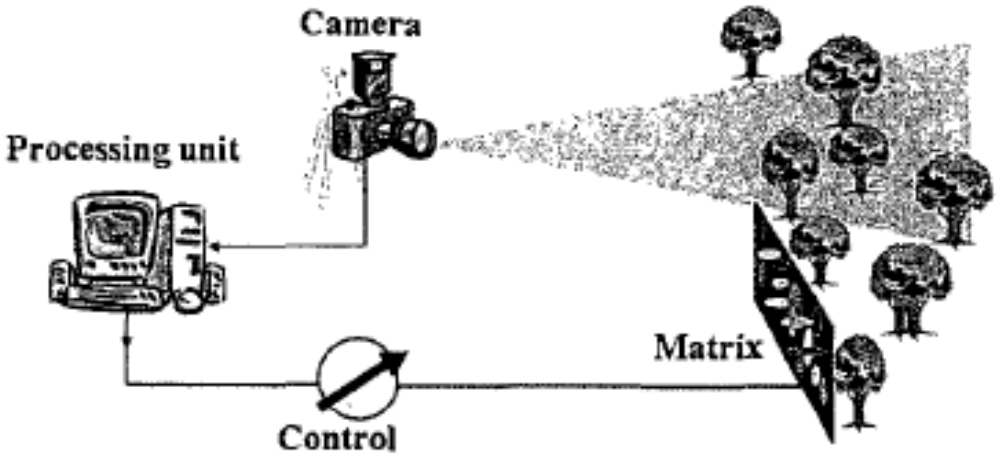
Developed by US Navy from 1943 onwards.

Increased interest due to stealth technology.

ACTIVE CAMOUFLAGE

- Adaptive camouflage: CAMELEON (TNO, Holst, CA, GE)

Green	Control VIS	Fixed emission	Control emission	Brown
Control emission	Fixed emission	Black	Fixed emission	Control VIS
……	……	……	……	……



ACTIVE CAMOUFLAGE

- CAMELEON (TNO, Holst, CA, GE)
  https://www.youtube.com/watch?v=zLdNeatXCvE

  or Google on:
  “Toet Cameleon Youtube”

