Sensory Thresholds and Signal Detection

Lecture 13

Qualities of Sensation

Boring (1953)

- Modality-Specific
  - Vision: Hue, Saturation
  - Audition: Pitch, Timbre
  - Olfaction: Odor
  - Gustation: Flavor
  - Touch: Roughness, Wetness
  - Pain: Sensory Pain (Fast/Slow), Suffering
- General: ***Intensity***
  - Vision: Brightness
  - Audition: Loudness

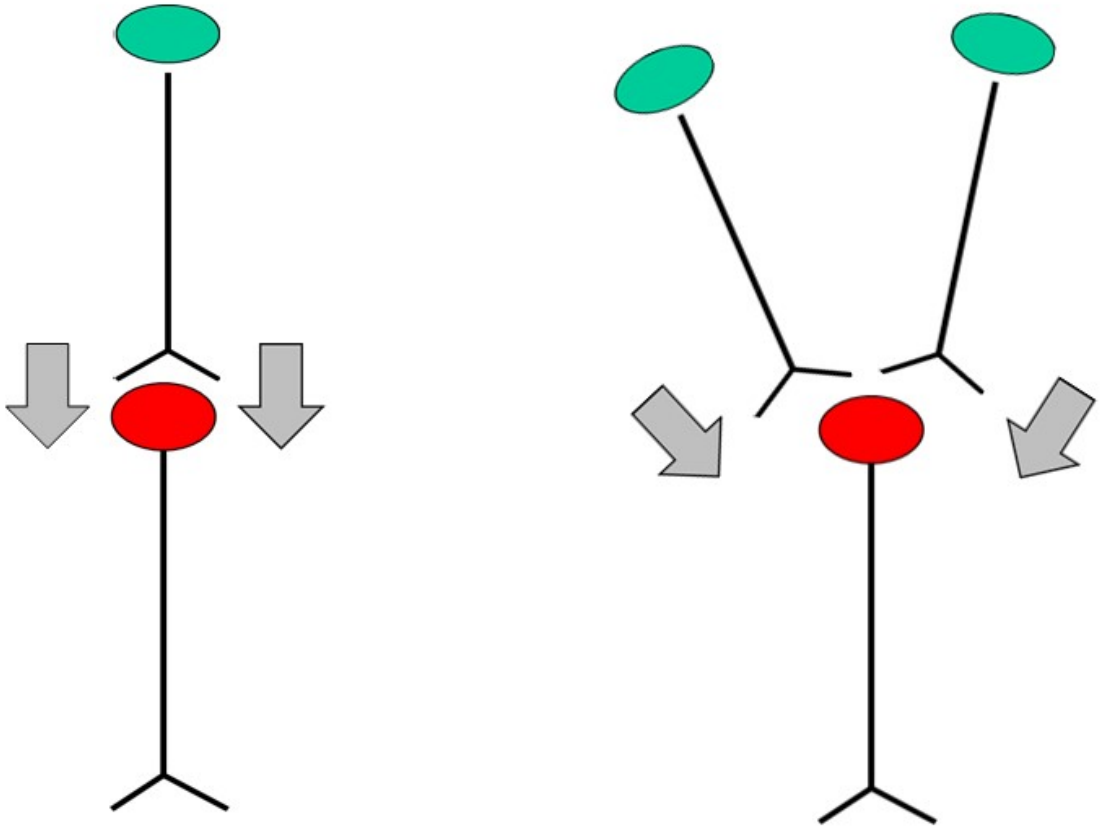
Thresholds for Conscious Awareness

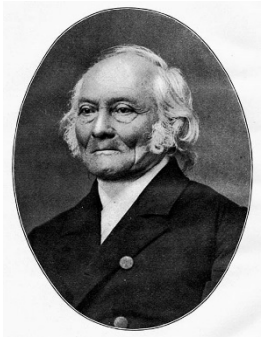
- Absolute
  - Weakest Detectable Stimulus
- Relative
  - Smallest Detectable Change
    - “Just-Noticeable Difference”
  - Absolute Threshold a Special Case
- Isomorphism
  - Physical Intensity
  - Sensory Intensity

