III. MESURES / METHODS

Performances

Response Time

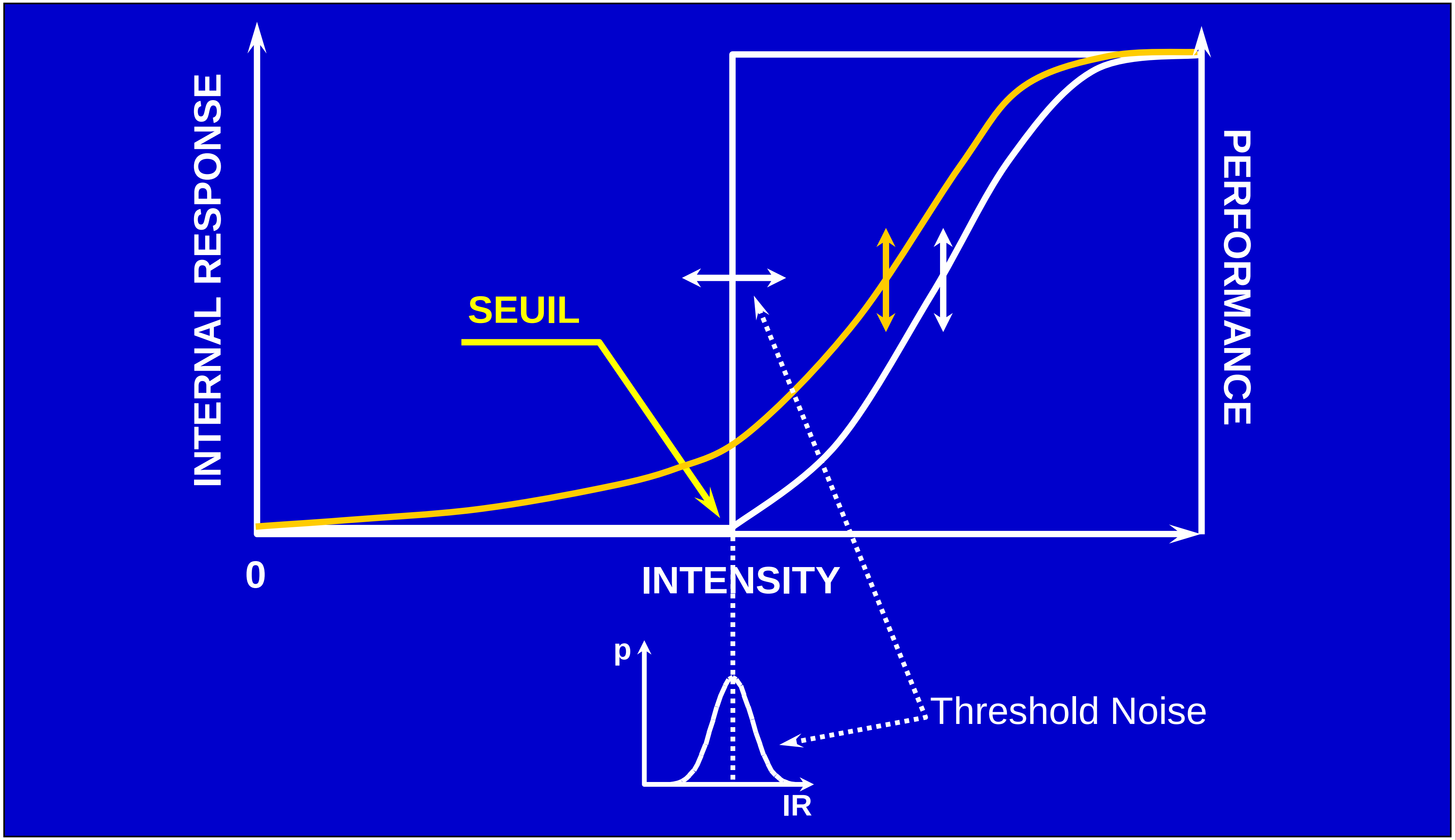
Pelli, D. G., & Farell, B. (1994) Psychophysical methods. In: M. Bass, E. W. Van Stryland, D. R. Williams, & W. L. Wolfe (Eds.), *Handbook of Optics, 2nd ed., I* (pp. 29.21-29.13). New York: McGraw-Hill.

Psychophysical measurement is usually understood to mean measurement of behavior to reveal internal processes. The experimenter is typically not interested in the behavior itself, such as pressing a button, which merely communicates a decision bv the observer about the stimulus.

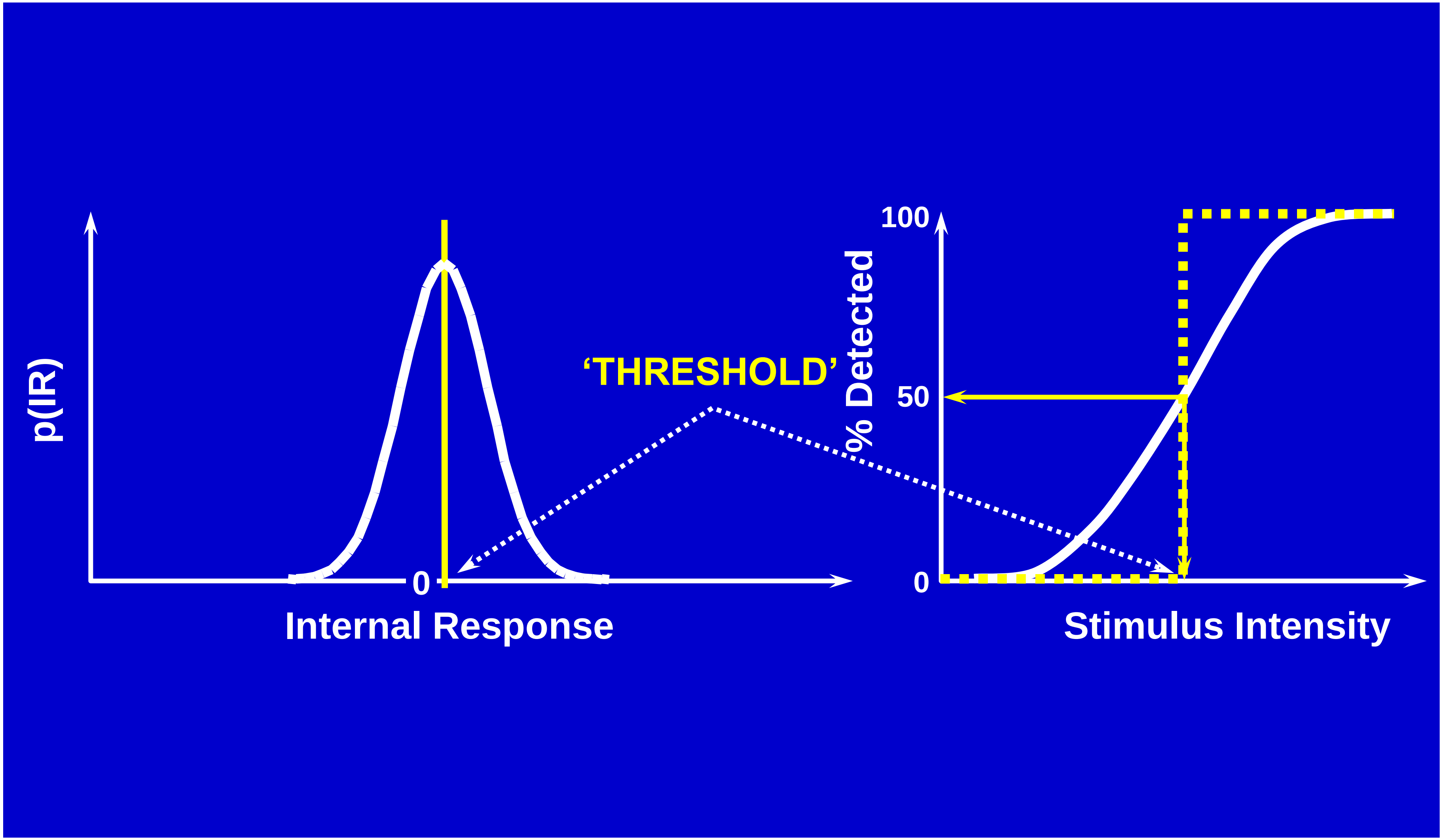
Mais d’abord quelques mots sur les concepts de

THRESHOLD, NOISE, PSYCHOMETRIC FUNCTION & TRANSDUCTION

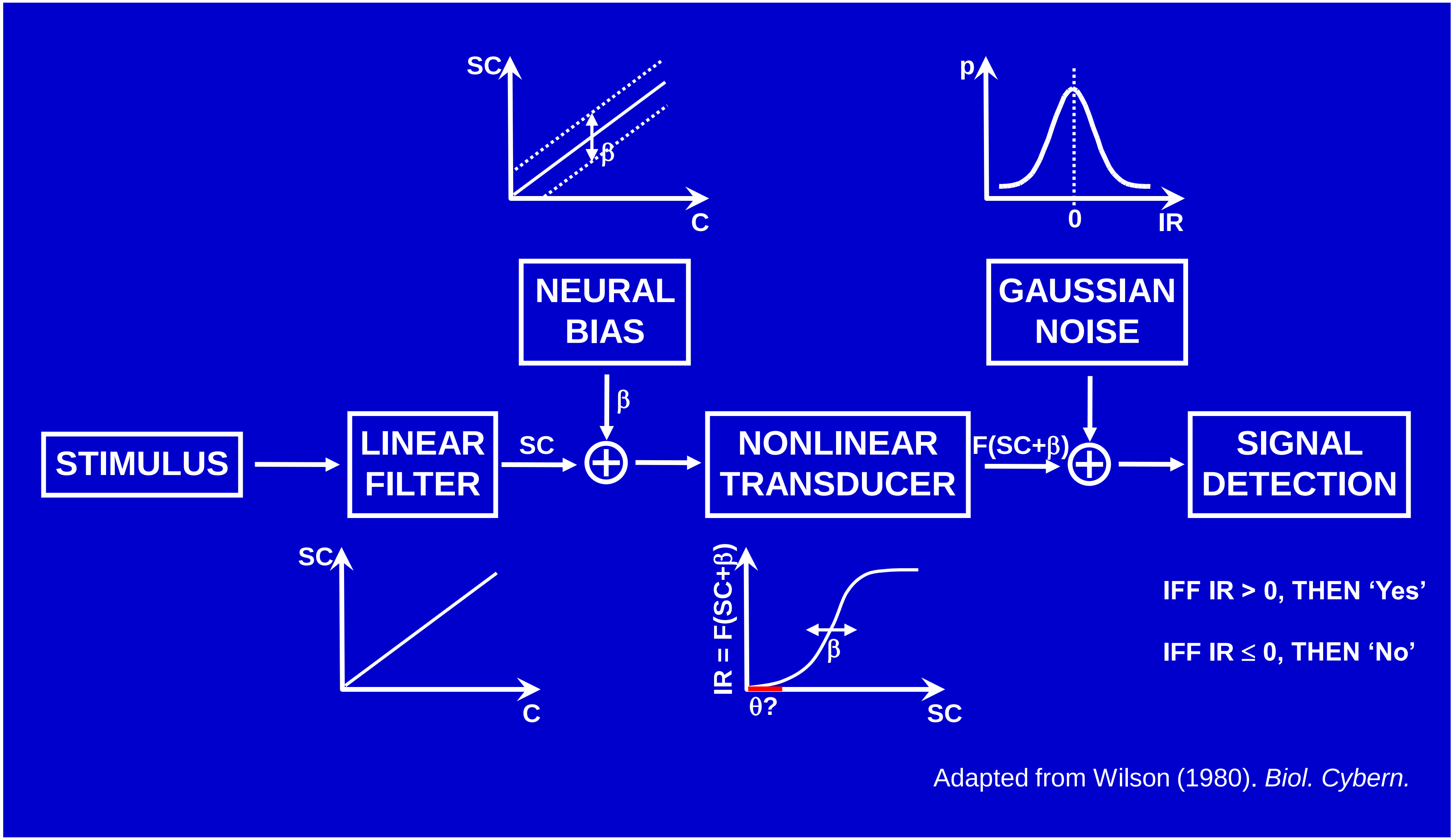
THE CONCEPT OF THRESHOLD (SEUIL)



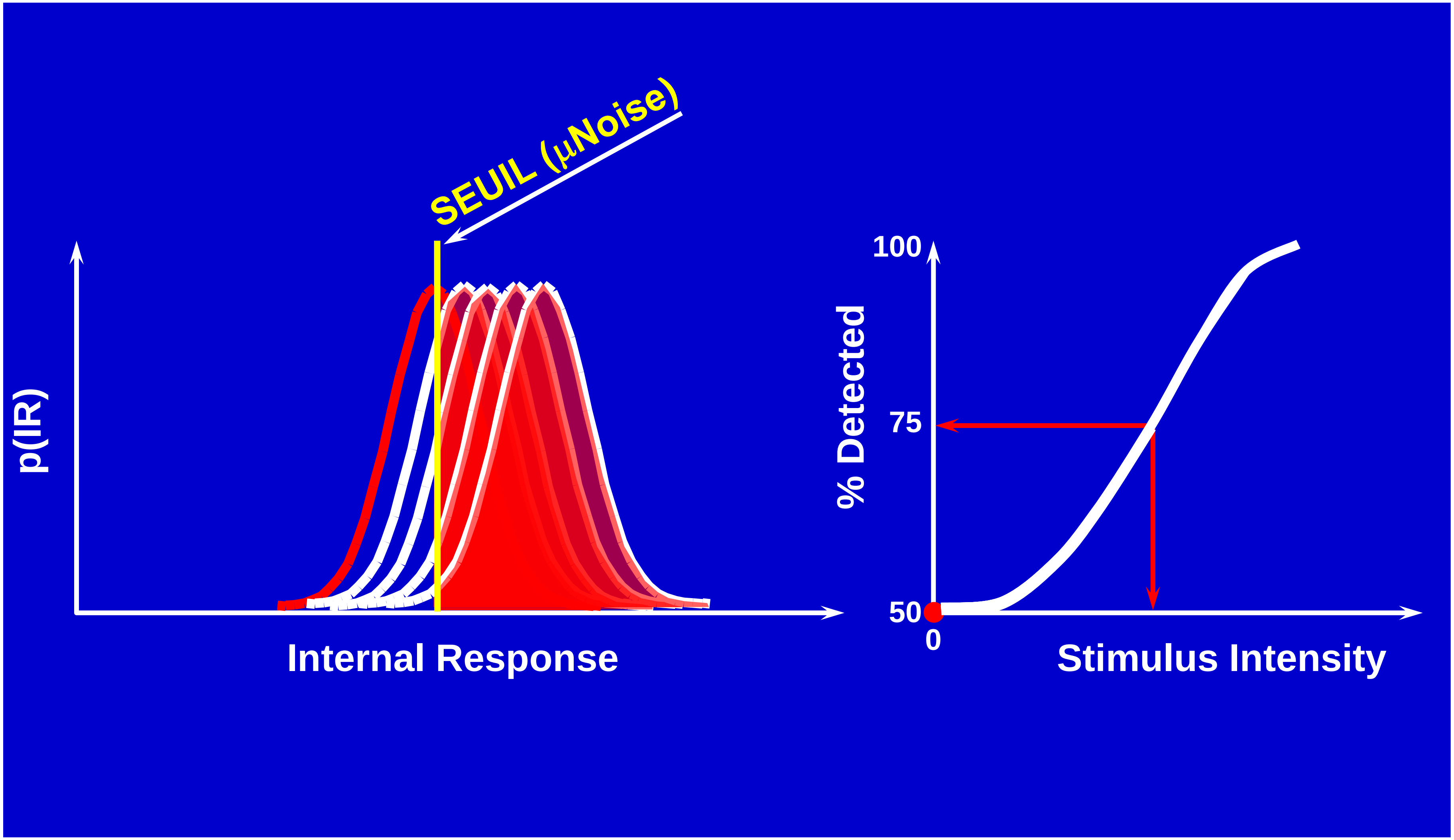
THE CONCEPT OF SENSORY NOISE



STANDARD MODEL OF DETECTION



SENSORY NOISE & THE Ψ-FUNCTION (2AFC)

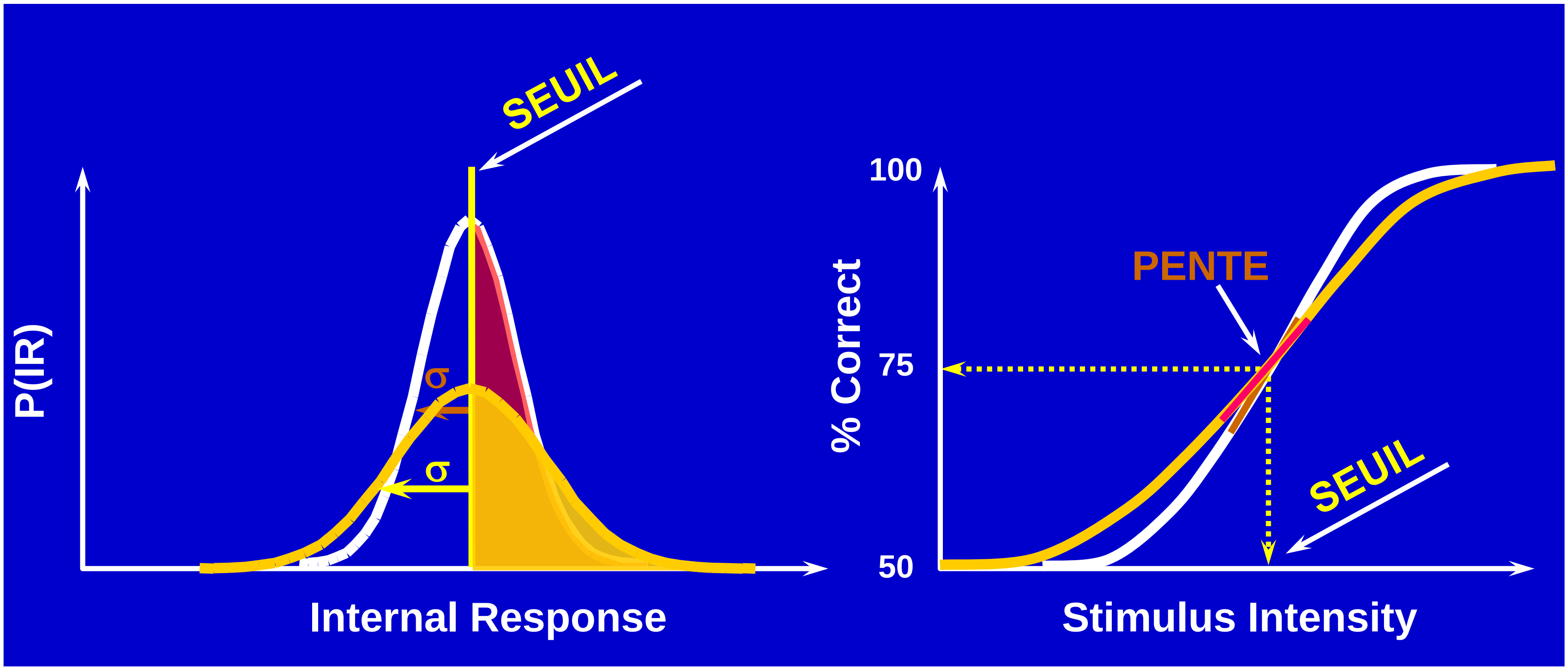


THE PSYCHOMETRIC FUNCTION

$$p(\mathrm{IR}) = \frac{1}{\sigma\sqrt{2\pi}}\, e^{-\left[\frac{\mu_{\mathrm{IR}} - x_{\mathrm{IR}}}{2\sigma^2}\right]}$$

$$p(\mathrm{Correct}) = \int_{-\infty}^{\mathrm{IR}_x} p(\mathrm{IR}), \quad \mathrm{IR}_x \geq 0$$

$$\mu_{\mathrm{IR}} = f(\mathrm{Stimulus\,intensity})$$



MEASURES & METHODS

Pelli, D. G., & Farell, B. (1994) Psychophysical methods. In: M. Bass, E. W. Van Stryland, D. R. Williams, & W. L. Wolfe (Eds.), *Handbook of Optics, 2nd ed., I* (pp. 29.21-29.13). New York: McGraw-Hill.

There are two kinds of decision tasks: judgments and adjustments. It is useful to think of one as the inverse of the other. In one case the experimenter gives the observer a stimulus and asks for a classification of the stimulus or percept; in the other case the experimenter, in effect, gives the observer a classification and asks for an appropriate stimulus back. Either the experimenter controls the stimulus and the observer makes a *judgment* based on the resulting percept, or the observer *adjusts* the stimulus to satisfy a perceptual criterion specified by the experimenter (e.g., match a sample).