ACTIVE CAMOUFLAGE

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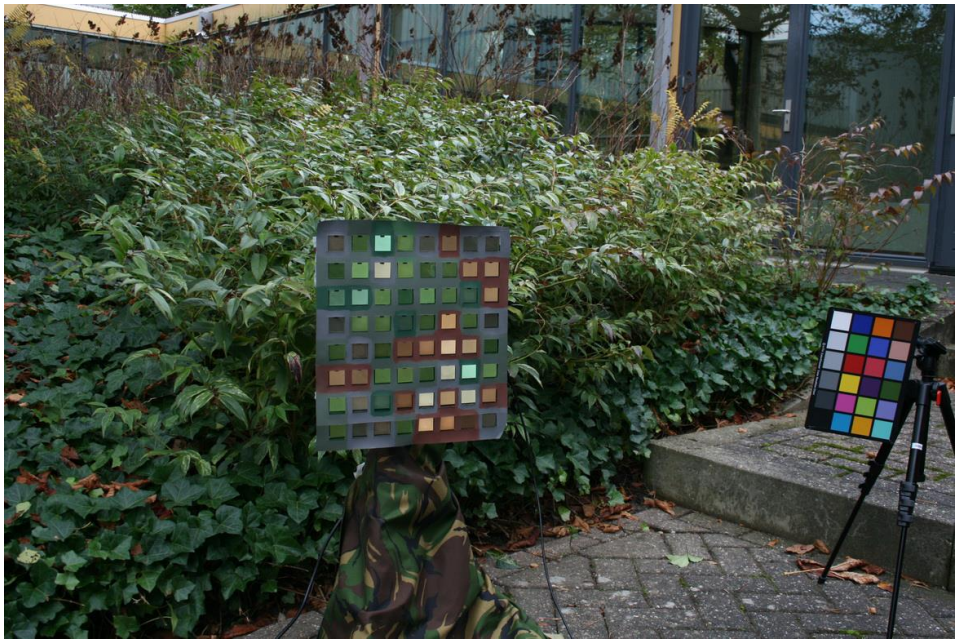
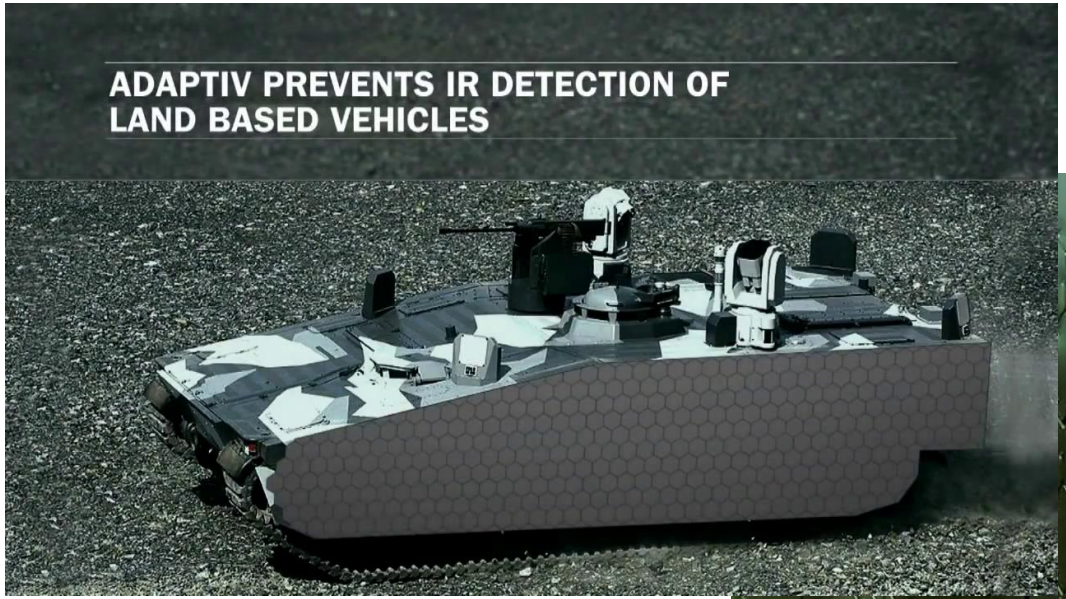
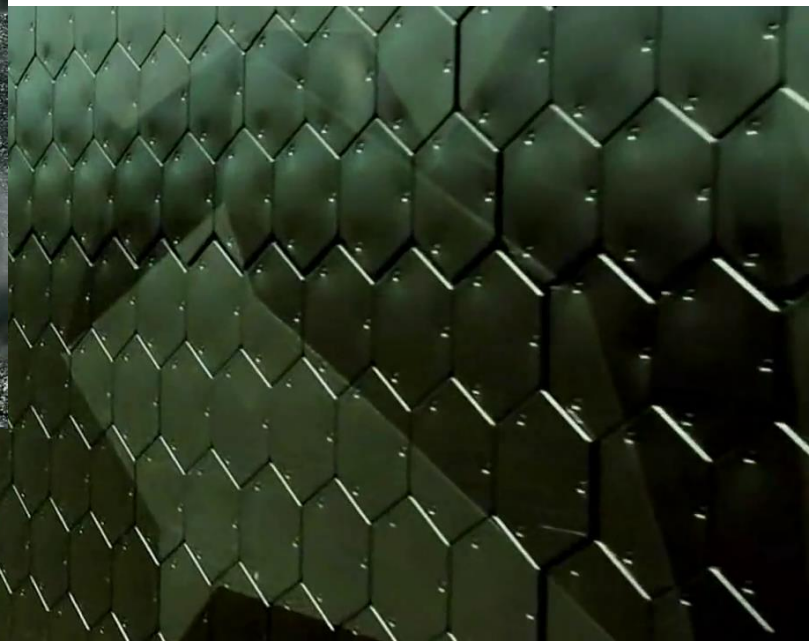