Neural Coding of Intensity

The “All or None” Law

Temporal and Spatial Summation

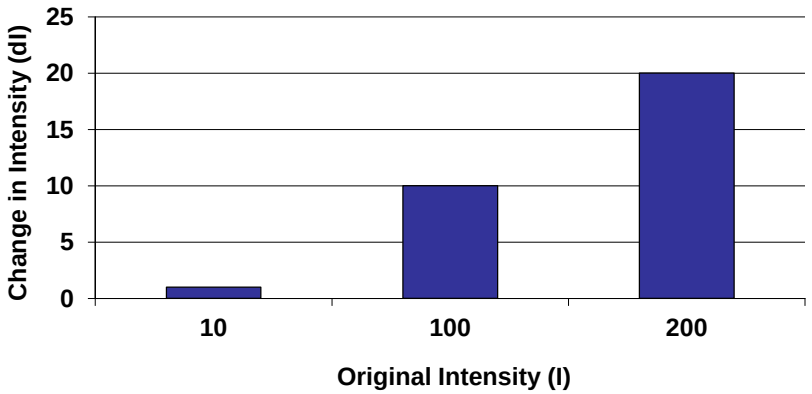




Weber's Law

Weber (1846)

$$\Delta I/I = c$$



$$c = 1/10$$

Original Intensity	***Noticeable Change***
10	11
100	110
200	220

Representative Weber Fractions for Human Sensation

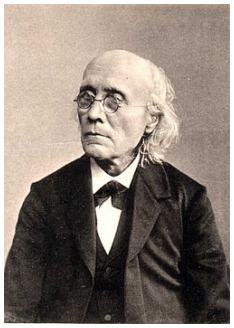
Geldard (1962)

Modality	c
Visual Brightness (White)	1/60
Lifted Weight	1/50
Thermal Pain	1/30
Auditory Loudness	1/10
Cutaneous Pressure	1/7
Smell of Rubber	1/4
Taste of Salt	1/3

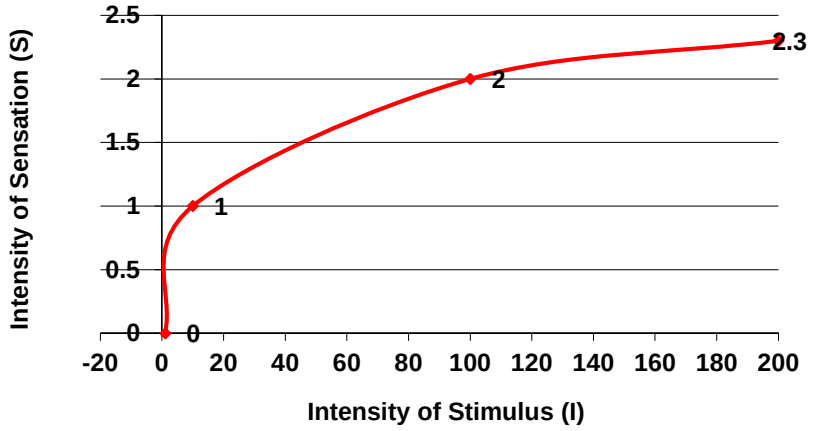
Fechner's Law

Fechner (1860)