Distinguishing between judgment and adjustment tasks emphasizes the kind of response that the observer makes. It is also possible to subdivide tasks in a way that emphasizes the stimuli and the question posed. In a *detection* task there may be any number of alternative stimuli, but one is a blank, and the observer is asked only to distinguish between the blank and the other stimuli. Slightly more general, a *discrimination* task may also have any number of alternative stimuli, but one of the stimuli, which need not be blank, is designated as the reference, and the observer is asked only to distinguish between the reference and other stimuli. A decision that distinguishes among more than two categories is usually called an "identification" or "classification" (Ashby, 1992).

The psychophysical approach : Paradigms & Measures

DIMENSIONS, STIMULI, QUESTIONS → PARADIGMS (Psycho-Anatomy) → MESUREMENT METHODS → TASKS & PERFORMANCES

DIMENSIONS, STIMULI, QUESTIONS

- ATTRIBUTE / DIMENSION (Color, Shape, Size, SF, TF, Motion, Binocular Disparity, Complex metrics (faces, natural images…)
- STIMULUS (Flashes, Bars, Gabors, Textures, Faces, Natural images …)
- QUESTIONS ASKED (Local vs. Global, Modular vs. Interactive processing, Segmentation/Fusion/Bin-ding, Attribute summation…)

PARADIGMS (Psycho-Anatomy)

- SELECTIVE ADAPTATION
- MASKING / INTERFERENCE
- VISUAL SEARCH
- PRIMING
- UNSTABLE STIMULI
- BINOCULAIR INTERACTIONS
- ATTENTIONNAL MANIPULATION

MESUREMENT METHODS

- SUBJECTIVE (Adjustement, Matching, Nulling, Scaling, Yes/No…)
- OBJECTIVE (Forced choice, Yes/No…)

TASKS & PERFORMANCES

- TASKS (Detection, Discrimination, Identification, Matching…)
- PERFORMANCES (%Correct, d'/Sensitivity, Ψ-Fonction, Bias, PSE, Response Times, other Motor characteristics…)

ONE POSSIBLE CLASSIFICATION

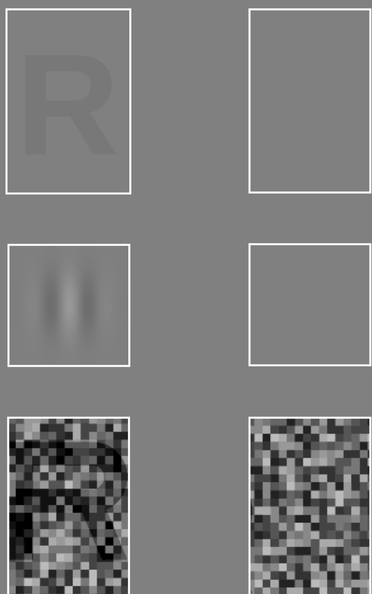
<table>
<tr><th>BASED ON</th><th>SUBJECTIVE</th><th>OBJECTIVE</th></tr>
<tr><td rowspan="4">Response type</td><td rowspan="2">Adjustment
Matching / Nulling
Method of limits
Magnitude estimation</td><td>Forced Choice</td></tr>
<tr><td>"Direct" behavioral or behavioral-related
RT, other motor characteristics, fMRI, neural responses, etc.</td></tr>
<tr><td colspan="2">Yes / No</td></tr>
<tr><td colspan="2">Classification</td></tr>
<tr><td rowspan="5">Stimulus presentation</td><td>At Subject's discretion
(Adjustment, etc.)</td><td></td></tr>
<tr><td colspan="2">At Experimenter's discretion</td></tr>
<tr><td>Method of limits</td><td></td></tr>
<tr><td colspan="2">Constant stimuli</td></tr>
<tr><td colspan="2">Adaptive methods</td></tr>
</table>

The 4 main experimental formats in psychophysics

'DETECTION'

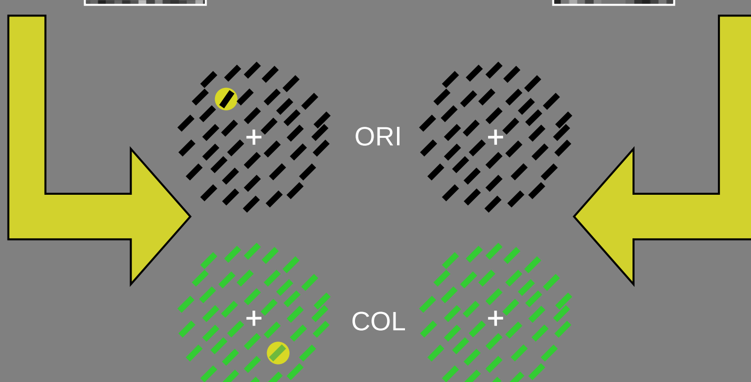
Forced choice
Left / Right

Yes / No
Present / Absent



Without
external noise

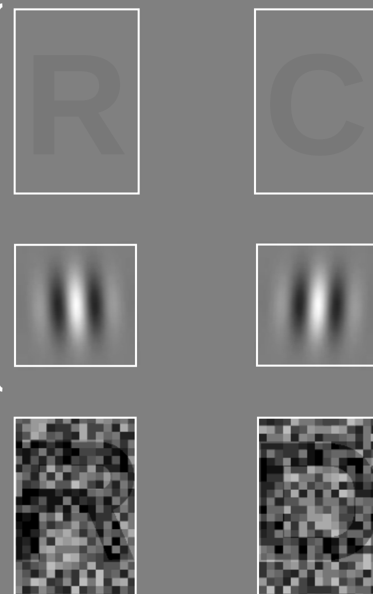
With
external noise



'DISCRIMINATION'

Forced choice
Stim. 1 / Stim. 2

Yes / No
Same / Differ.



'IDENTIFICATION'

Identification
1 out of N ;
Can be regarded as a discrimination among N (=large) distracters

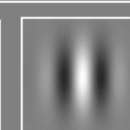
What letter?

Who?

'APPEARANCE'

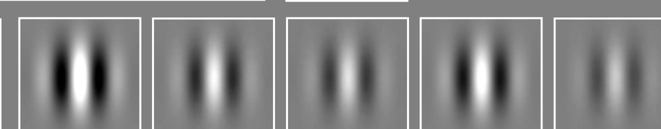
Matching to sample
Probe vs. Test

Scaling
Choose x2

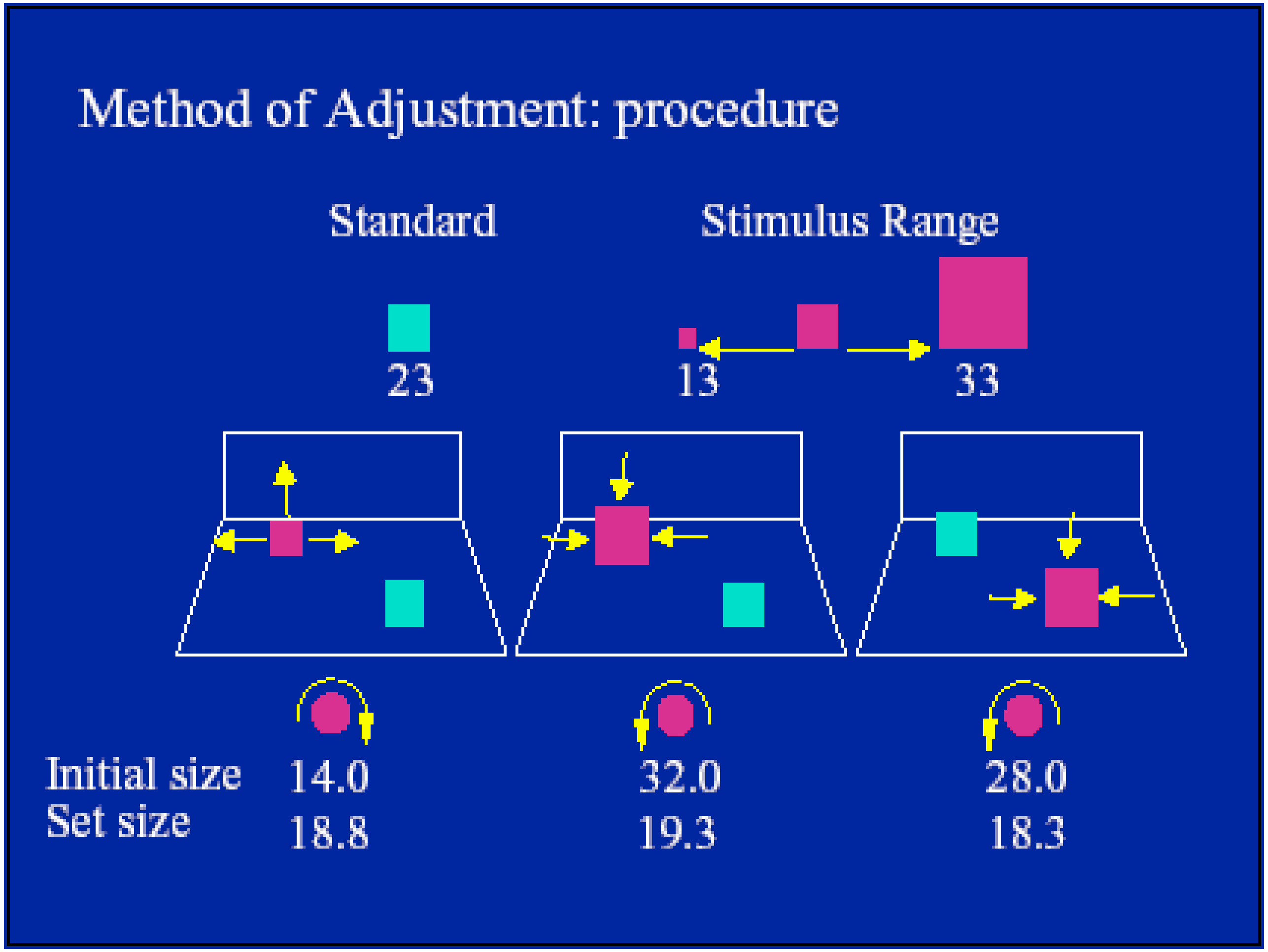


Probe

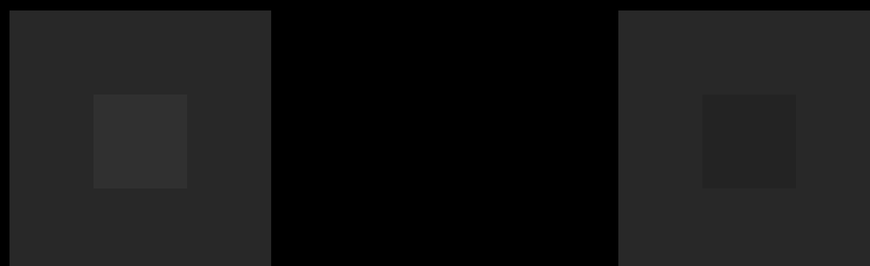
Test



ADJUSTEMENT



ADJUSTEMENT



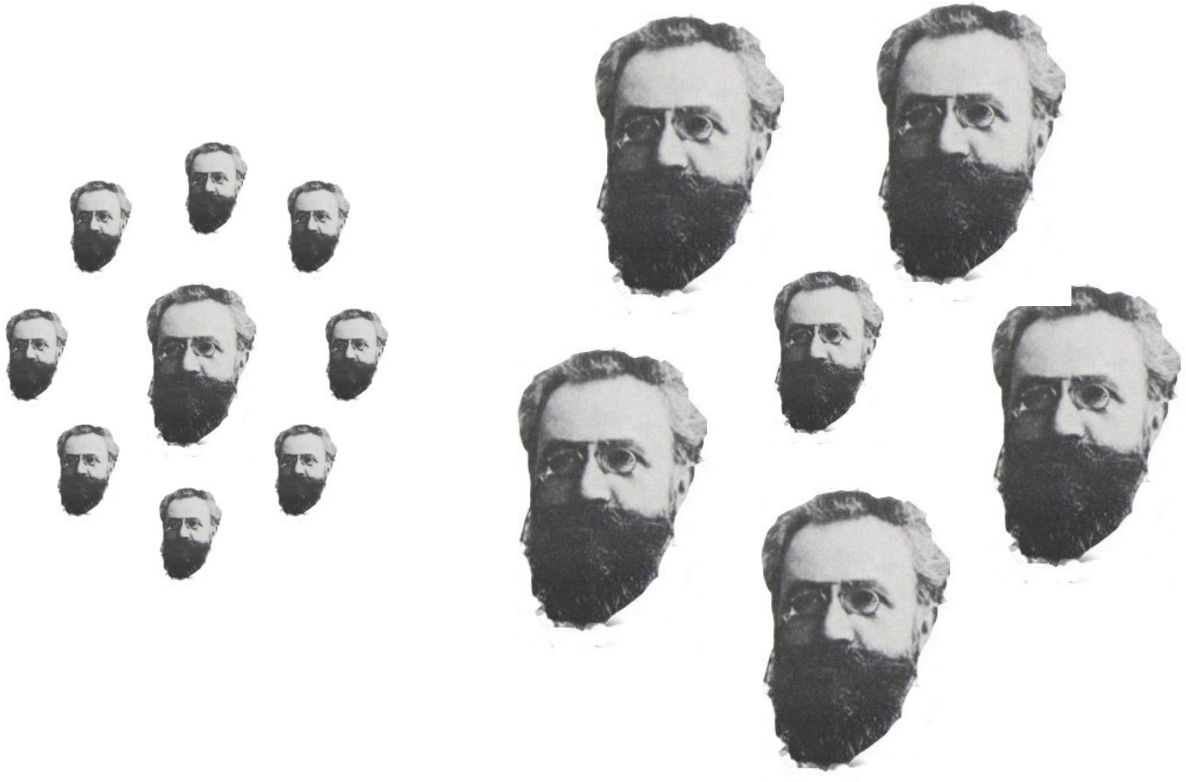
ADJUSTEMENT: *NULLING*

http://visionlab.harvard.edu/Members/Patrick/Demos/index.html

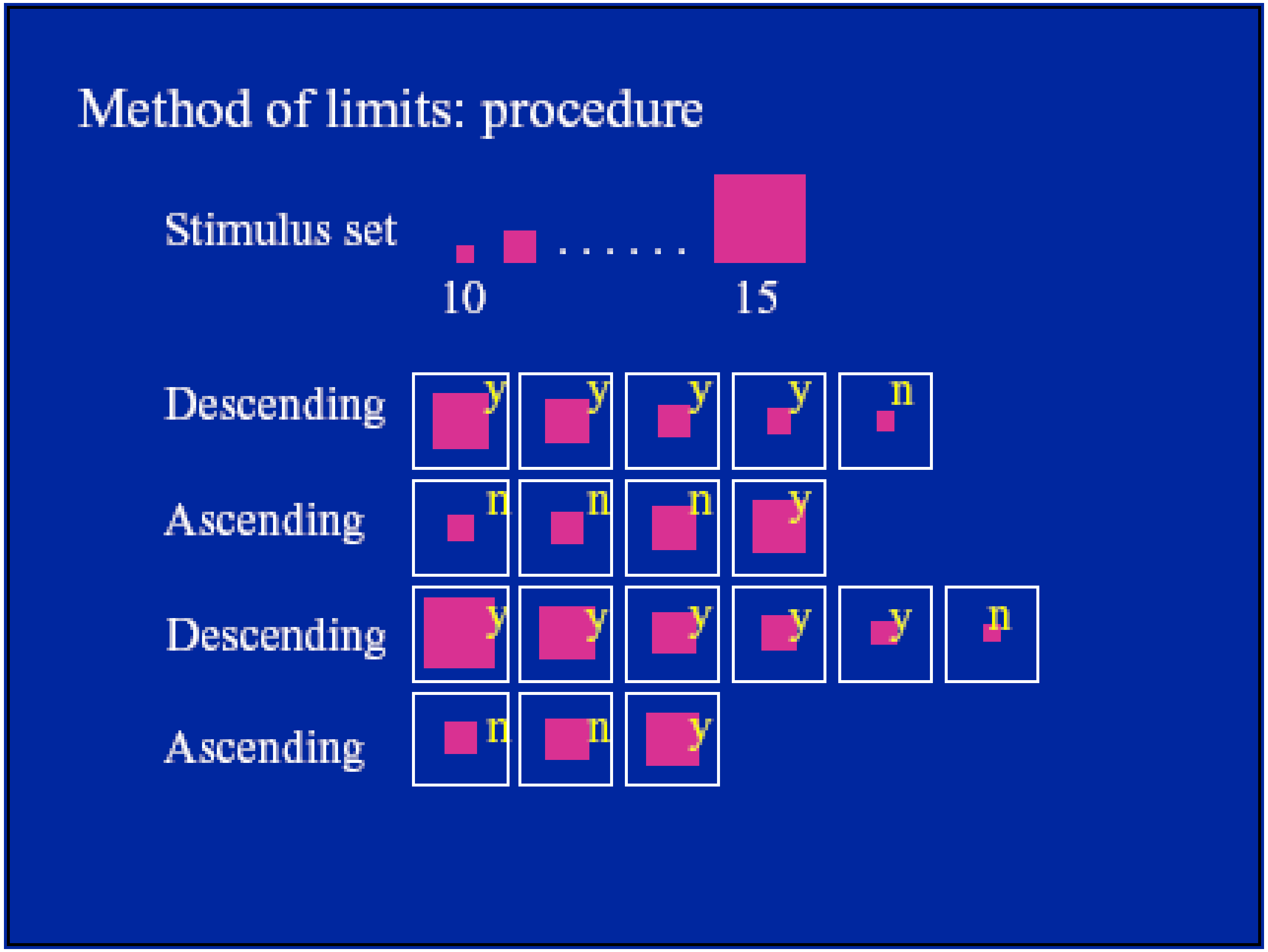
CAFFE WALL

ADJUSTEMENT: *NULLING*

EBBINGHAUS



METHOD OF LIMITS



METHOD OF LIMITS

Method of limits: analysis

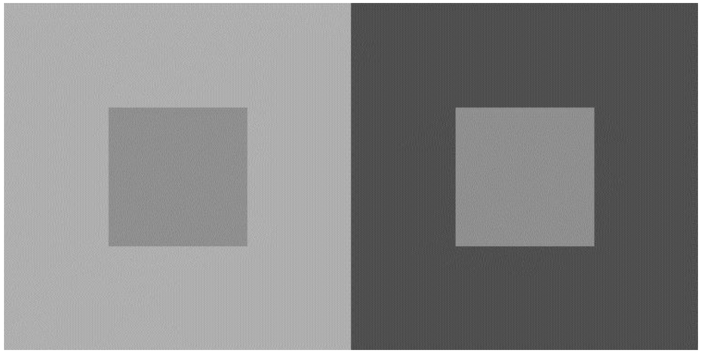
Stimulus Size	Series Order: Descending	Ascending	Descending	Ascending
15			y	
14	y		y	
13	y	y	y	
12	y	n	y	y
11	y	n	y	n
10	n	n	n	n
Crosspoint	10.5	12.5	10.5	11.5

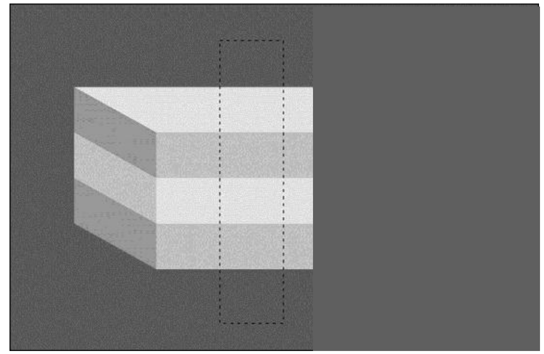
Hysteresis

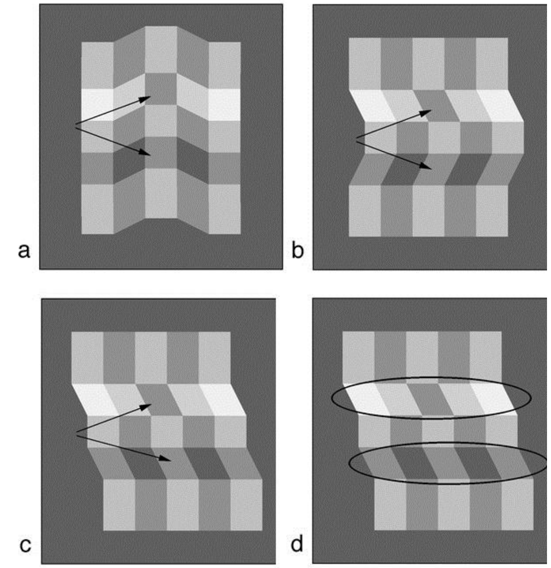
Descending threshold= (10.5+ 10.5)/2= 10.5