ACTIVE CAMOUFLAGE: BAE ADAPTIVE SYSTEM

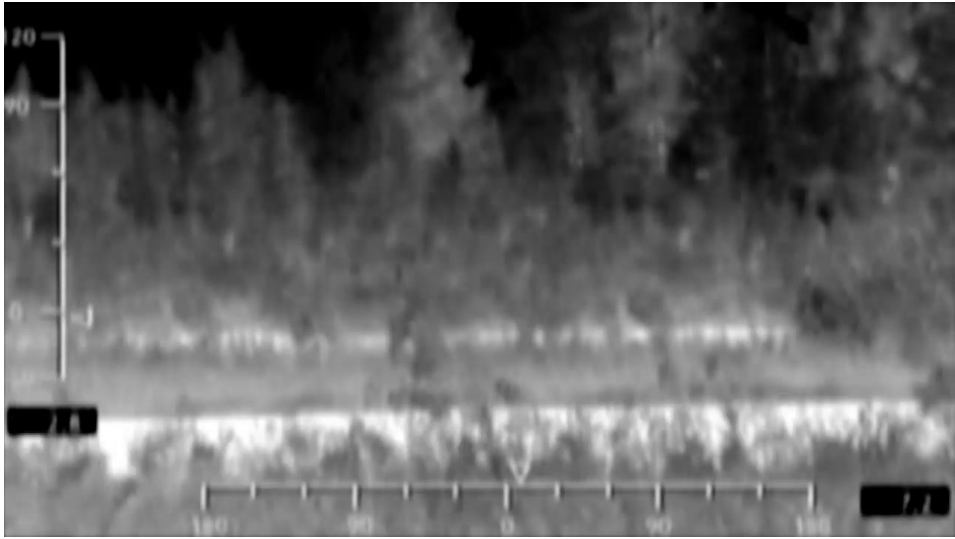




Peltier elements

ACTIVE CAMOUFLAGE: BAE ADAPTIVE SYSTEM

system inactive



system activated

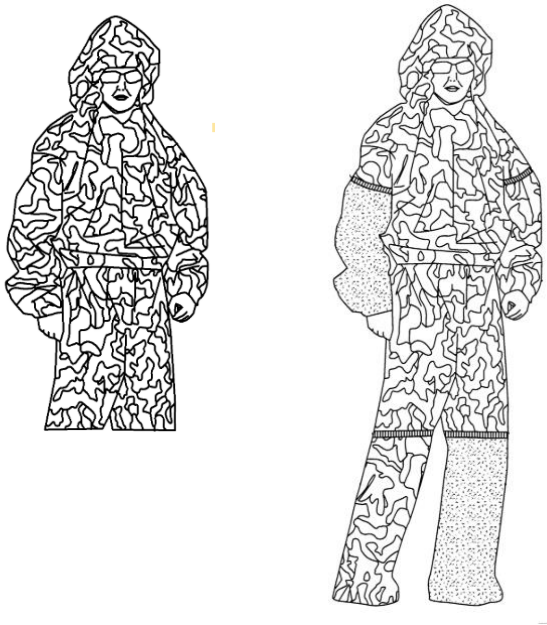
ACTIVE CAMOUFLAGE: BAE ADAPTIVE SYSTEM

ACTIVE CAMOUFLAGE: BAE ADAPTIVE SYSTEM

MULTISPECTRAL CAMOUFLAGE

- A multispectral image is typically a 4-6 band image: RGB + one or more infrared bands
- Camouflage through multilayered textiles with
  - different reflection and absorption characteristics
  - different patterns

  in each of the spectral bands



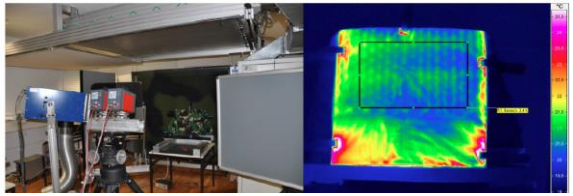
ACTIVE MULTISPECTRAL CAMOUFLAGE

- Adaptive Camouflage for the Soldier II (ACAMSII)
  - Project in EU PADR program
  - SE, DE, PT, LT, NL, FR
  - Start: May 1, 2018
  - End: April 30, 2021
  - 2.6 M€