$$S = k \log I$$



Physical Intensity	***Sensory Intensity***
1	0
10	1
100	2
200	2.3

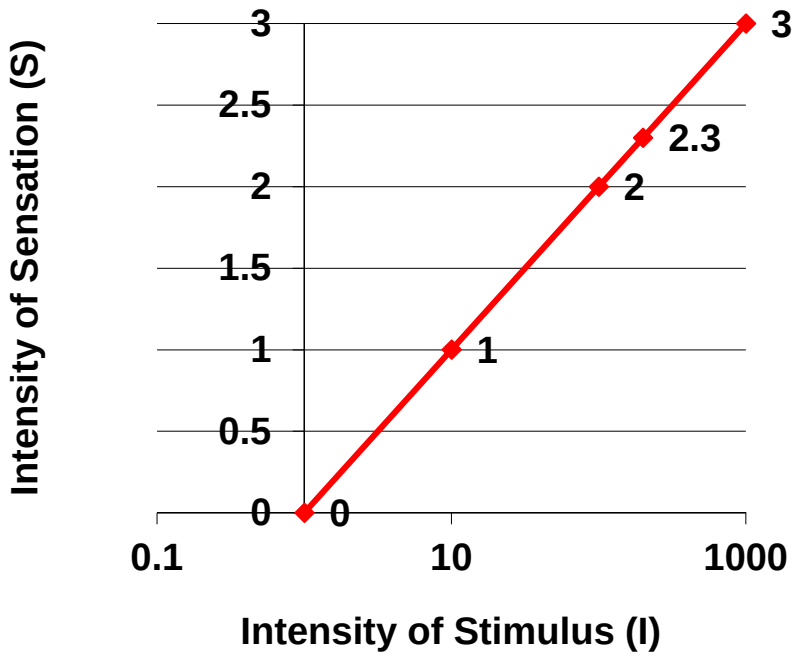


$k = 1$, $\log = \log_{10}$

Fechner's Law as Logarithm

Fechner (1868)

$$S = k \log I$$

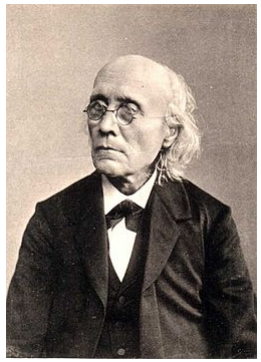


Physical Intensity	***Sensory Intensity***
1	0
10	1
100	2
200	2.3
1000	3

Fechner's Law

Fechner (1868)

$$S = k \log I$$

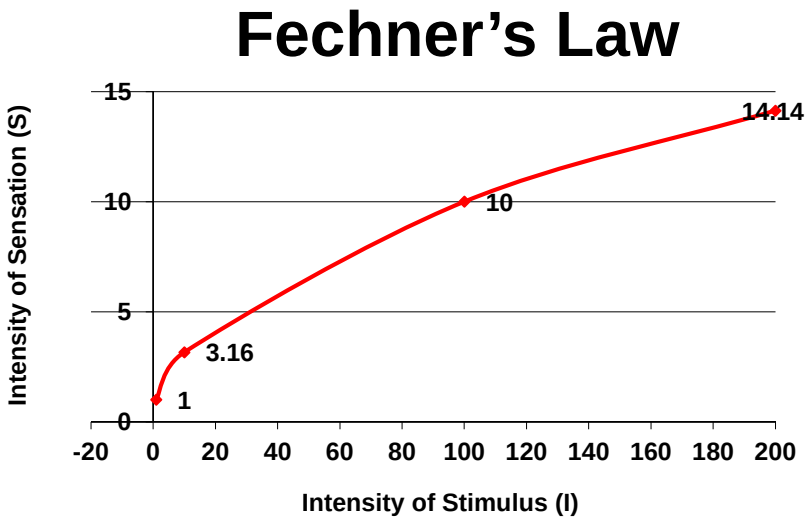


- Sensation Grows More Slowly Than Stimulation
  - Sensory Receptors Compress Stimuli
- Exceptions
  - Perceived Length
  - Perceived Pain

Stevens' Law

Stevens (1961)

$$S = kI^N$$



$k = 1,\ N = 1/2$

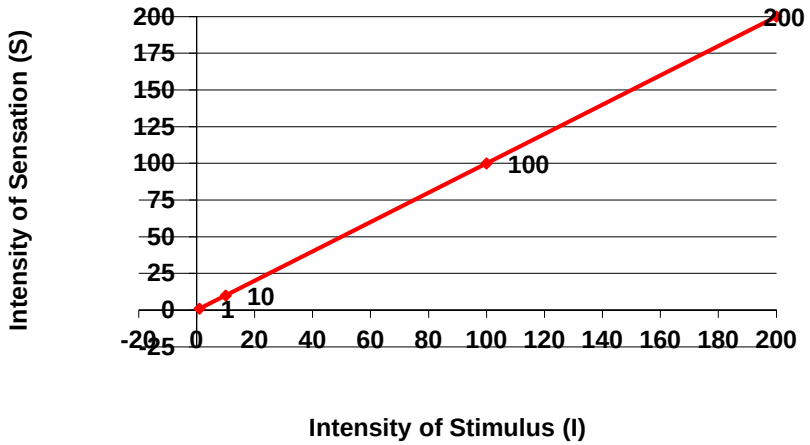
Physical Intensity	***Sensory Intensity***
1	1
10	3.16
100	10
200	14.14