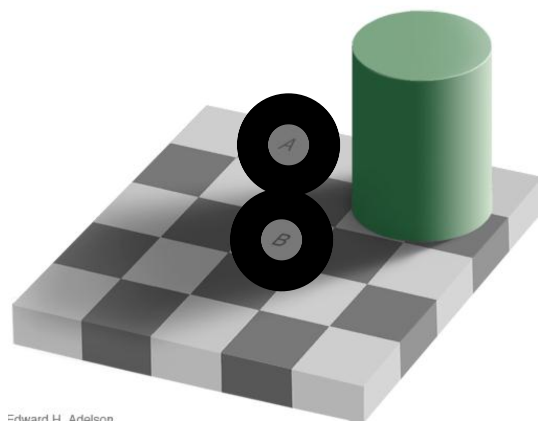
Ascending threshold= (12.5+ 11.5)/2= 12.0

Absolute threshold= (10.5+ 12.0)/2= 11.25

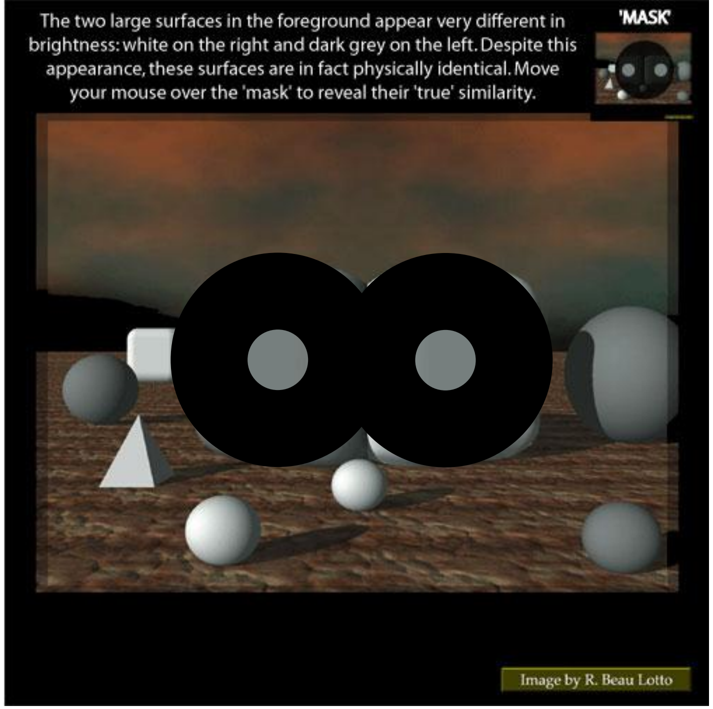


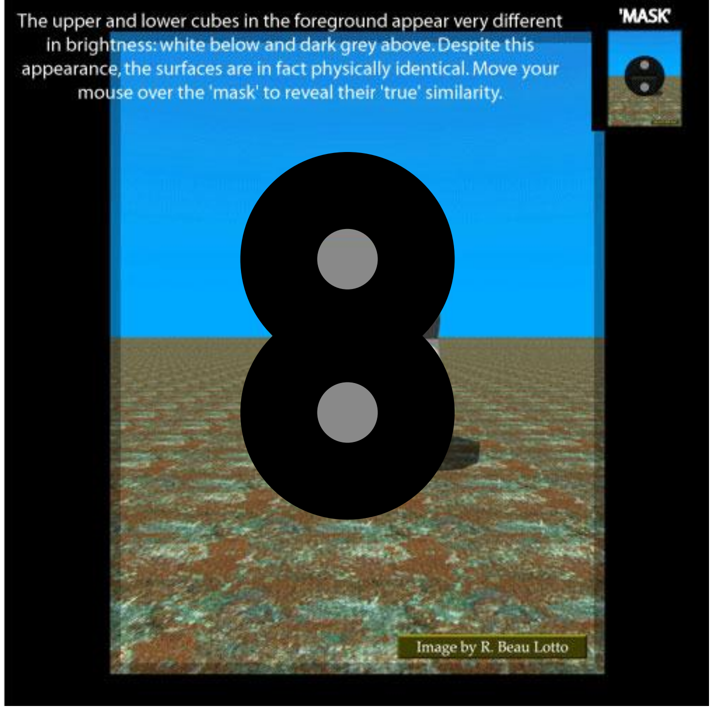




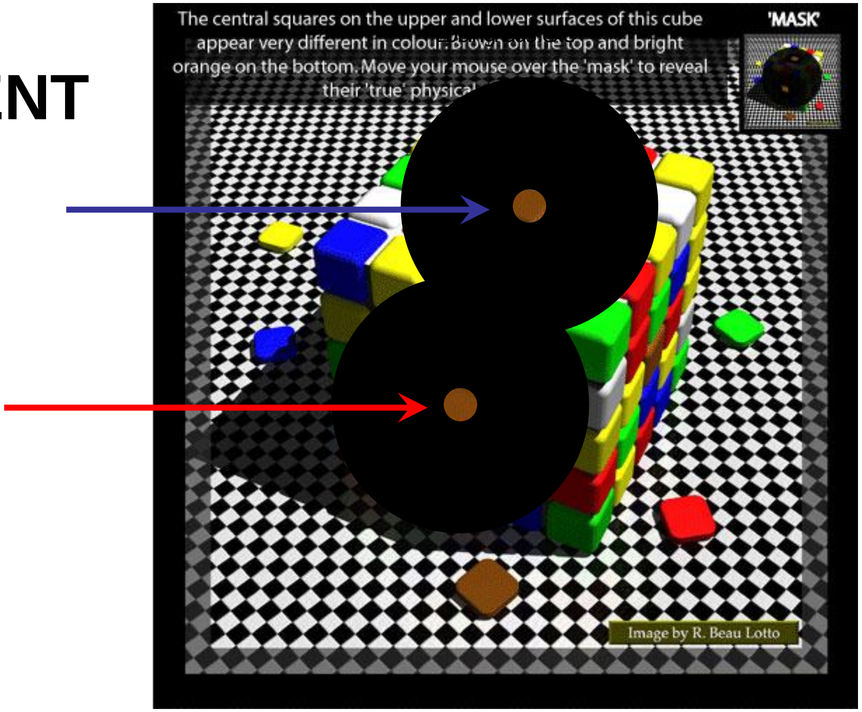


Adelson, E. H. (1993). Perceptual organization and the judgment of brightness. *Science*, **262**, 2042–4.


The two large surfaces in the foreground appear very different in brightness: white on the right and dark grey on the left. Despite this appearance, these surfaces are in fact physically identical. Move your mouse over the 'mask' to reveal their 'true' similarity.
'MASK'
Image by R. Beau Lotto


The upper and lower cubes in the foreground appear very different in brightness: white below and dark grey above. Despite this appearance, the surfaces are in fact physically identical. Move your mouse over the 'mask' to reveal their 'true' similarity.
'MASK'
Image by R. Beau Lotto

AJUSTEMENT

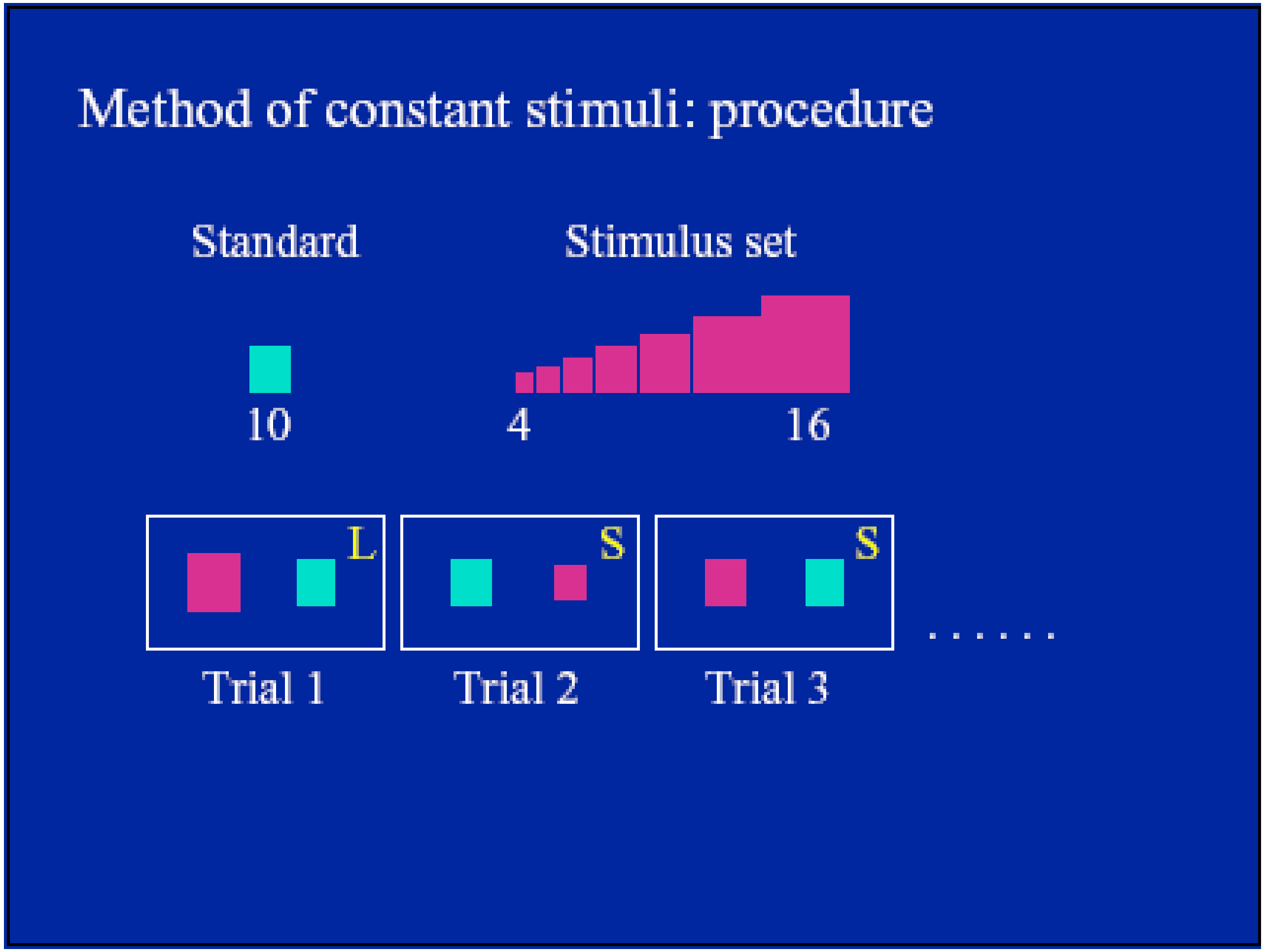

The central squares on the upper and lower surfaces of this cube appear very different in colour. Brown on the top and bright orange on the bottom. Move your mouse over the 'mask' to reveal their 'true' physica
'MASK'
Image by R. Beau Lotto

ADJUSTEMENT & METHOD OF LIMITS

Sources of response bias

- habituation
- anticipation
- adaptation
- **purely subjective (bias)**

CONSTANT STIMULI



CONSTANT STIMULI

Method of constant stimuli: analysis

Stimulus Size	Judgment Frequency Larger	Smaller	Total	Proportion of Judgments Larger	Smaller
4	4	96	100	0.04	0.96
6	6	44	50	0.12	0.88
8	32	68	100	0.32	0.68
10	56	44	100	0.56	0.44
12	69	31	100	0.69	0.31
14	89	11	100	0.89	0.11
16	48	2	50	0.96	0.04

METHODES ADAPTATIVES

- **Levitt**
- **QUEST**

The only unknown is threshold, which is treated as a random variable, X, to be estimated. The experimenter supplies an initial guess, by specifying the mean and SD of a Gaussian probability density function. For the reader's convenience, we supply a one-line simulation of an observer with threshold *tActual*, so the program can be run on its own. To run a real experiment, that line must be replaced by code that presents a stimulus (at intensity x) and collects the observer's response (1 if right, 0 if wrong). After each response, the probability density function, q, is updated by Bayes's rule. Each trial is placed at x, the current maximum-probability estimate of threshold, i.e. the mode. The final threshold estimate is also the mode.

REGLES UP-DOWN DE L'ESCALIER PSYCHOPHYSIQUE

Levitt. H. (1971). Transformed Up-Down methods in psychoacoustics. *J. Acoust. Soc. Am. 49*, 467-477.

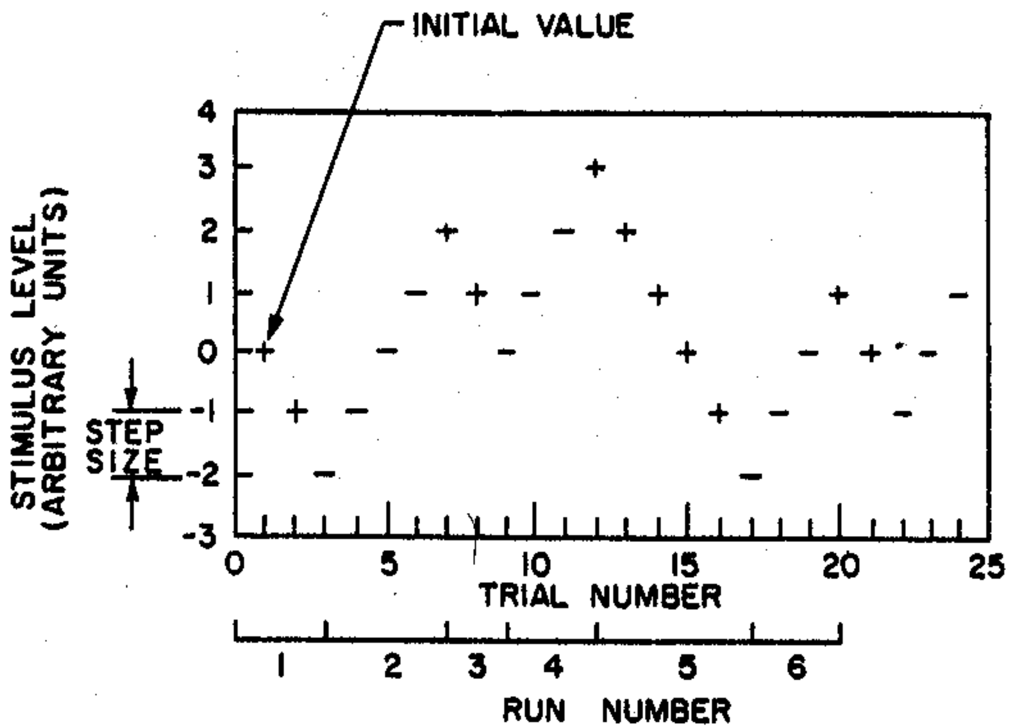


FIG. 4. Typical data for simple up–down procedure. A typical set of data using a fixed step size is shown. The initial value is usually the best *a priori* estimate of X_{50}. A run consists of a sequence of changes in stimulus level in one direction only. A highly efficient estimation procedure is to use the midpoint of every second run as an estimate of X_{50}. These estimates would be 0, 1.5, and −0.5 for runs 2, 4, and 6, respectively.

REGLES UP-DOWN DE L'ESCALIER PSYCHOPHYSIQUE

Levitt. H. (1970). Transformed Up-Down methods in psychoacoustics. *J. Acoust. Soc. Am. 49*, 467-477.

TABLE I. Response groupings for transformed up–down strategies. Several simple response groupings are shown. Entry 1 corresponds to the simple up–down procedure. Entry 2 corresponds to the method used by Zwislocki *et al*. (1968) and Heinemann (1961). Entries 2 and 3, and 5 and 6, with random interleaving, were used by Levitt (1964). Entry 7 is typical of the BUDTIF procedure proposed by Campbell (1963). Entry 8 was used by Levitt and Rabiner (1967).

Entry	Response sequences: UP group increase level after:	Response sequences: DOWN group decrease level after:	Response groupings: Probability of a sequence from DOWN group = $P[\text{DOWN}]$	Response groupings: Probability of positive response at convergence
1	−	+	$P(X)$	$P(X)=0.5$
2	+ − or −	+ +	$[P(X)]^2$	$P(X)=0.707$
3	− −	− + or +	$[1-P(X)]P(X)+P(X)$	$P(X)=0.293$
4	+ + − or + − or −	+ + +	$[P(X)]^3$	$P(X)=0.794$
5	+ + + − or + + − or + − or −	+ + + +	$[P(X)]^4$	$P(X)=0.841$
6	− − − −	− − − + or − − + or − + or +	$1-[1-P(X)]^4$	$P(X)=0.159$
7	Any group of 4 responses with 1 or more negative responses	+ + + +	$[P(X)]^4$	$P(X)=0.841$
8	− − − + − + − −	+ + + − + − + +	$[P(X)]^2[3-2P(X)]$	$P(X)=0.5$

UP-DOWN STAIRCASE RULES

(a) At what stimulus level should the staircase start?

(b) How big the step-size should be?

(c) When to stop testing?

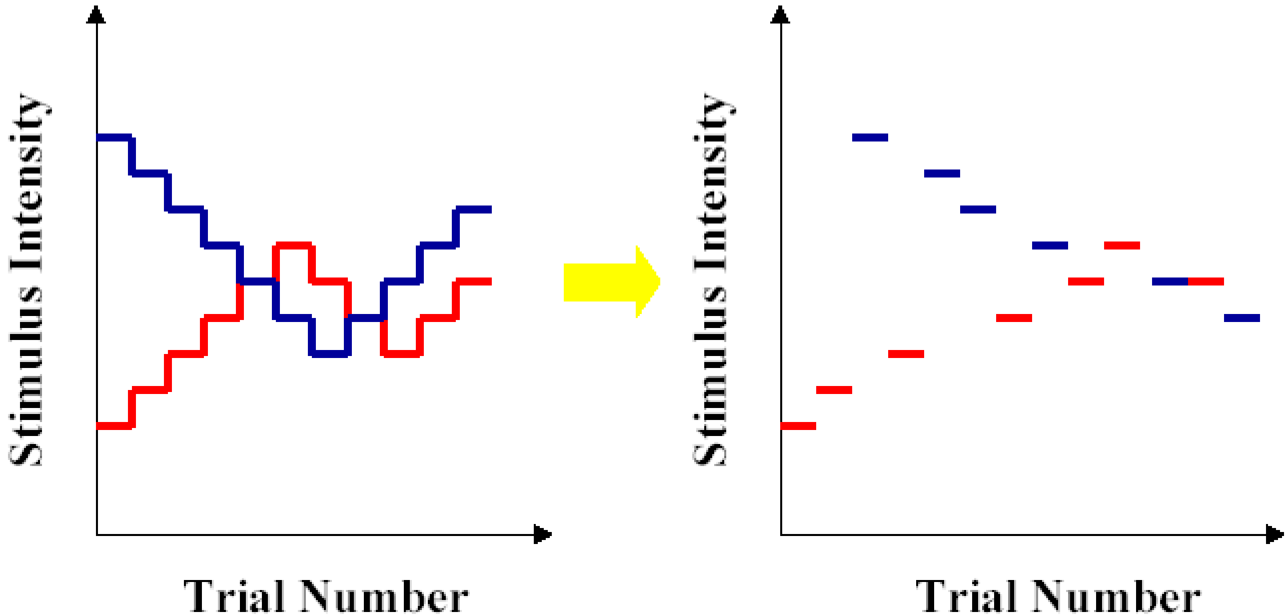
(a) Starting at vertical is unwise because the subject could merely guess randomly, even with eyes shut, and would nicely track around vertical. Starting well right or left of vertical is also unwise for three reasons. **First**, a subject responding "L,L,L,L,L,L ...." will become anxious because subjects expect to say L and R about equally often (response frequency equalization) and may therefore throw in an "R" based on bias rather than perception. **Second**, a long string of L or R stimuli could cause adaptation. **Third**, long strings are inefficient because the only information of use to the experimenter comes from reversal at peaks or valleys. **Fourth**, even if the starting point was a long way from the true PSV, a bad or lazy subject could just guess randomly and produce a nice oscillation around the starting point that actually had no relation to that subject's PSV.

The way to solve this problem is to run two staircases simultaneously, randomly switching from one to the other, with one starting way L and the other way R. You could do this by having two staircase grids in front of you and randomly moving from one to the other. This means: Not only have we solved the starting level problem; but have now removed the obvious sequential dependency of the trial *n* stimulus on the trial *n-1* response. Within each staircase this dependence remains; but the random interleaving of the two staircases conceals it from the subject!

(b) If it is too big, then the subject will simply oscillate between L and R giving no real estimate. If the step size is too small, say 0.005 deg, then the method becomes inefficient because there will be long strings of L or R without reversals; and remember that this will also worry the subject. To choose step size, one way is to run pilot experiments to find out what is a good size. Another way is to choose a size roughly equal to the standard deviation(s) of the statistic being measured.