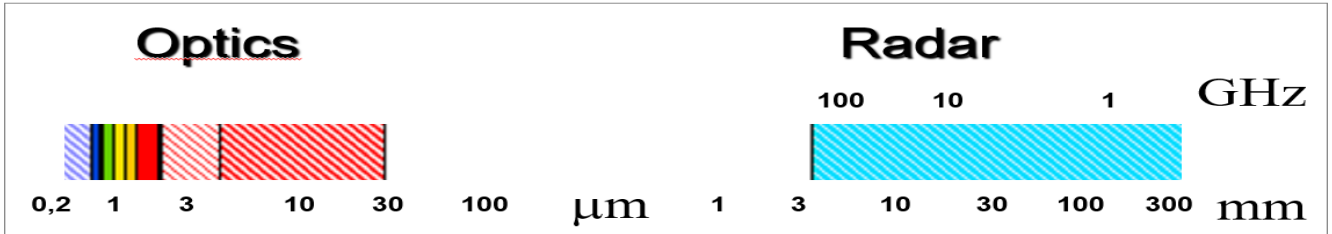
ACTIVE MULTISPECTRAL CAMOUFLAGE

- Adaptive Camouflage for the Soldier II (ACAMSII)

- *research on novel materials and components*



- Multispectral camouflage: Visual, NIR, SWIR, MWIR, LWIR, Radar

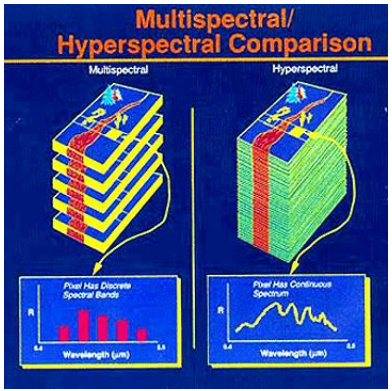


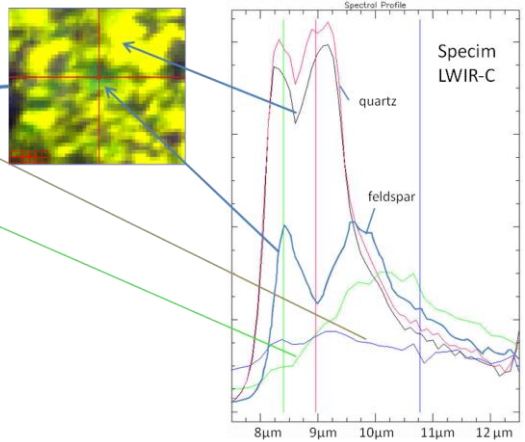
ACTIVE CAMOUFLAGE

Ultimate goal: the invisible soldier

HYPERSPECTRAL CAMOUFLAGE

- A hyperspectral image typically has ~200 bands, each band representing the response to a precise wavelength of light.
  - A representative (200 D) signal for a material is called a hyperspectral signature.
  - We can form these signatures into a spectral library for classification.