Stevens' Law

Stevens (1961)

$$S = kI^N$$

The Case of Length



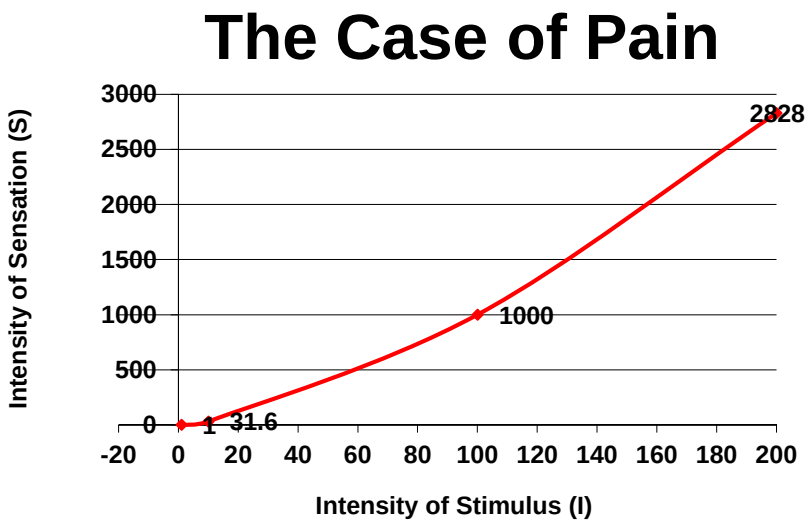
Physical Intensity	***Sensory Intensity***
1	1
10	10
100	100
200	200

$k = 1, N = 1$

Stevens' Law

Stevens (1961)

$$S = kI^N$$



Physical Intensity	***Sensory Intensity***
1	1
10	31.6
100	1000
200	2828

$k = 1,\ N = 3/2$

Stevens' Law

Stevens (1961)

- A General Psychophysical Law: $S = kI^n$
- Operating Characteristic of Receptors
  - Most Compress Stimulation: $n < 1$
  - Some Expand Stimulation: $n > 1$

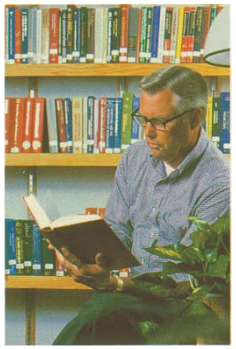
Representative Exponents (n)

Viscosity of silicone Fluid: 042
Brightness of Point Source: 0.5
Loudness of Pure Tone: 0.67
Area of Square 0.70
Length of Line: 1.00

Pressure on Palm: 1.10
Taste of Saccharin: 0.8
Taste of Sucrose: 1.3
Heaviness of Lifted Weight: 1.45
Electric Shock to Fingers: 3.50

Signal-Detection Theory

Green & Swets (1966), after Tanner & Swets (1954)



- Discriminate between “Signal” and “Noise”
- Components of Decision
  - Sensitivity (Information) – *d’*
  - Bias (Criterion) – β
    - Expectation
    - Motivation

The Signal Detection Paradigm

Green & Swets (1966)

Response	***Signal***	
	On	*Off (Catch Trials)*
"Yes"	**HIT**	**FALSE ALARM**
"No"	**MISS**	Correct Rejection

An Observer with High Sensitivity

Hit Rate = 100%; False Alarm Rate = 0%

Response	***Stimulus***		
	On	*Off*	
"Yes"	**50%**	**0%**	**50%**
"No"	0%	50%	**50%**
	50%	**50%**	

An Observer with Less Sensitivity

Hit Rate = 80%; False Alarm Rate = 0%

Response	***Stimulus***		
	On	*Off*	
"Yes"	**40%**	**0%**	**40%**
"No"	10%	50%	**60%**
	50%	**50%**	

“Liberal” Bias toward *Yes*

Hit Rate = 80%; False Alarm Rate = 80%

Response	***Stimulus***		
	On	*Off*	
“Yes”	**40%**	**40%**	**80%**
“No”	10%	10%	**20%**
	50%	**50%**	

“Conservative” Bias toward *No*

Hit Rate = 30%; False Alarm Rate = 30%

Response	***Stimulus***		
	On	*Off*	
“Yes”	**15%**	**15%**	**30%**
“No”	35%	35%	**70%**
	50%	**50%**	