(c) Consider that we would like to base every subject's PSV estimate on the identical number of measures. What are the measures which enter into the estimate? They are not trials but reversals. Hence, the thing to do is to select a fixed number of reversals. All subjects will then have the same number of reversals but more variable subjects will need more trials to reach that criterion.

ESCALIERS PSYCHOPHYSIQUES INTERCALÉS



- Ascending method of limits: controls adaptation level
- Forced choice method: detects random guessing
- Tracking: quick and dirty screening
- Staircase methods: efficient

SCALING (MAGNITUDE ESTIMATION)

Types of psychophysical scales

- nominal (categories)
- ordinal (sequences)
- interval (distances)
- ratio (magnitudes)

Psychophysical scaling methods

Indirect methods

- categorical rating
- confusion scaling

Direct methods

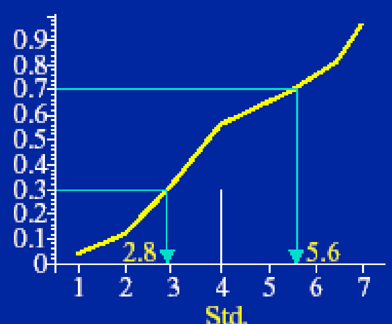
- fractionation
- magnitude estimation

Indirect scaling methods

Categorical Rating

Cat.	Description
7	Much much larger than
6	Much larger than
5	Larger than
4	As large as
3	Smaller than
2	Much smaller than
1	Much much smaller than

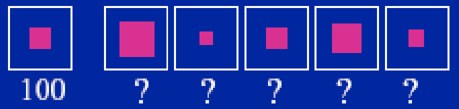
Confusion Scaling



Direct scaling methods

Fractionation

Magnitude estimation

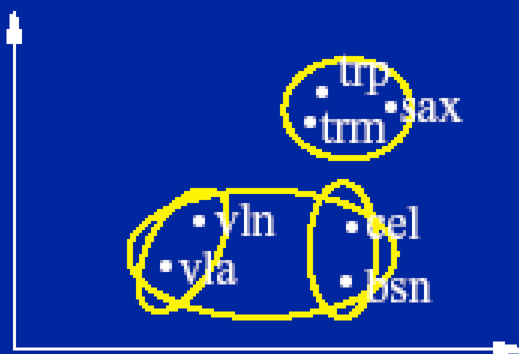


MULTIDIMENSIONAL SCALING

Multidimensional scaling

Similarity Matrix

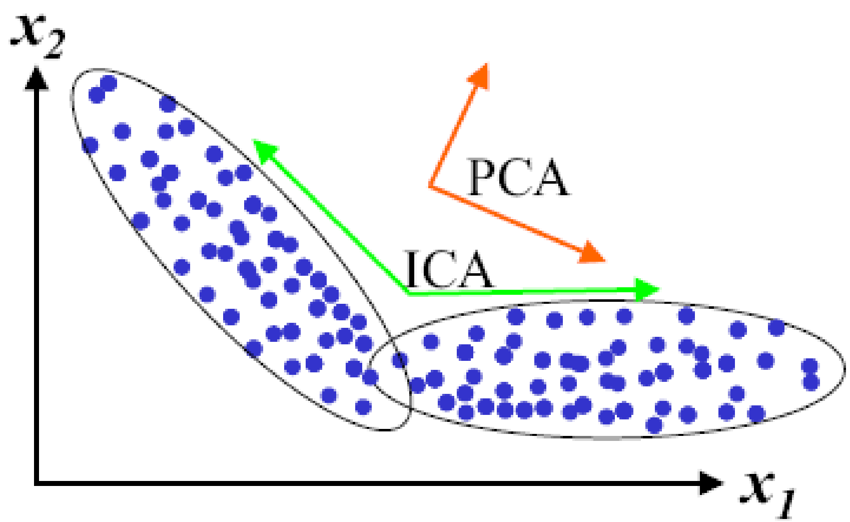
Trumpet	1.0						
Violin		1.0					
Trombone			1.0				
Saxophone		0.3		1.0			
Cello					1.0		
Bassoon	0.6			0.8		1.0	
Viola			0.7				1.0
	Trp	Vln	Trm	Sax	Cel	Bsn	Vla



PRINCIPAL & INDEPENDENT COMPONENT ANALYSIS

PCA:
- Decorrelated
- Orthogonal

ICA:
- Statistically Independent



PCA

ICA

Image removed due to copyright considerations. See Figure 1 in:
Baek, Kyungim, et. al. "PCA vs. ICA: A comparison on the FERET data set." International Conference of Computer Vision, Pattern Recognition, and Image Processing, in conjunction with the 6th JCIS. Durham, NC, March 8-14 2002, June 2001.

EXPERIMENTAL DESIGN

- Choice of stimulus levels/categories (linear, log)
- Ordered (learning) vs. Random stimulus levels/categories
- Balanced/unbalanced groups
- Within- vs. Across-subjects experimental designs…

Assess / test *Weber law*

Dans quel ordre va-t-on présenter les différents niveaux ?

- *En ordre croissant / descendant ?*
- *Tirés au hasard ?*

(NB. Sti Csts requièrent la randomisation.)

Comment doit-on choisir les différents niveaux ?

- *Sur une échelle linéaire ?*
- *Logarithmique ?*

SOME CLASSICAL EXPERIMENTAL PARADIGMES

- **Adaptation & Selective adaptation (Blakemore & Campbell, 1968)**
- **Masking (channels, critical bands)**
- **Subliminal summation (King-Smith & Kulikowski, 1974)**
- **Combined detection & identification measurements (Watson & Robson, 1981)**
- **Uncertainty manipulations (Pelli, 1985)**
- **Priming & stimulus interference (e.g. Stroop)**

- ***Psychophysics as Psycho-Anatomy (Julesz)***

Dark Adaptation

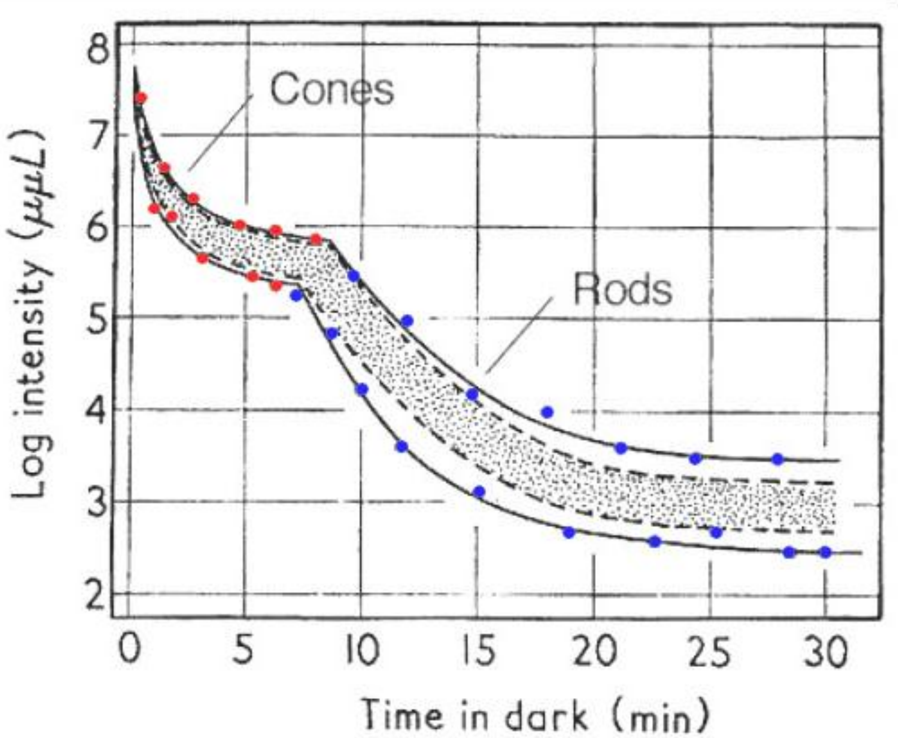


Figure 1. Dark adaptation curve. The shaded area represents 80% of the group of subjects. Hecht and Mandelbaum's data from From Pirenne M. H., Dark Adaptation and Night Vision. Chapter 5. In: Davson, H. (ed), The Eye, vol 2. London, Academic Press, 1962.

Hecht, 1937; Stiles, 1939; Rushton, 1961

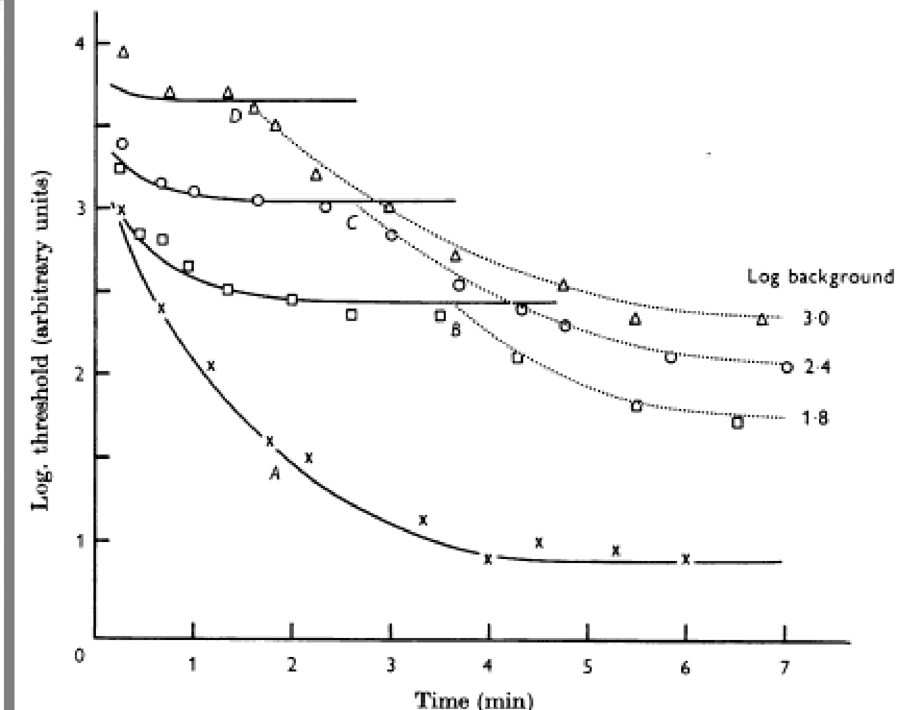
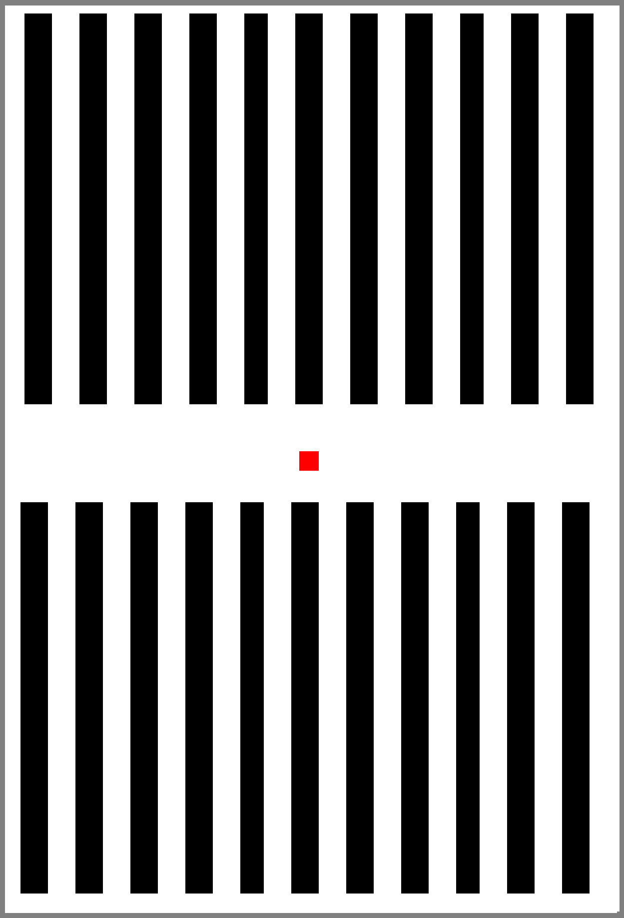


Fig. 2. Dark adaptation curves for a blue test-flash after a white bleach: Curve *A*: threshold measured in the dark; *B–D*: test presented on a yellow-green background of intensities: 1·8 *B*, 2·4 *C*, and 3·0 *D* log. units, these units being the same as for the backgrounds in Fig. 1*a*. Solid curves: predictions derived from Fig. 3.

Du Croz &. Rushton, J. Physiol., 1966.

SF Adaptation



Adapted from Blakemore & Sutton, 1969.

Selective SF Adaptation

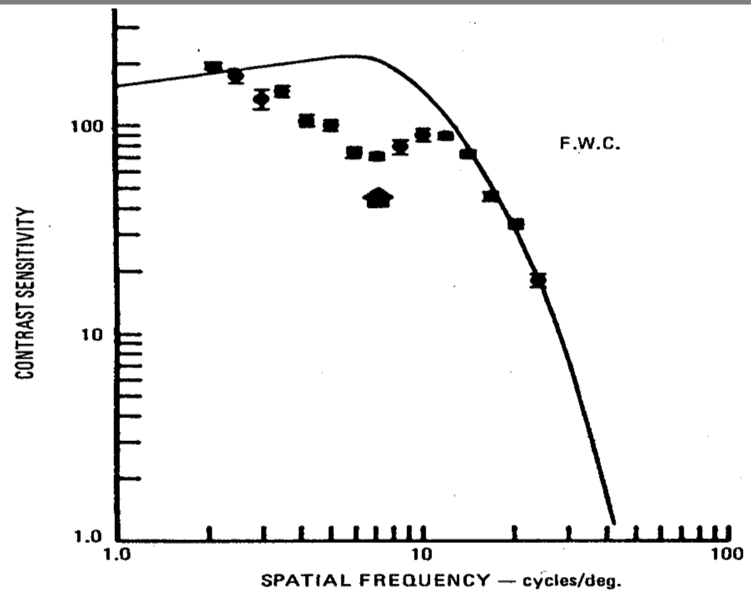


FIGURE 14. Adapted and unadapted contrast sensitivity functions from which Blakemore and Campbell[13] calculated the threshold elevation curve shown in Figure 13. 1969

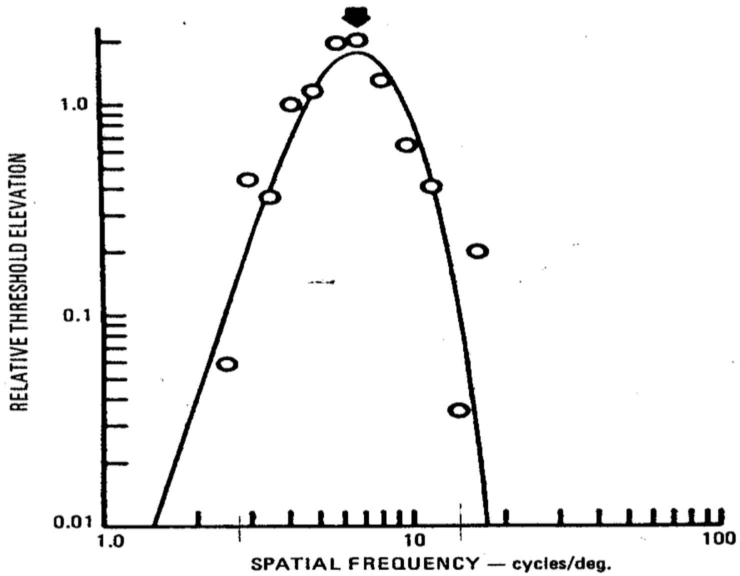
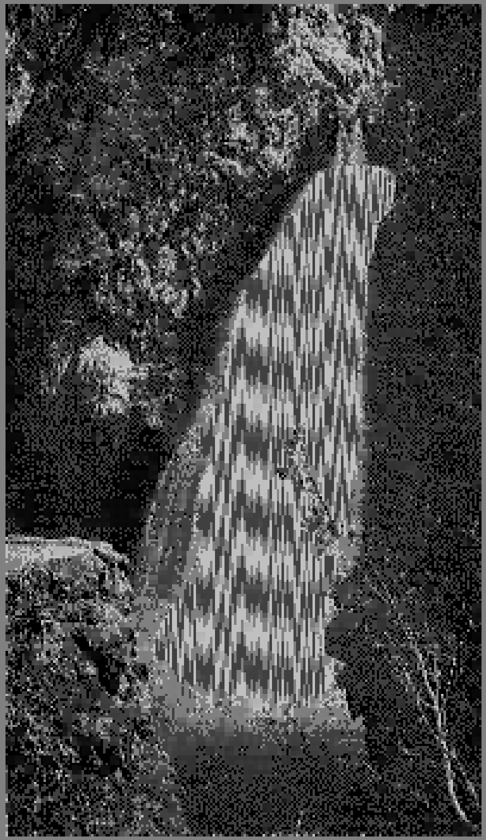
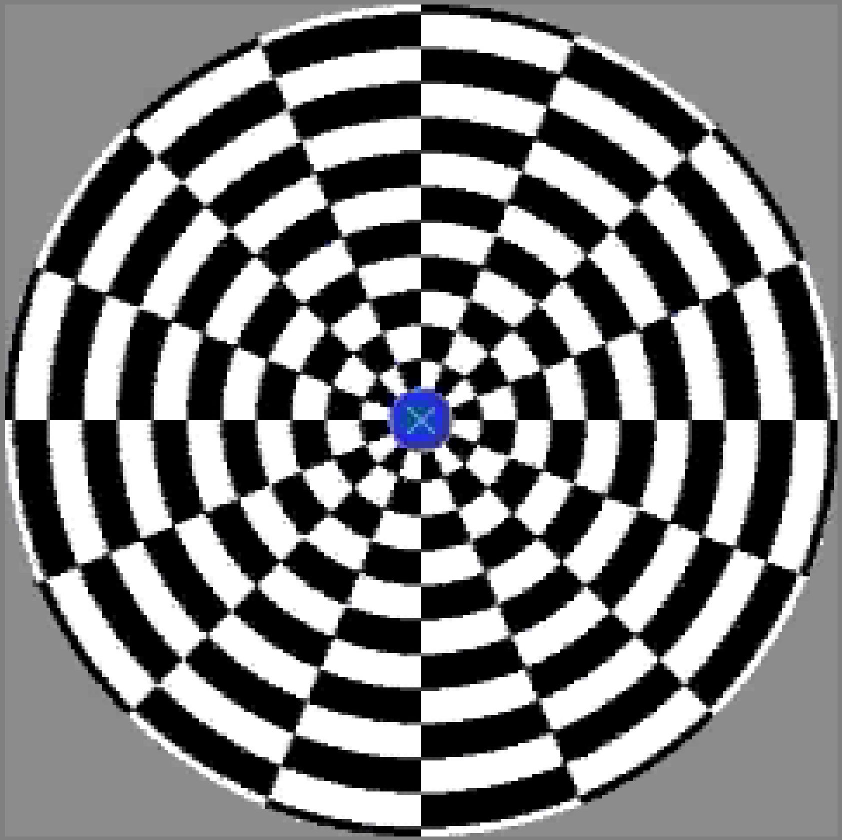


FIGURE 13. Threshold elevation ratios produced by adaptation to a (7.1 c/degree) sine-wave grating. Data from Blakemore and Campbell. 1969