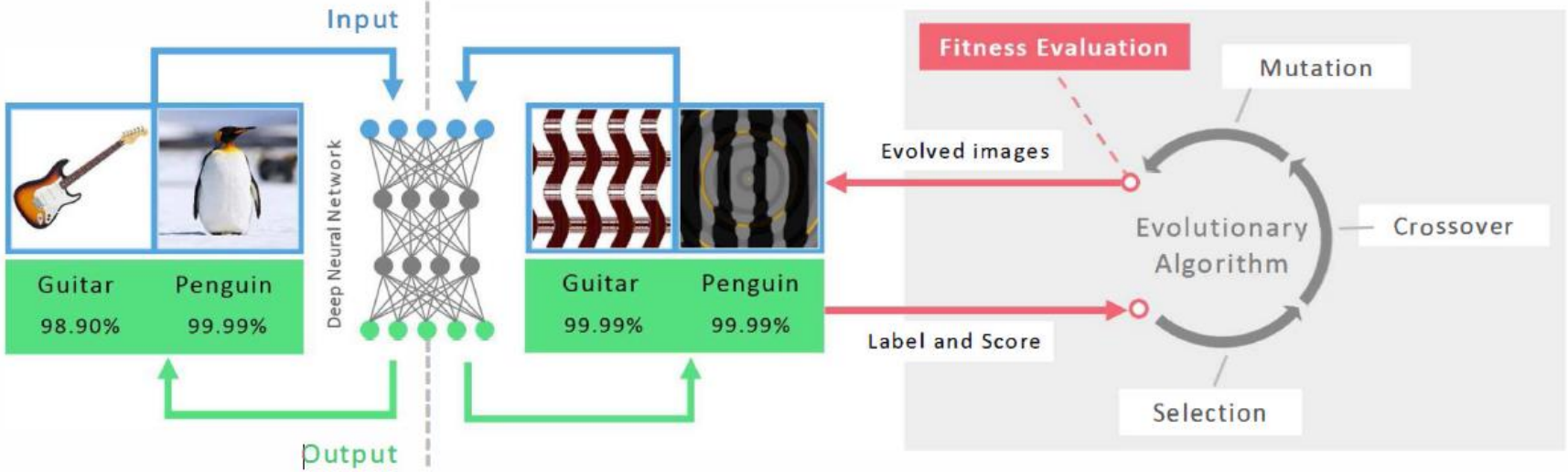




FOOLING AUTOMATIC DETECTION SYSTEMS

1 State-of-the-art DNNs can recognize real images with high confidence

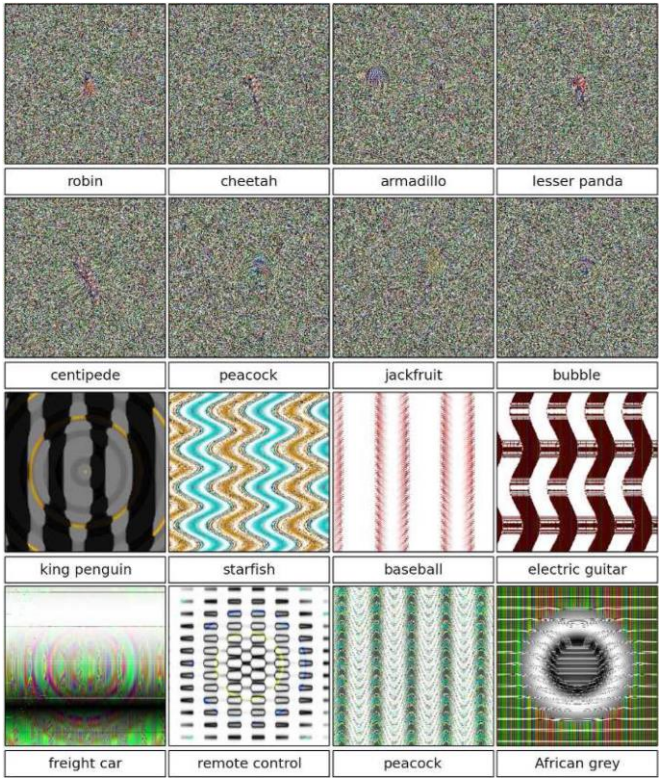
2 But DNNs are also easily fooled: images can be produced that are unrecognizable to humans, but DNNs believe with 99.99% certainty are natural objects



FOOLING RECOGNITION SYSTEMS

- it is easy to produce images that are completely unrecognizable by humans

- but that state-of-the-art DNNs believe to be familiar objects with 99.99% confidence