Sensitivity + “Liberal” Bias

Hit Rate = 80%; False Alarm Rate = 40%

Response	***Stimulus***		
	On	*Off*	
“Yes”	**40%**	**20%**	**60%**
“No”	10%	30%	**40%**
	50%	**50%**	

Sensitivity + "Conservative" Bias

Hit Rate = 50%; False Alarm Rate = 10%

Response	***Stimulus***		
	On	*Off*	
"Yes"	**25%**	**5%**	**30%**
"No"	25%	45%	**70%**
	50%	**50%**	

Inducing Liberal Response Bias by Decreasing Catch Trials

Response	***Stimulus***		
	On	*Off*	
"Yes"	**52%**	**18%**	**70%**
"No"	18%	12%	**30%**
	70%	**30%**	100%

Inducing Conservative Response Bias by Increasing Catch Trials

Response	***Stimulus***		
	On	*Off*	
"Yes"	**18%**	**12%**	30%
"No"	12%	58%	70%
	30%	**70%**	100%

A Balanced Payoff Matrix

Response	***Stimulus***		
	On	*Off*	
"Yes"	+25¢	-25¢	0
"No"	-25¢	+25¢	0
	0	0	

A Payoff Matrix
Inducing “Liberal” Bias

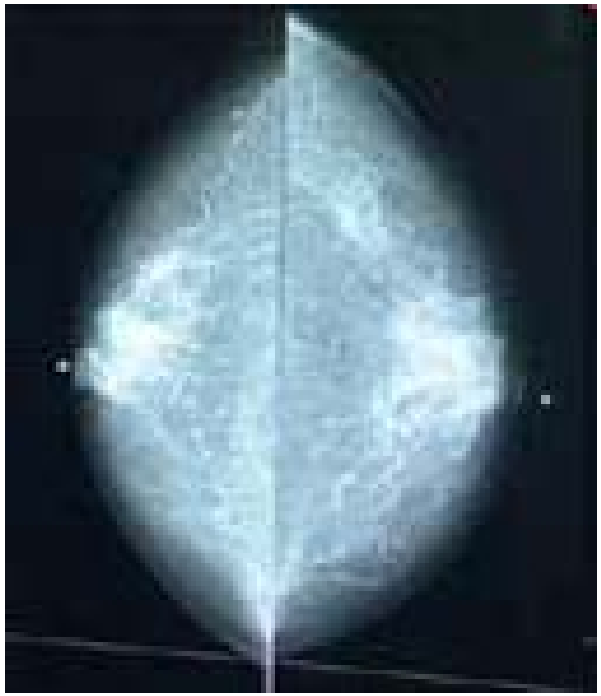
Response	***Stimulus***		
	On	*Off*	
“Yes”	+25¢	-10¢	+15¢
“No”	0¢	0¢	0¢

A Payoff Matrix
Inducing “Conservative” Bias

Response	***Stimulus***		
	On	*Off*	
“Yes”	+10¢	-25¢	-15¢
“No”	0¢	0¢	0¢

Signal Detection as Decision Under Uncertainty

- Detection not simply a matter of intensity
  - Judgment Under Uncertainty
- Example: Mammography
  - Family History
  - Cost/Benefit Analysis
- Determinants of Decisions
  - Expectations
  - Motives



Radiological Society of N.A.

Implications of Signal Detection Theory

- Detection Not a Simple Matter of Intensity
- Passive vs. Active Observer
  - Expectations, Motives
- “Lower” vs. ‘Higher” Mental Processes
  - Proximity to Physical Stimulus
  - Ties to Sensory Physiology
- Sensory Detection as Judgment
  - Decision-Making