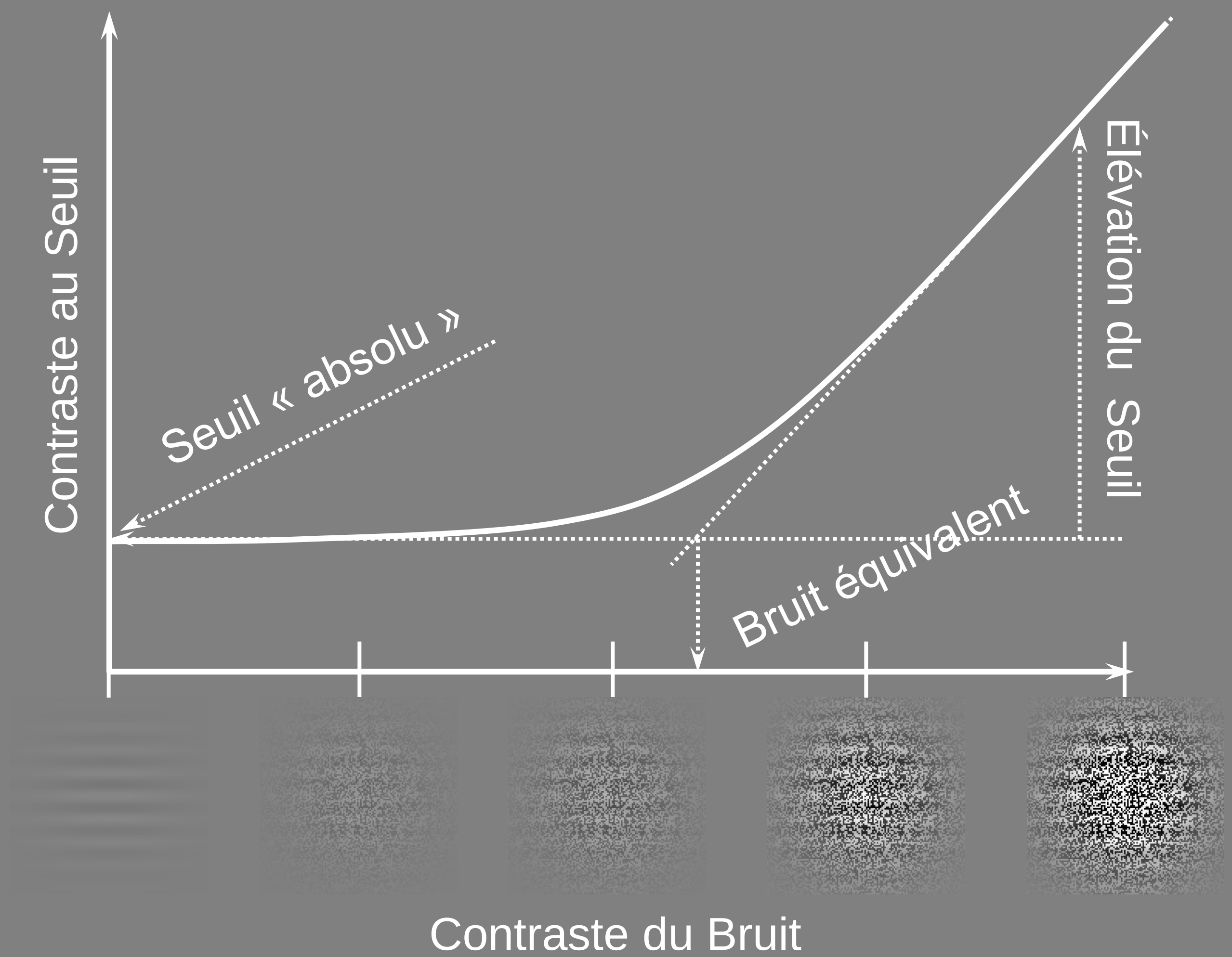
Blakemore and Campbell, 1969

Motion Adaptation



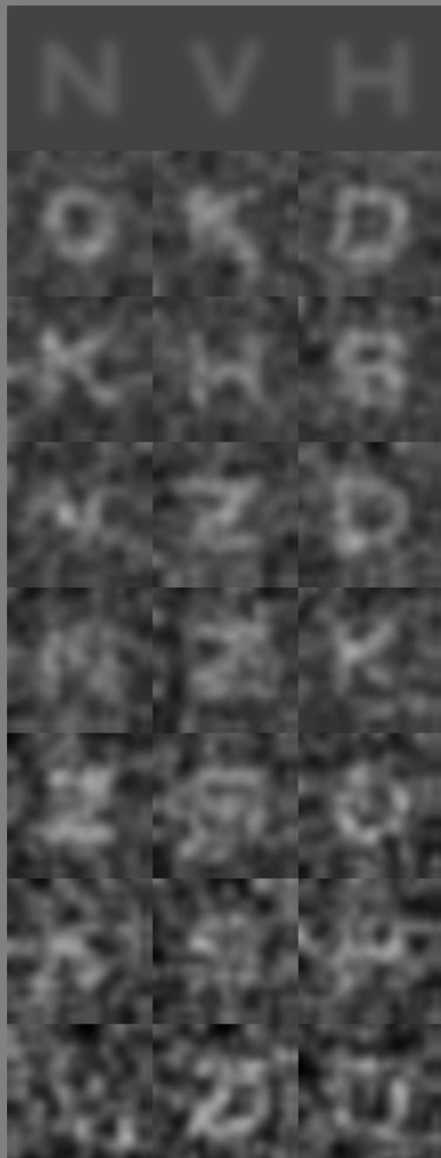


Masking



Contraste au Seuil
Seuil « absolu »
Élévation du Seuil
Bruit équivalent
Contraste du Bruit

Masking

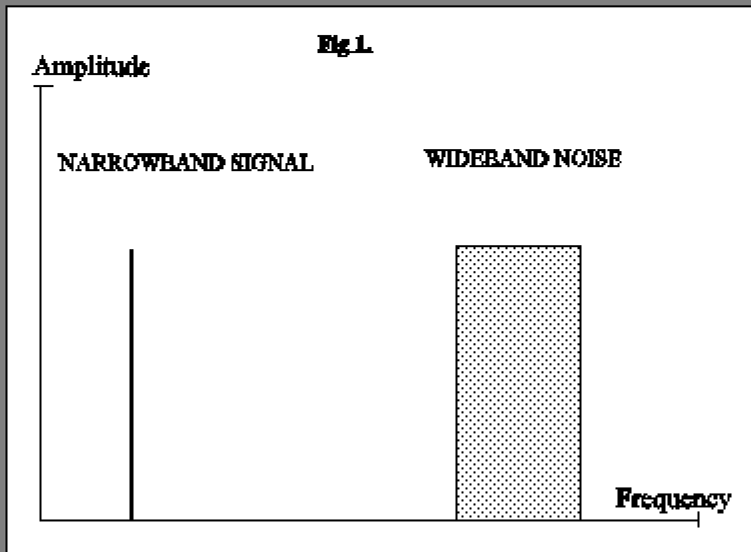


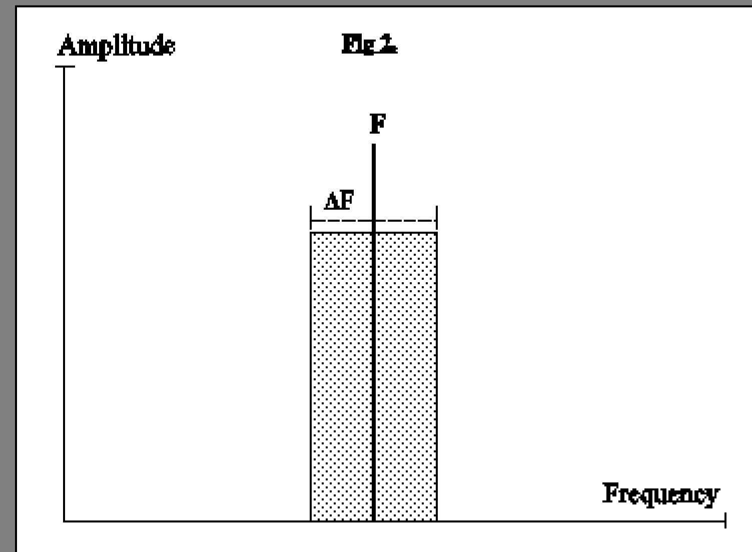
A visual assessment chart consisting of letters in noise that is designed to test for some neural deficits while being unaffected by optical deficits.

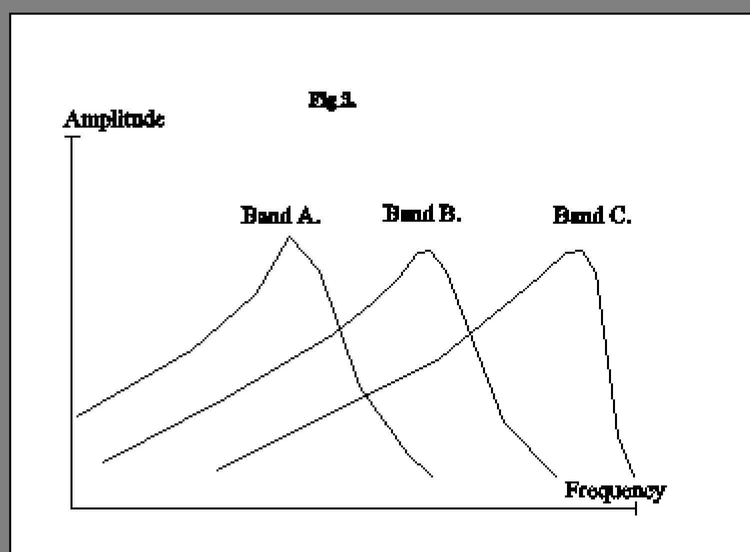
Denis Pelli (NYU, USA) & John Hoepner (Depart. of Opthalmology, Health Science Center, Syracuse, NY, USA.)

http://viperlib.york.ac.uk/scripts/PortWeb.dll?field=keywords&op=contains&value1=noise&template=thumbs_details&join=or&field2=imageDescription&op=contains&value2=noise&sorton=Filename&catalog=proto1&submit2.x=0&submit2.y=0&submit2=Search

Masking & Critical bands

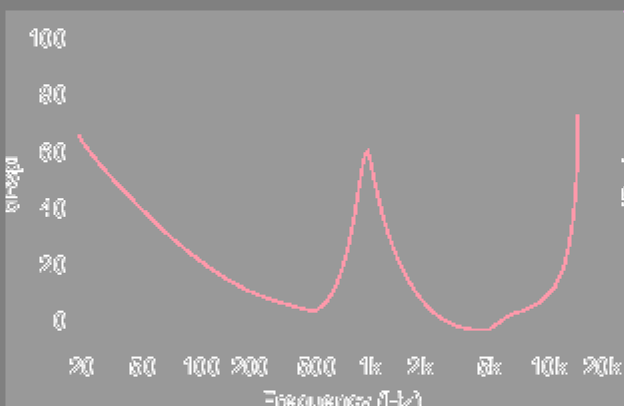




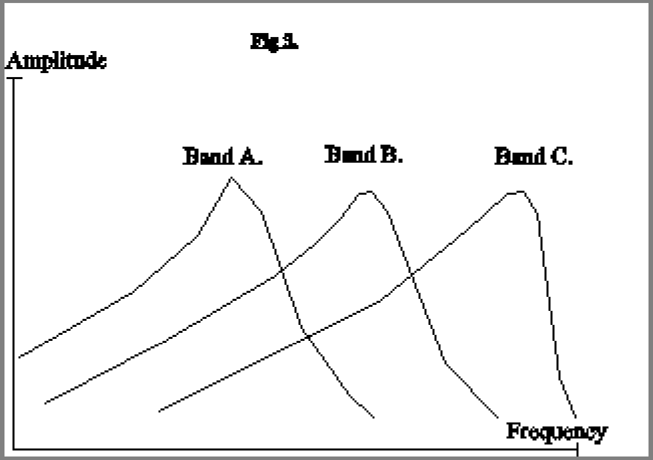


Masking & Critical bands

Threshold of hearing curve
in a quiet environment.

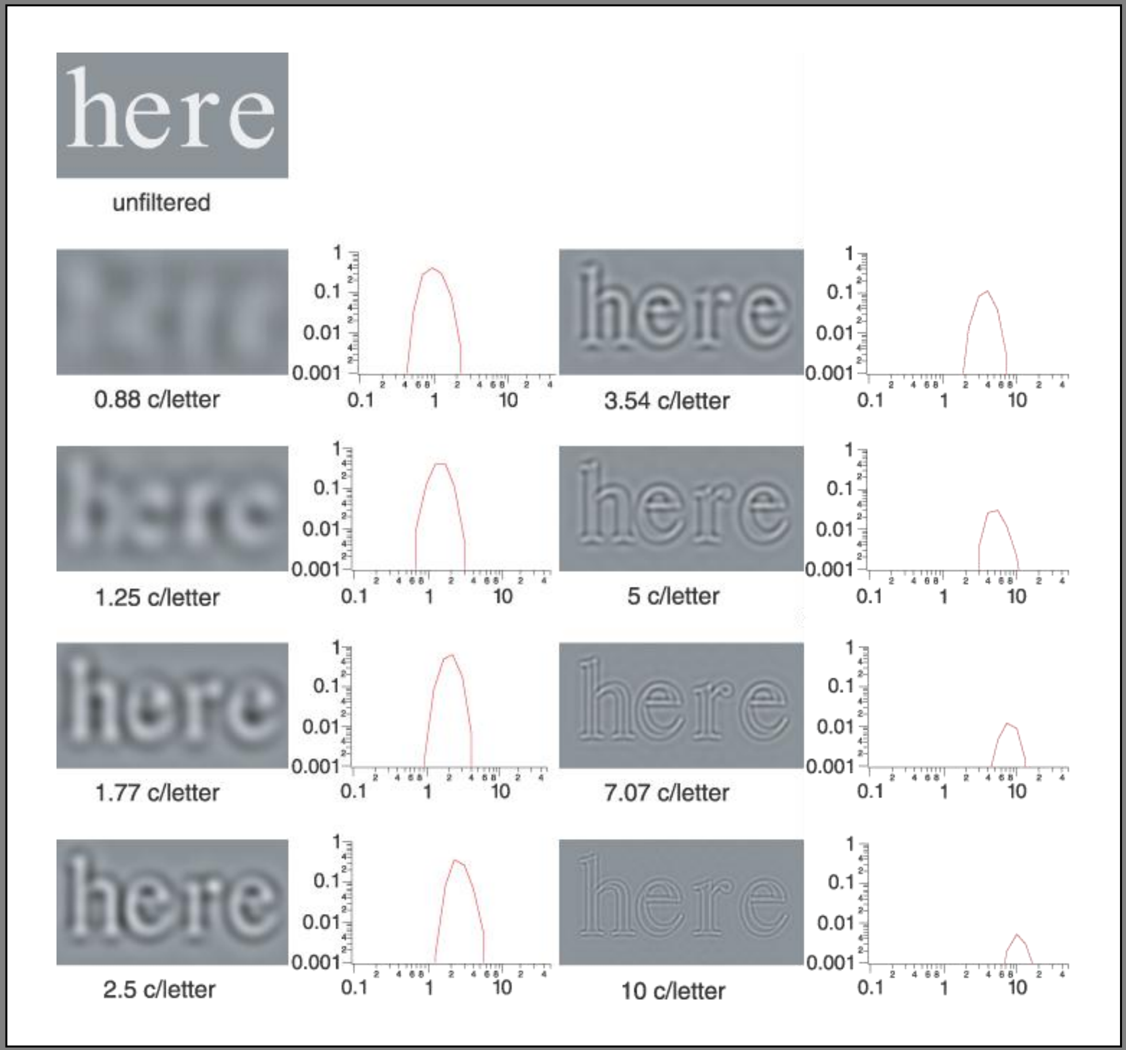


Threshold of detection curve in the presence of a masking noise with a bandwidth equal to the critical bandwidth, a centre frequency of 1 kHz and a level of 60 dBspl.



Zwicker and Fastl, 1999.

Filtering



Chung & Tjan (2009). Spatial-frequency and contrast properties of reading in central and peripheral vision. *Journal of Vision 9*(9), 16, 1-19.

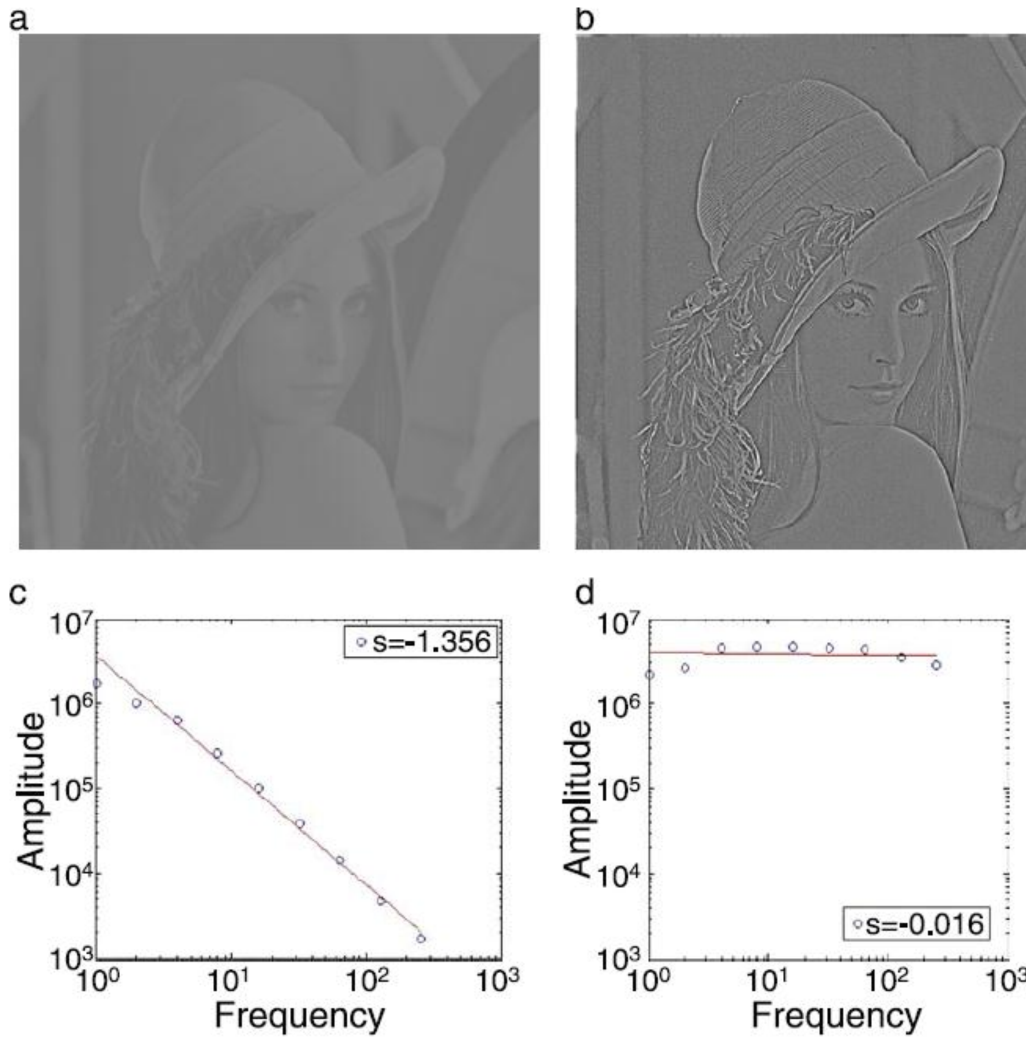
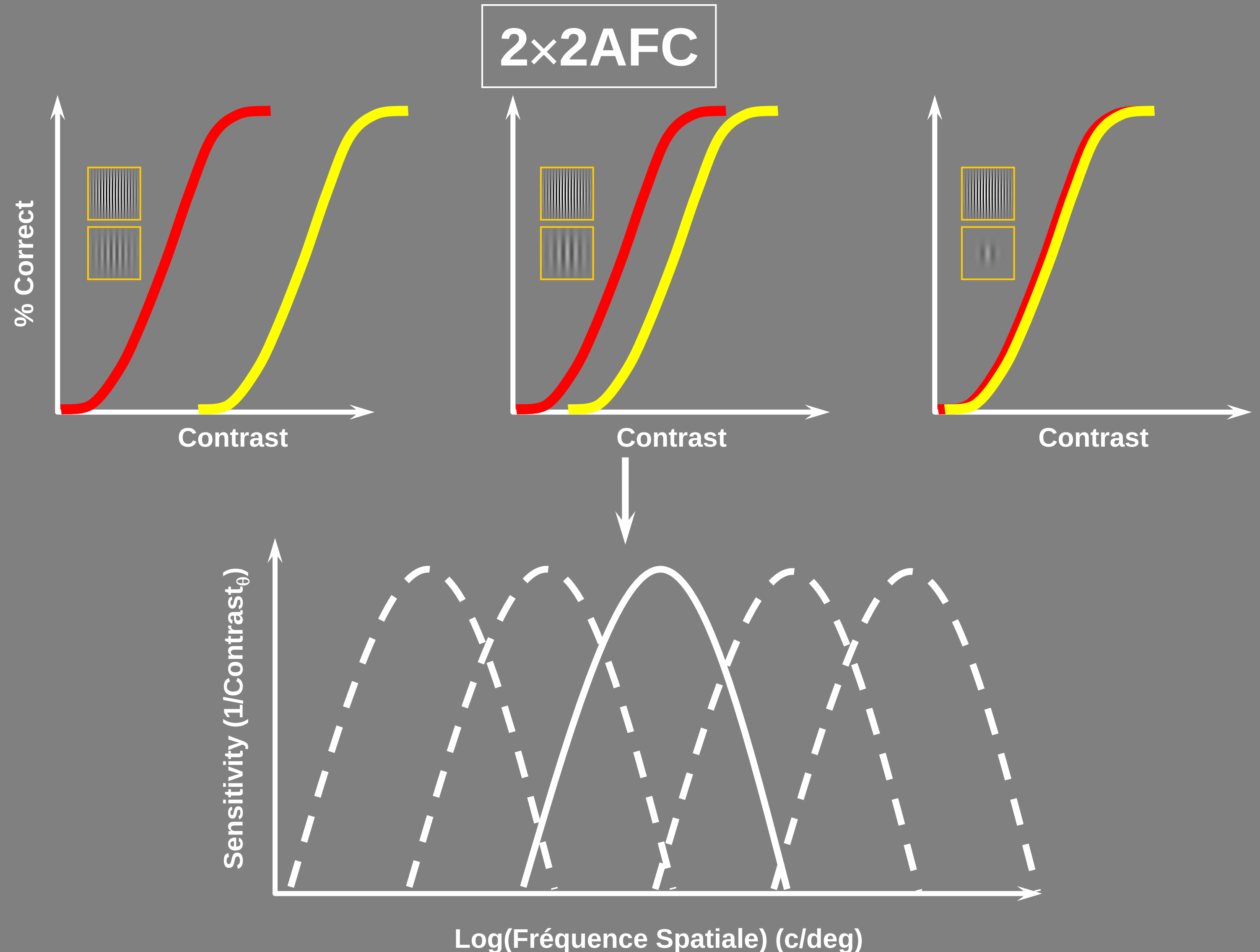