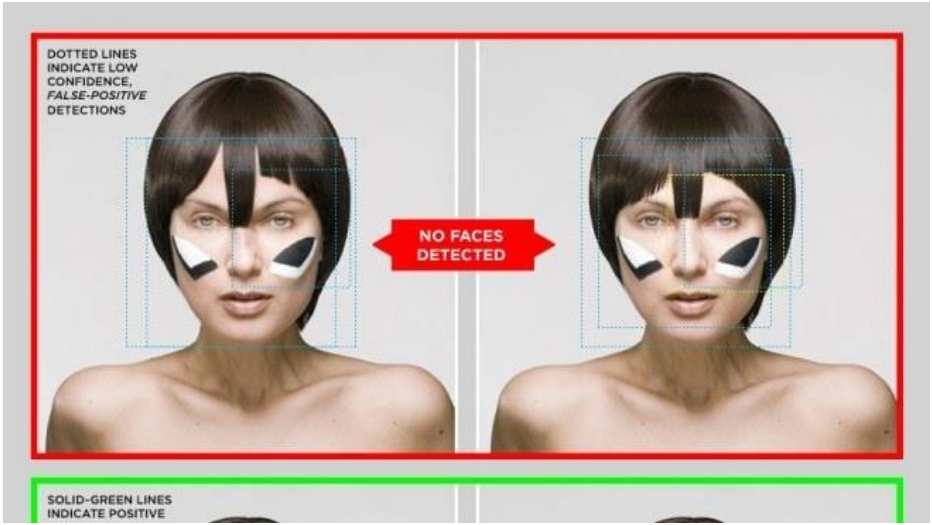


FOOLING AUTOMATIC DETECTION SYSTEMS

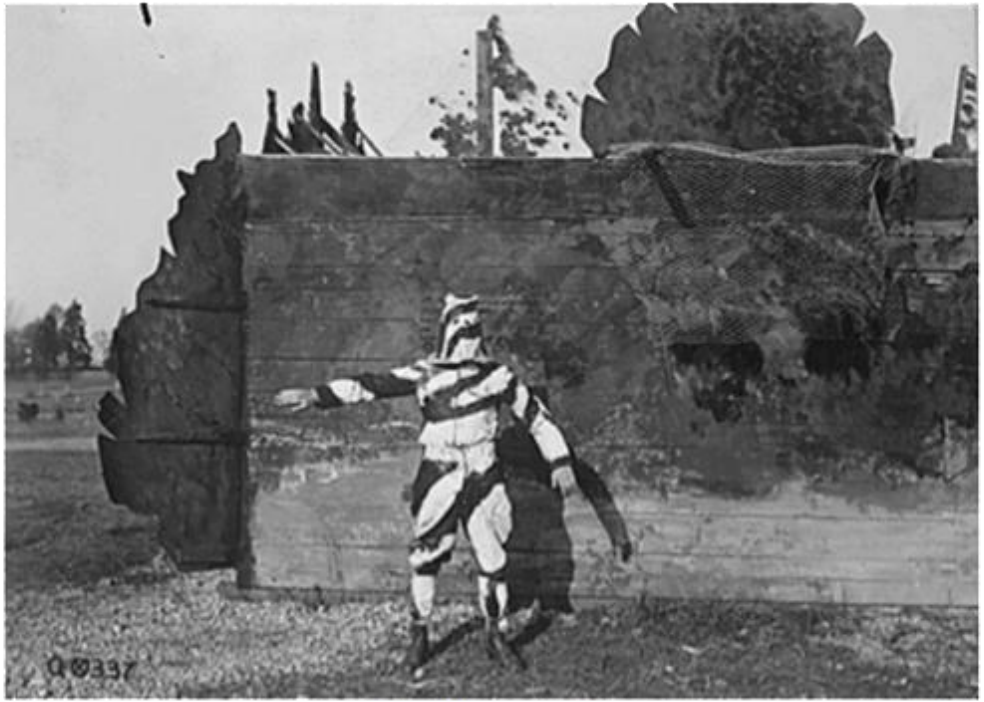
- Automatic person detection systems can easily be fooled

FOOLING RECOGNITION SYSTEMS

- Automatic face recognition systems can easily be fooled



- So WWI camouflage may become fashionable again



1917: A soldier in World War I models early camouflage. *(Courtesy: National Archives/Department of Defense*


Thank you
for
your attention !