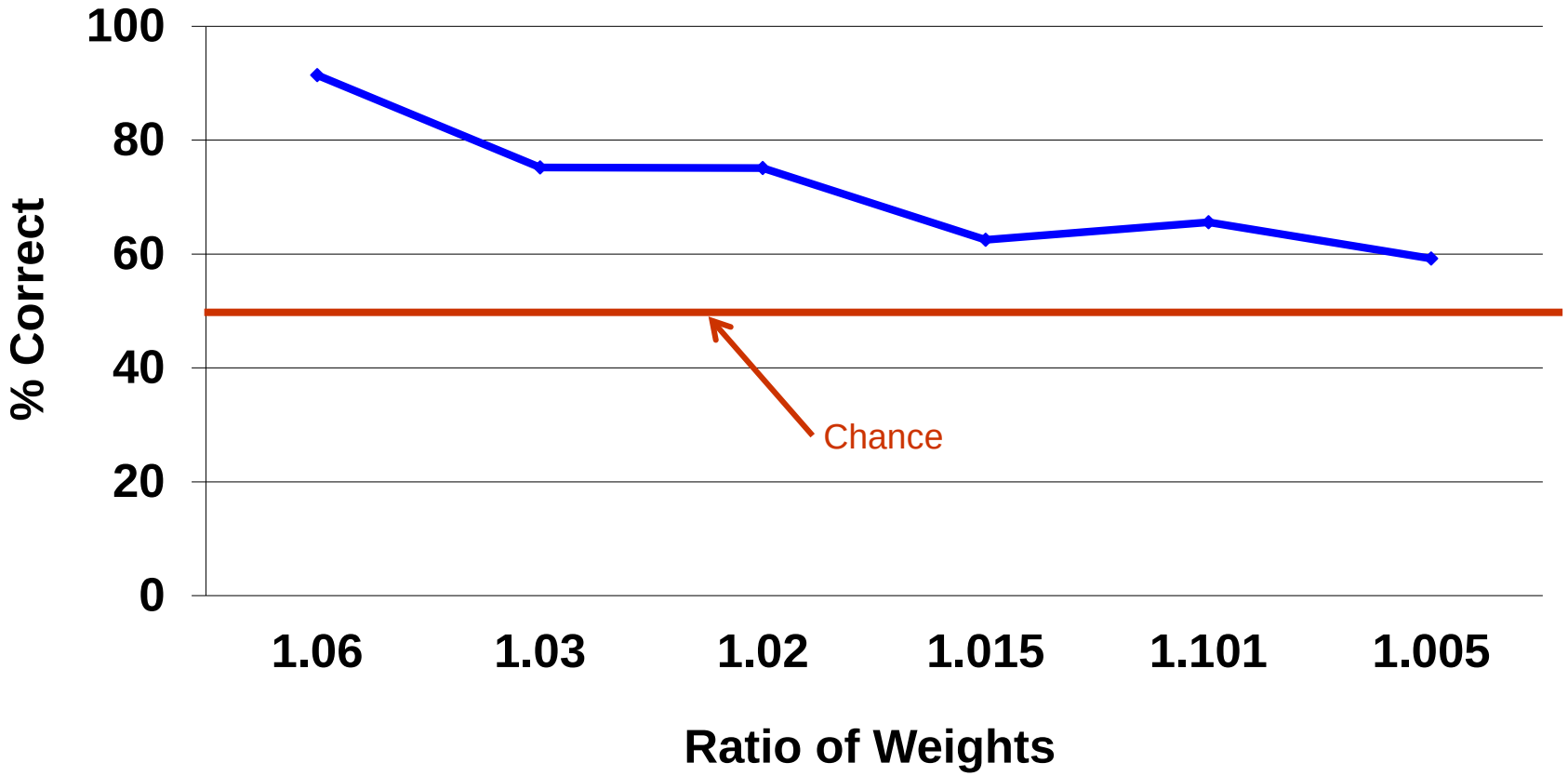
Subliminal Perception?

Herbart (1819); Kihlstrom et al. (1992)

- Threshold = *Limen*
- Conscious Perception
  - Conscious Awareness of Distal Stimulus
- Subliminal Perception
  - Change in Experience, Thought, or Action
    - Attributable to Stimulus
  - No Conscious Awareness of Stimulus
  - Perception Implied by Changes in Task Performance

Judgment Accuracy at Zero Confidence

Peirce & Jastrow (1884)



Scope of Subliminal Perception

Kihlstrom et al. (1992)

- Methodological Variations
  - Weak Intensity
  - Short Duration
  - "Masking"
  - Unattended
- Not Simple Guessing
  - Hits > False Alarms
- Analytic Limitation
  - Exaggerated Claims for Subliminal Influence

Prof. Gil Einstein, Furman U.