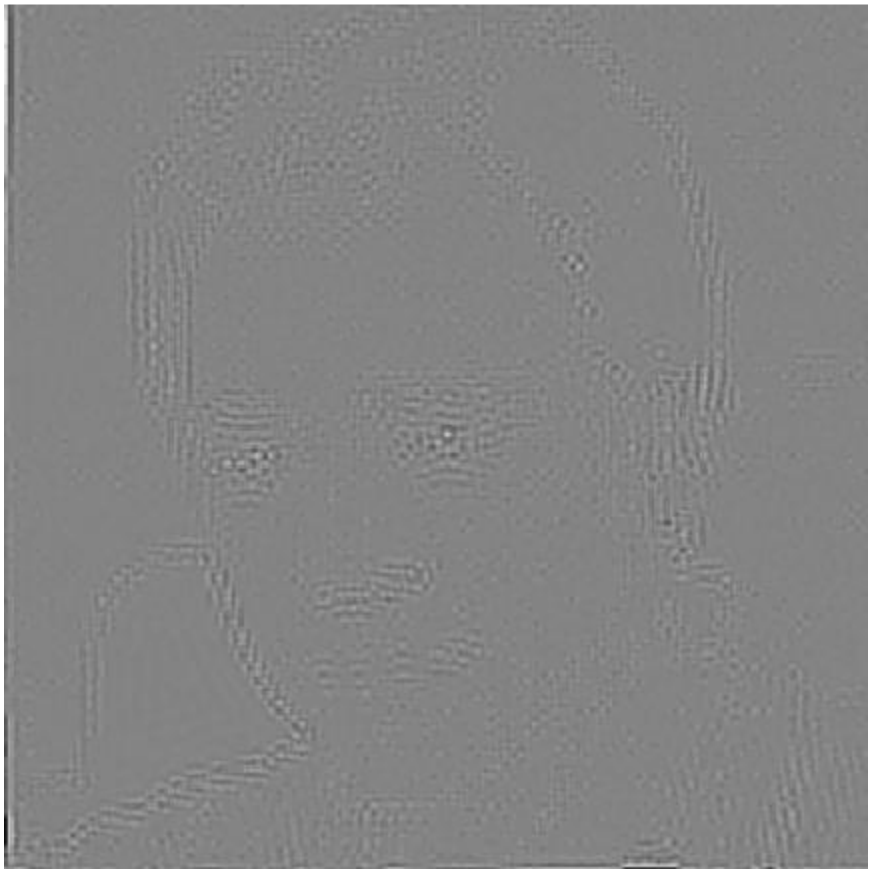
Figure 4. Illustration of spatial whitening. (a) A natural image whose amplitude spectrum, plotted in (c), falls approximately as "1/F" on log–log axes with a slope of j1.4. Whitening the amplitude spectrum produces an image (b) that appears sharpened, but otherwise structurally quite similar. (d) The amplitude spectrum of the whitened image has approximately the same amplitude at all spatial frequencies and a resultant spectral slope close to 0. The rms contrasts of the source and whitened images have been fixed at 0.25.

Bex, Solomon & Dakin, (2009). Journal of Vision, 9(10):1, 1–19.

Critical Band : Detection vs. Identification

(Watson & Robson, 1985)





Spatial Frequency filtering of a face

Spatial Frequency and Orientation filtering of a face

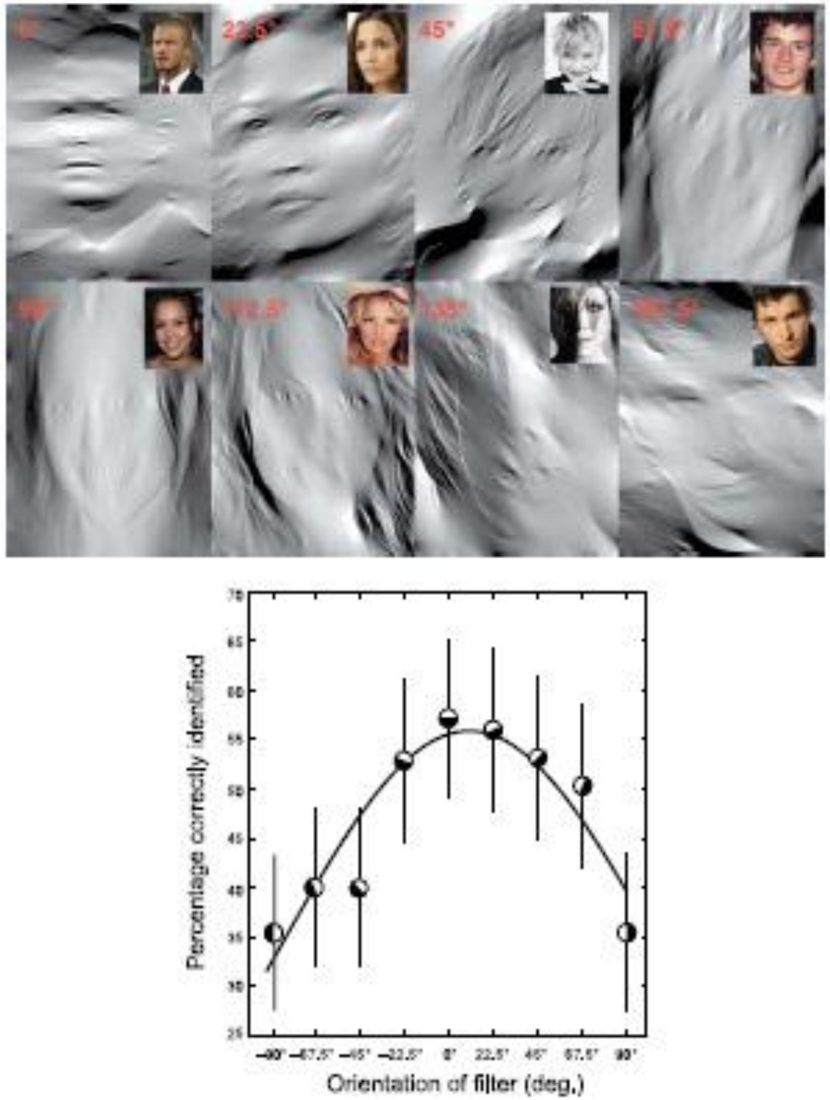
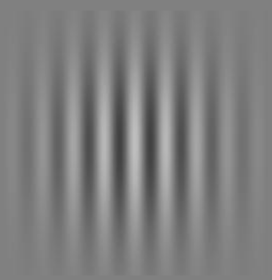


Figure 3. (Top) Stimuli from the psychophysical experiment. Each panel shows a face stimulus filtered to a single orientation band (indicated in red) along with the source image (top-right color inset in each panel). (Bottom) Percentage correct identification of filtered images as a function of orientation information (solid line shows the least-squares-fit of a Gaussian function).

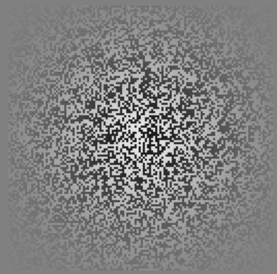
Dakin & Watt (2009). Biological “bar codes” in human faces. *Journal of Vision*, *9*(4):2, 1-10.

Reverse correlation
(Ahumada & Lovell, 1971)

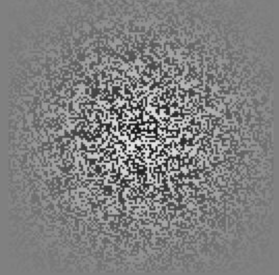


+

White noise

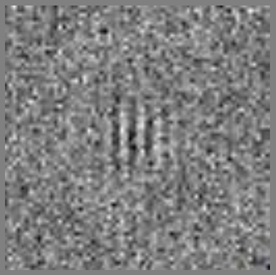


=



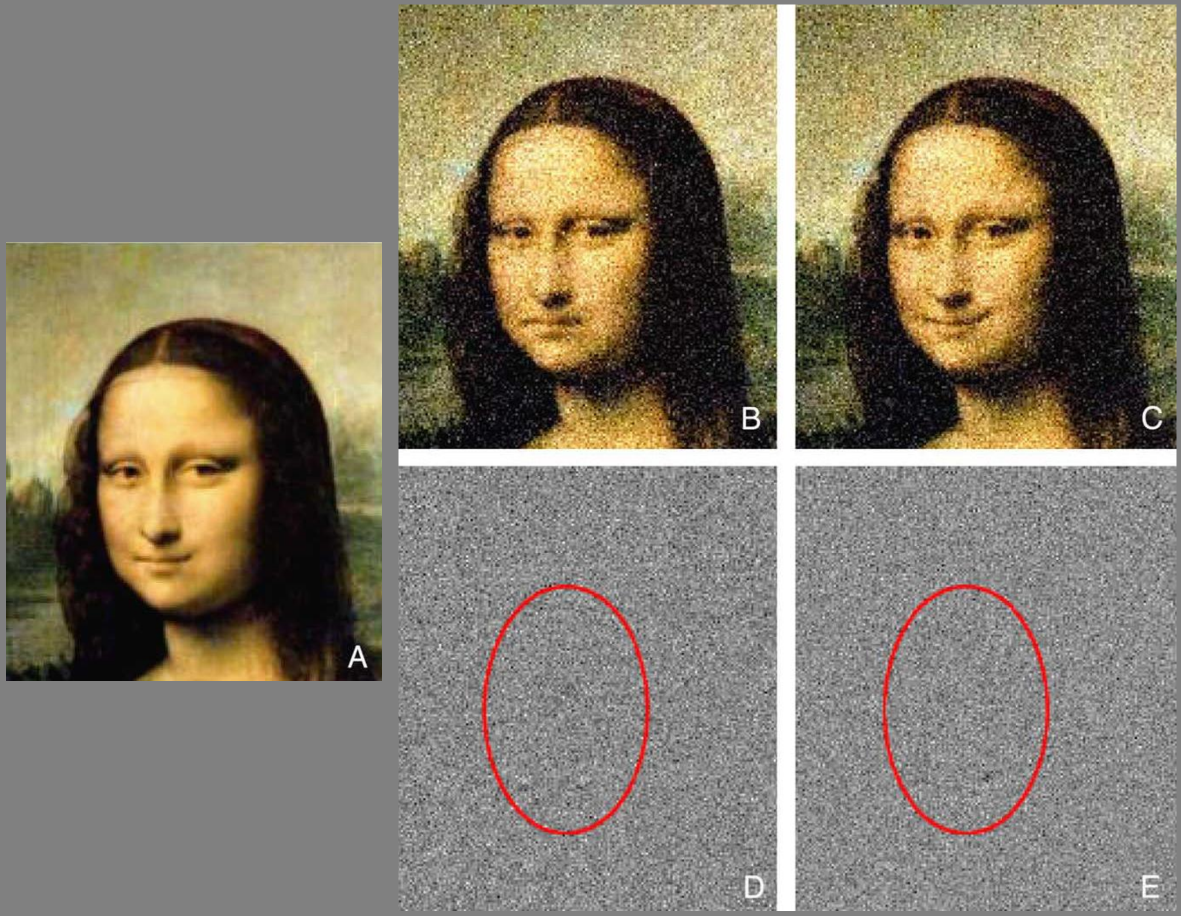
	Response	
	Yes	No
S + N	Hits	Misses
N	FA	CR

$$\frac{\sum_{i}^{n_H} N_{i,H}}{n_H} + \frac{\sum_{i}^{n_{FA}} N_{i,FA}}{n_{FA}} - \frac{\sum_{k}^{n_M} N_{k,M}}{n_M} - \frac{\sum_{l}^{n_{CR}} N_{l,CR}}{n_{CR}} \Rightarrow$$



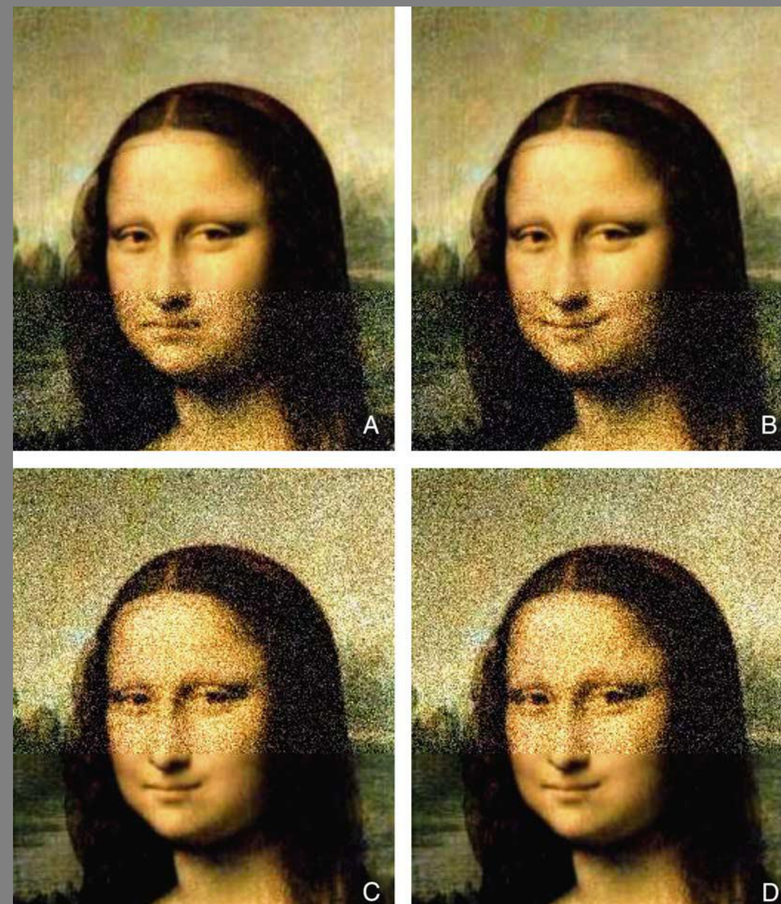
See *Journal of Vision*, 2002, Vol. 2

Reverse correlation
(Kontsevich & Tyler, 2004)



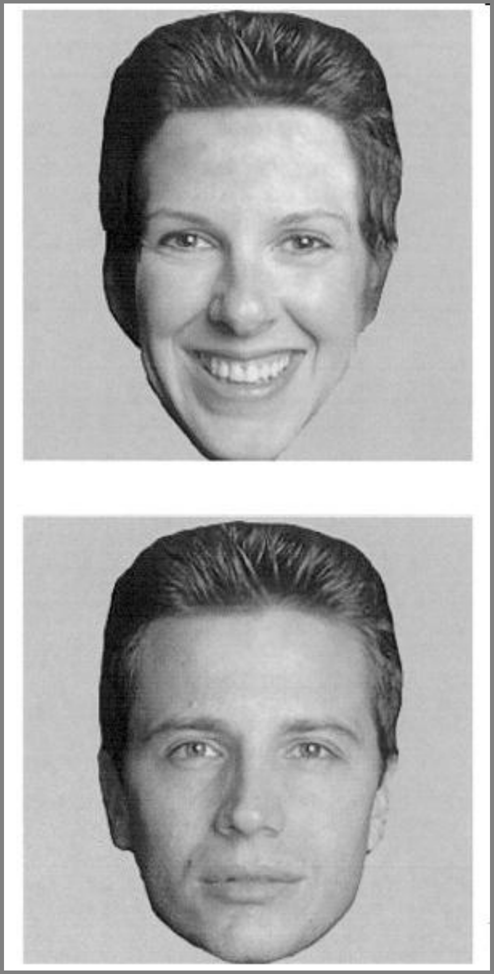
Kontsevich, L. & Tyler, C.W. (2004). What makes Mona Lisa smile? *Vision Res. 44,* 1493-1498.

Reverse correlation
(Kontsevich & Tyler, 2004)



Kontsevich, L. & Tyler, C.W. (2004). What makes Mona Lisa smile? *Vision Res. 44,* 1493-1498.

Masking with bubbles
(Gosselin & Schyns, 2001)



Gosselin, F & Schyns, F.G. (2001). Bubbles: a technique to reveal the use of information in recognition tasks. *Vision Res., 41*, 2261-2271.

Masking with bubbles
(Gosselin & Schyns, 2001)

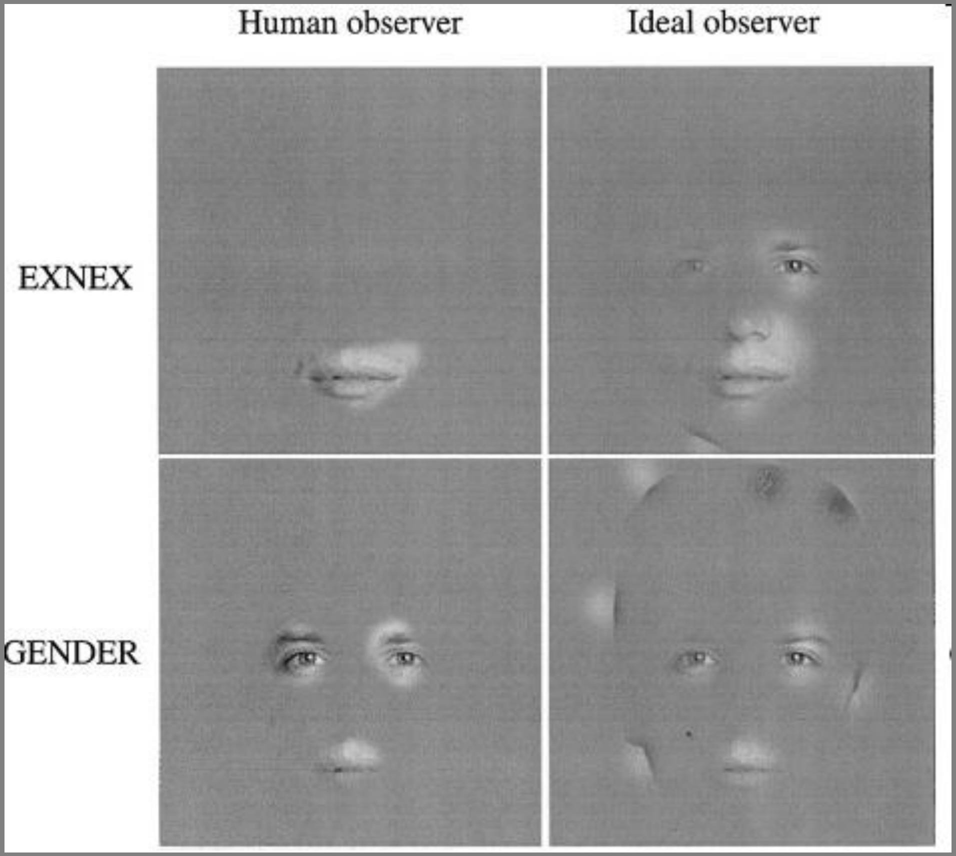


Fig. 2. This figure illustrates diagnostic face information for judging whether a face is expressive or not (EXNEX), or its gender (GENDER). The pictures are the outcome of Bubbles in the EXNEX and GENDER categorizations of experiment 1 on human (left column) and ideal observers (right column).

Gosselin, F & Schyns, F.G. (2001). Bubbles: a technique to reveal the use of information in recognition tasks. *Vision Res., 41*, 2261-2271.

Masking with bubbles
(Gosselin & Schyns, 2001)

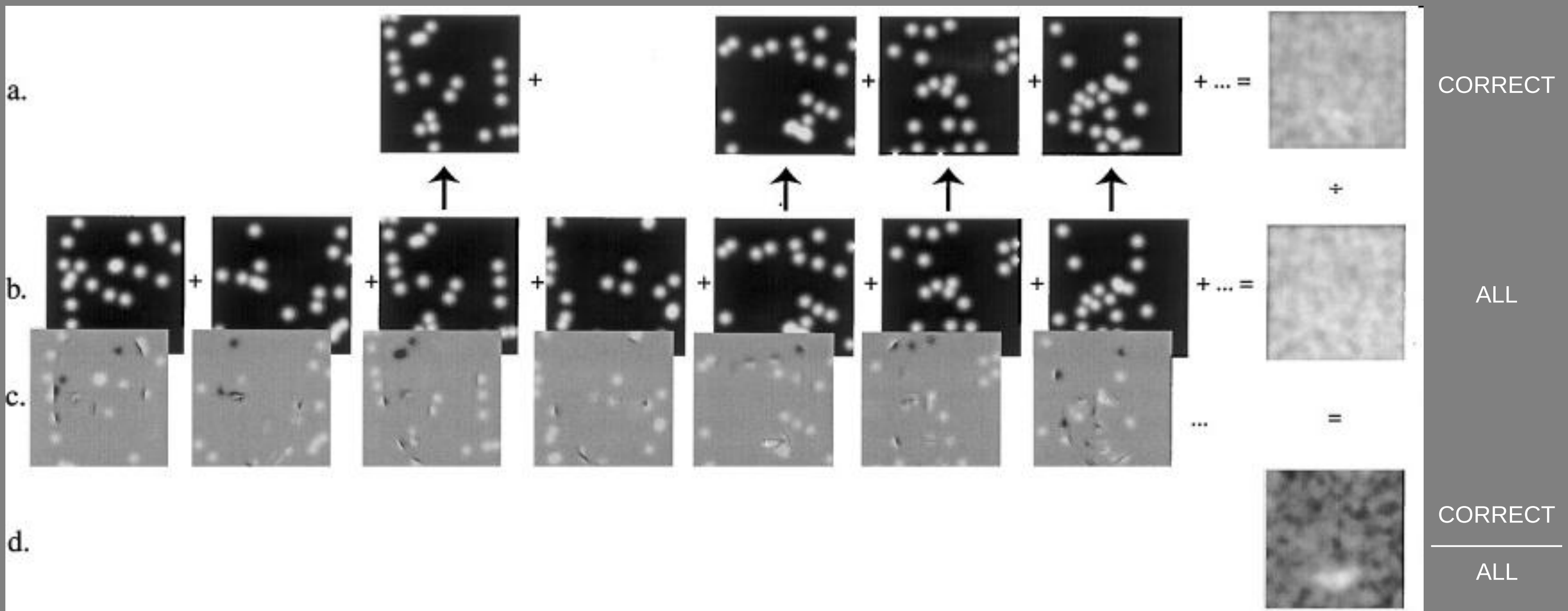


Fig. 3. This figure illustrates Bubbles in experiment 1 for the EXNEX task. In (a), the bubbles leading to a correct categorization are added together to form the CorrectPlane (the rightmost greyscale picture). In (b), all bubbles (those leading to a correct and incorrect categorizations) are added to form TotalPlane (the rightmost greyscale picture). In (c), examples of experimental stimuli as revealed by the bubbles of (b). It is illustrative to judge whether each sparse stimulus is expressive or not. ProportionPlane (d) is the division of CorrectPlane with TotalPlane. Note the whiter mouth area (the grey scale has been renormalized to facilitate interpretation). See Fig. 2 for the outcome of experiment 1.

Gosselin, F & Schyns, F.G. (2001). Bubbles: a technique to reveal the use of information in recognition tasks. *Vision Res., 41*, 2261-2271.

Masking with bubbles

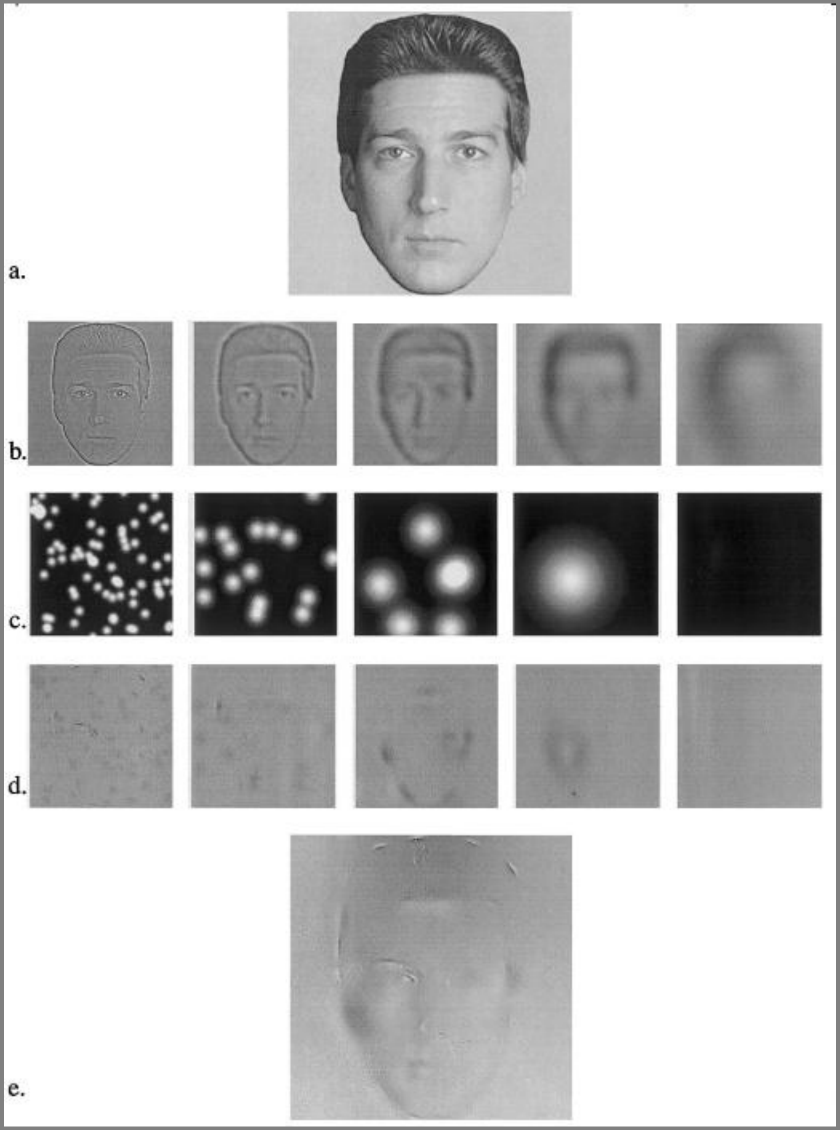
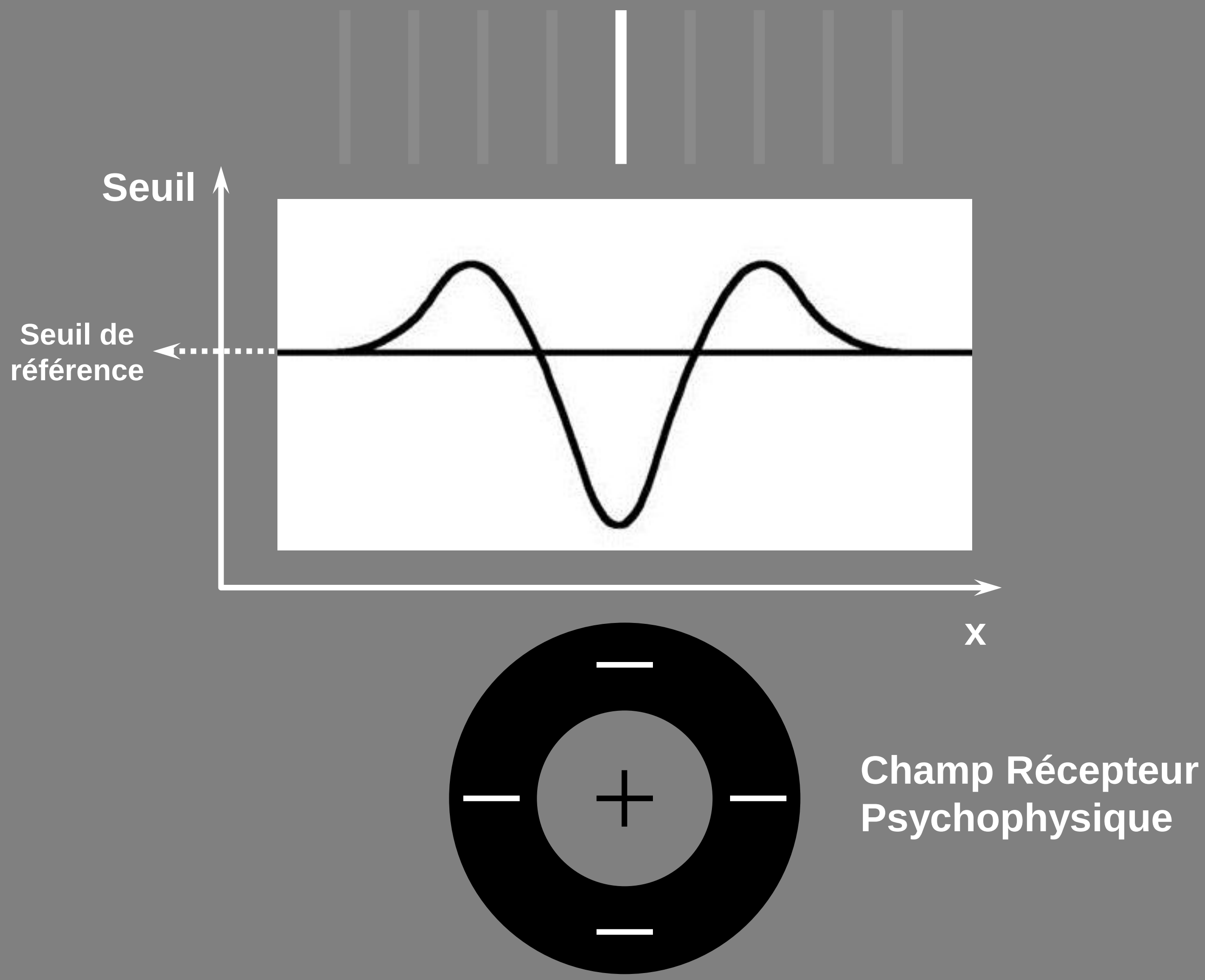


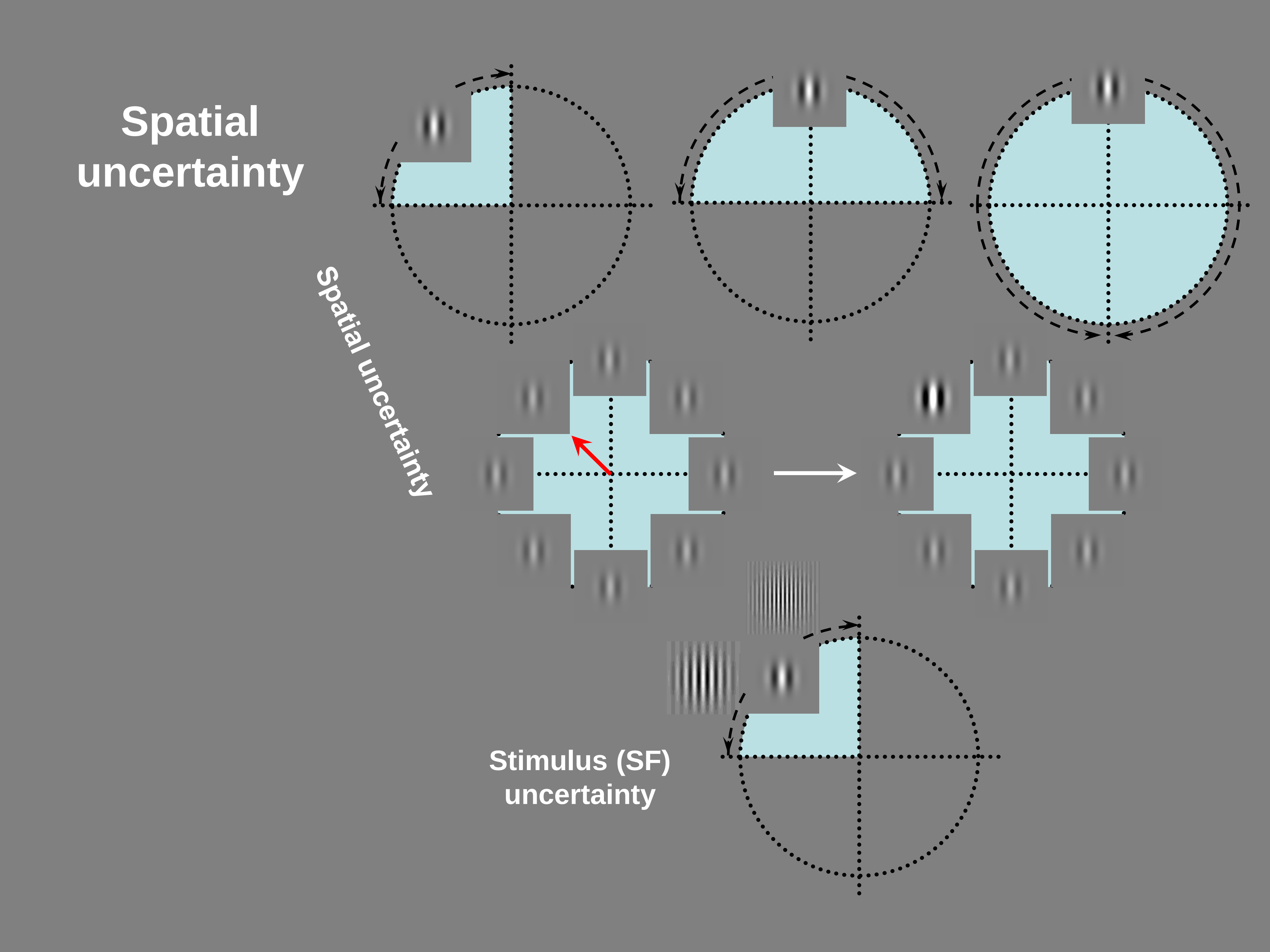
Fig. 4. This figure illustrates the application of Bubbles in experiment 2. Pictures in (b) represent five different scales of (a); (c) illustrate the bubbles applied to each scale; (d) are the revealed information of (b) by the bubbles of (c). Note that on this trial there is no revealed information at the fifth scale. By integrating the pictures in (d) we obtain (e), a stimulus subjects actually saw.

Gosselin, F & Schyns, F.G. (2001). Bubbles: a technique to reveal the use of information in recognition tasks. *Vision Res., 41*, 2261-2271.

Subliminal summation



Kulikowski, J.J. & King-Smith, P.E. (1973). *Vision Res. 13,* 1455-1478.


Spatial uncertainty
Spatial uncertainty
Stimulus (SF) uncertainty

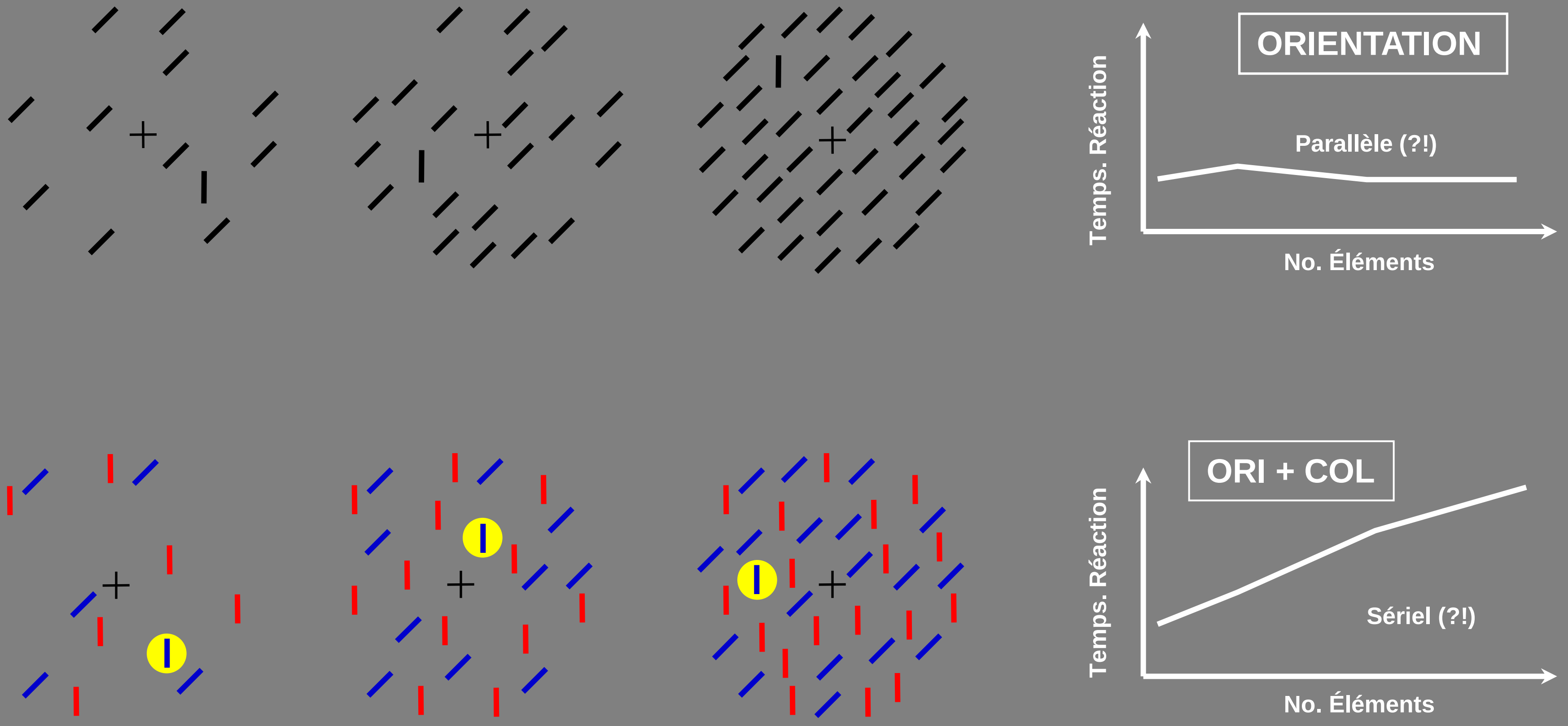
Manipulation de l'incertitude

Le foulard vert parmi tant de rouges *saute aux yeux*

Manipulation de l'incertitude

Mais la calvitie d'un tel parmi tant de tignasses…
il faut la chercher

Visual search

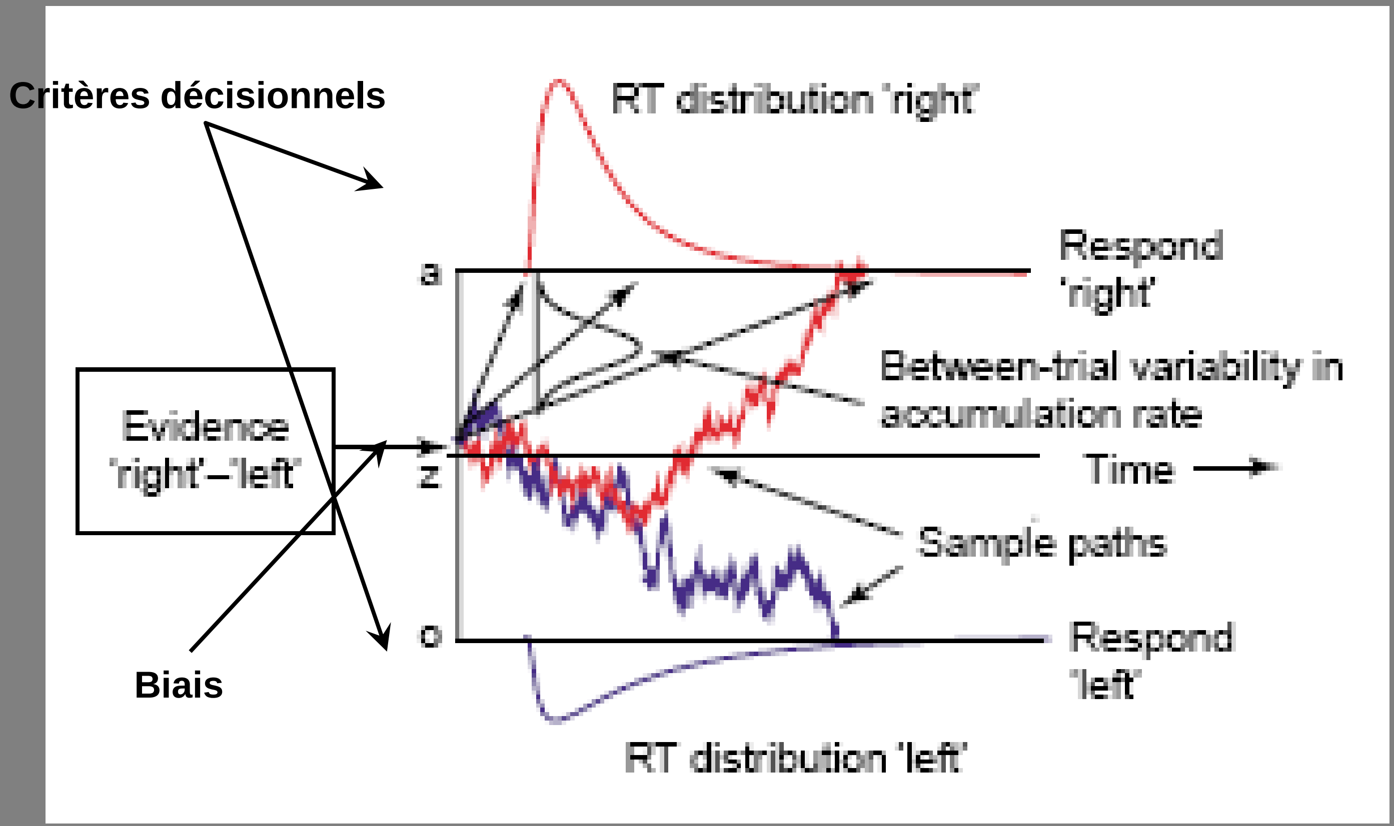


Treisman A.M. & Gelade G. (1980)

Quelques mots sur les

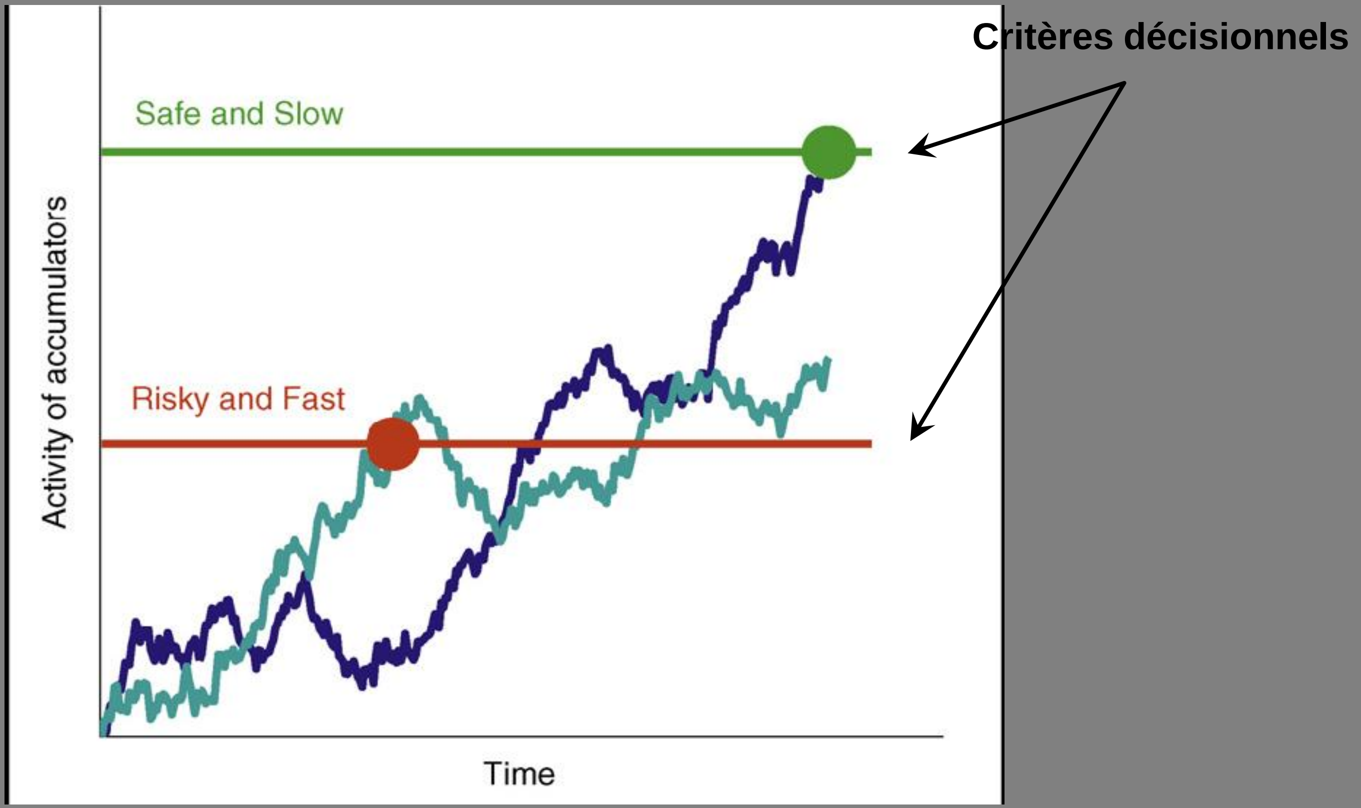
Temps de Réponse

Diffusion race models



Smith, P.L. & Ratcliff, R. (2004). Psychology and neurobiology of simple decisions. *Trends in Neurosci., 27*, 161-168.

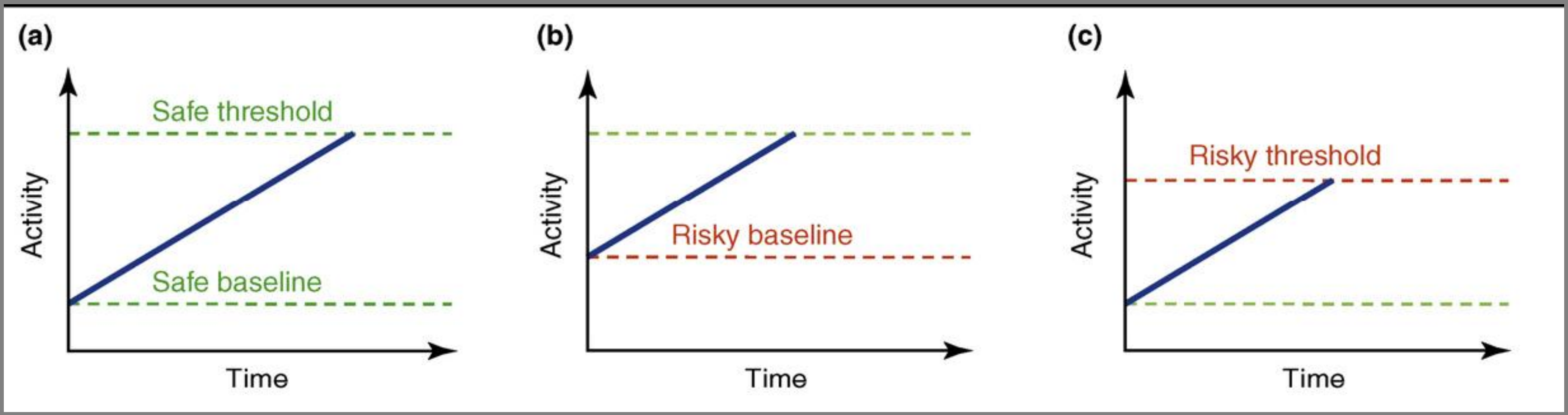
Diffusion race models
Speed Accuracy Tradeoff



An accumulator model account of SAT. The figure shows a **simulation of a choice between two alternatives**. The model includes **two accumulators**, whose activity is shown by blue lines. The inputs to both accumulators are noisy, but the input to the accumulator shown in **dark blue has a higher mean, because this accumulator represents the correct response**. Lowering the threshold (horizontal lines) leads to faster responses at the expense of an increase in error rate. In this example, the green threshold leads to a correct but relatively slow response, whereas the red threshold leads to an incorrect but relatively fast response.

Bogacz, Wagenmakers, Forstmann & Nieuwenhuis (2010).
Trends in Neurosci., 33(1), 10-16.

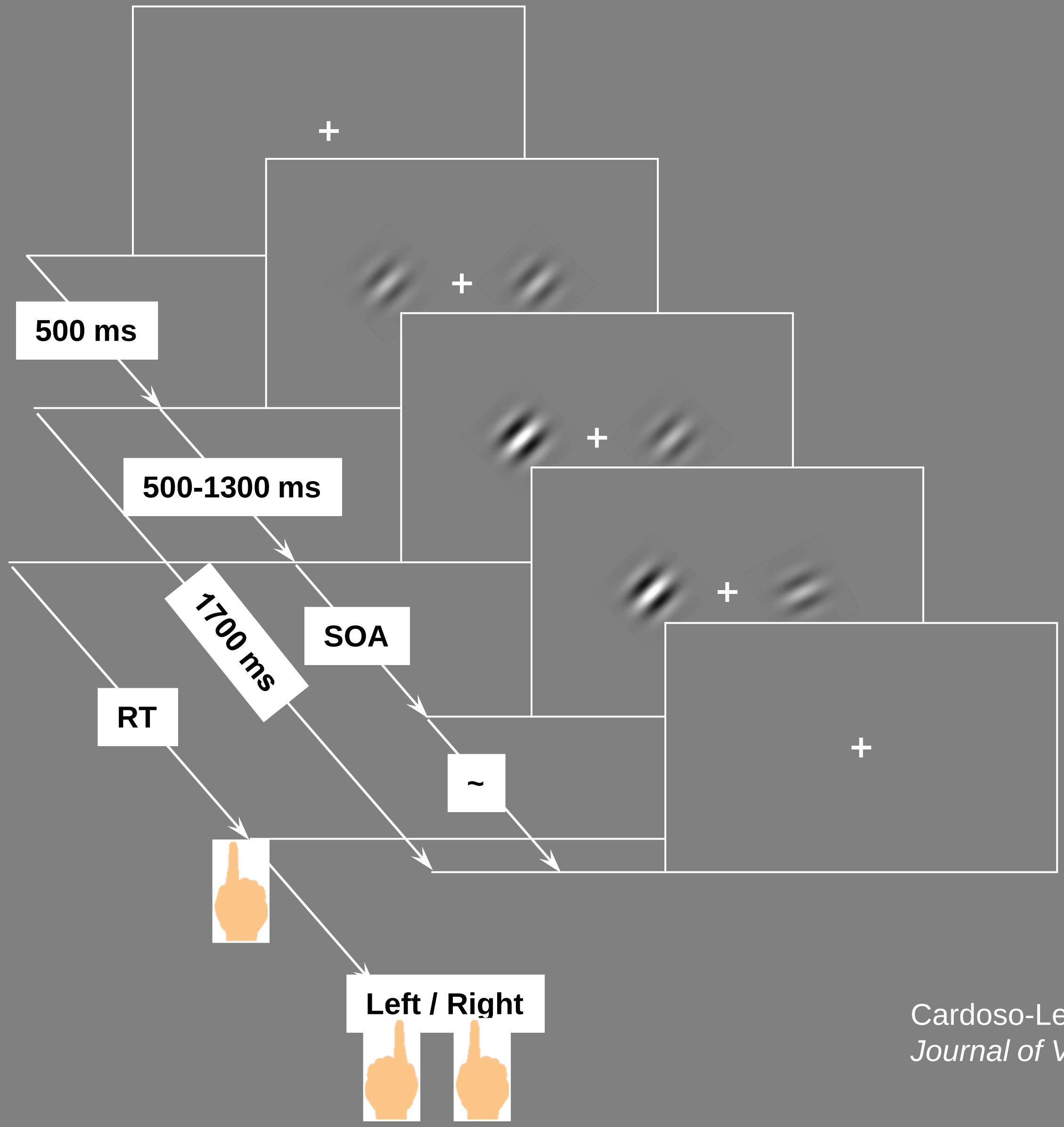
Diffusion race models
Speed Accuracy Tradeoff



Schematic illustration of changes in the activity of neural integrators associated with SAT. Horizontal axes indicate time, while vertical axes indicate firing rate. The blue lines illustrate the average activity of a neural integrator selective for the chosen alternative, and the dashed lines indicate baseline and threshold. (a) **Accuracy emphasis is associated with a large baseline–threshold distance.** (b,c) **Speed emphasis can be caused either by increasing the baseline** (panel b) or by lowering the **threshold** (panel c); in formal models, these changes are often mathematically equivalent.

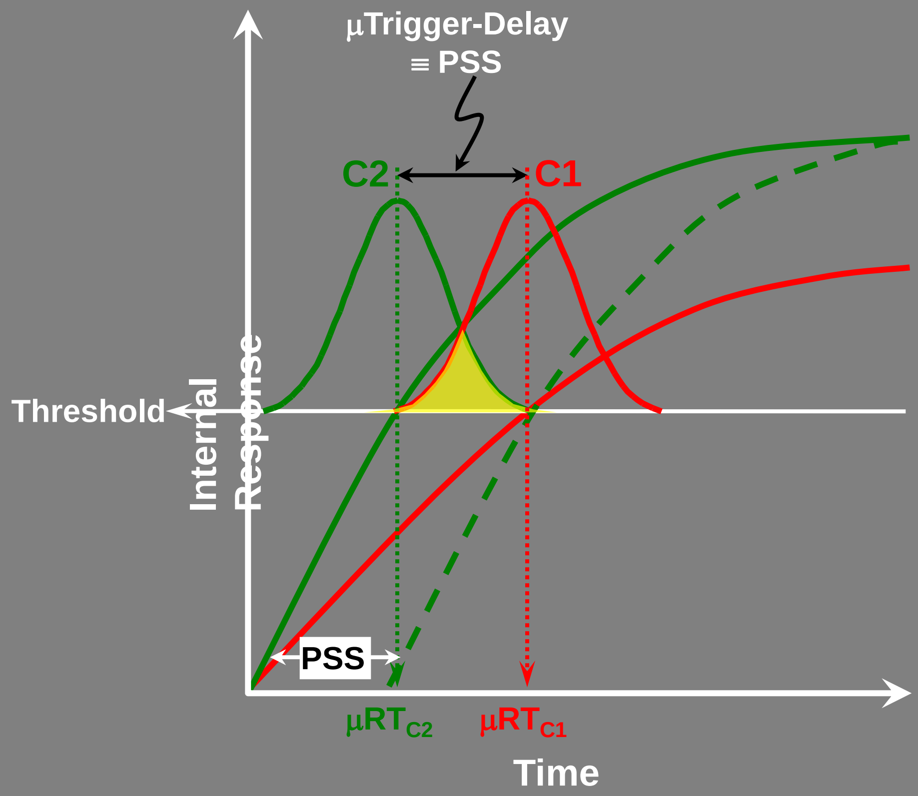
Bogacz, Wagenmakers, Forstmann & Nieuwenhuis (2010).
Trends in Neurosci., 33(1), 10-16.

Response Time & Temporal Order Judgments



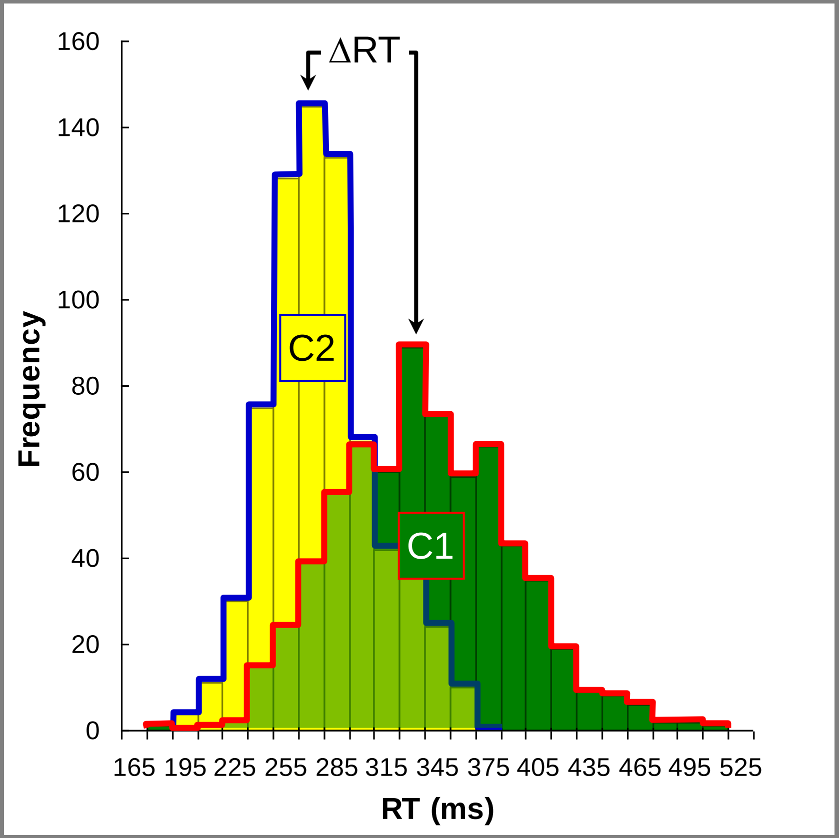
Cardoso-Leite, Gorea & Mamassian, *Journal of Vision*, 2007.

Response Time & Temporal Order Judgments



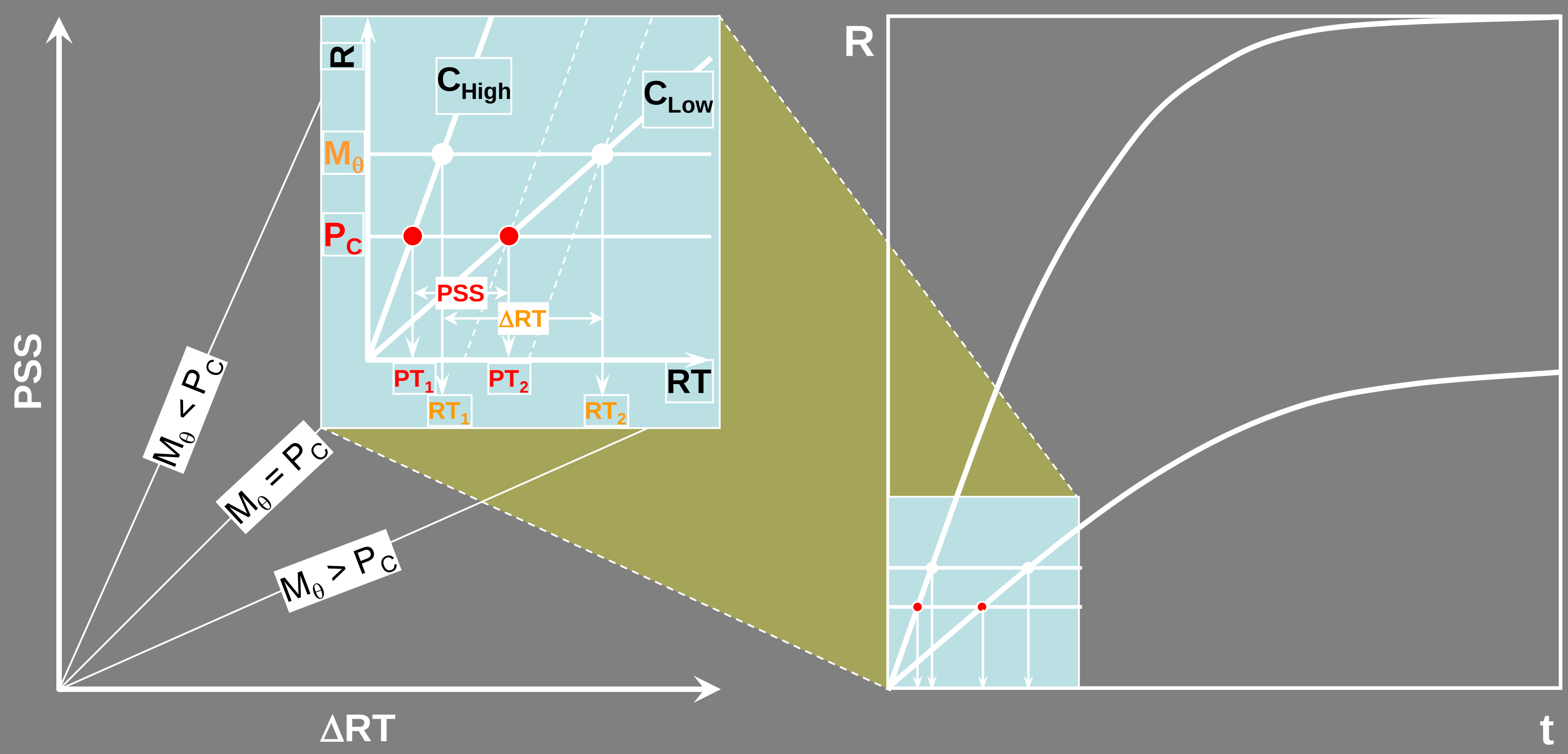
Cardoso-Leite, Gorea & Mamassian,
Journal of Vision, 2007.

Response Time & Temporal Order Judgments



Cardoso-Leite, Gorea & Mamassian,
Journal of Vision, 2007.

Response Time & Temporal Order Judgments



Cardoso-Leite, Gorea & Mamassian,
Journal of Vision, 2007.