Practical Issues in Designing and Conducting an AI Experiment

Five Issues to be Considered

- **Range of stimulus parameter (*R*)**
- **Number of stimulus alternatives (*k*)**
- **Spacing between the *k* stimuli (*linear vs. log*)**
- **Total number of trials (*n*)**
- **Training procedure**

Issue #1:
Range of Stimulus Parameter (*R*)

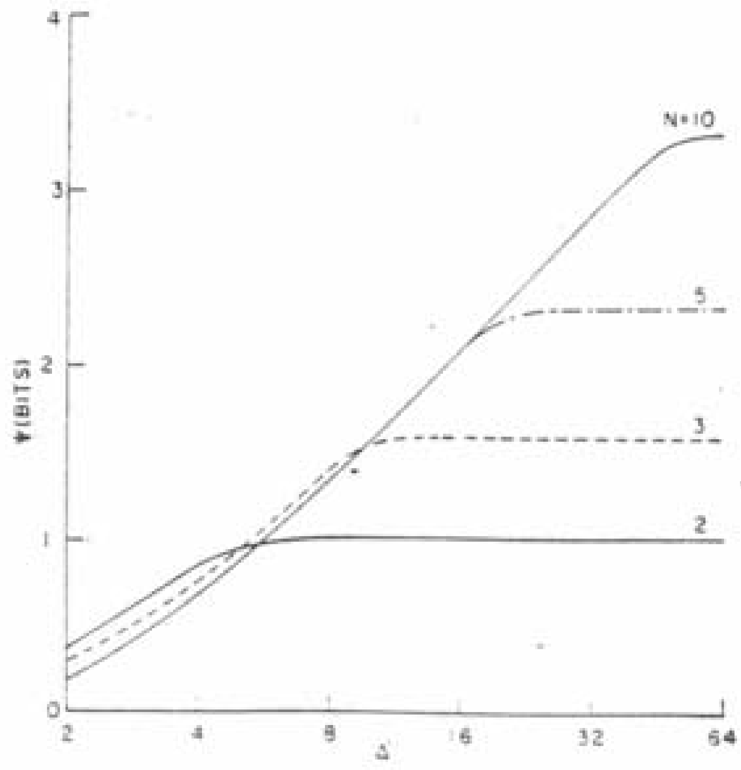
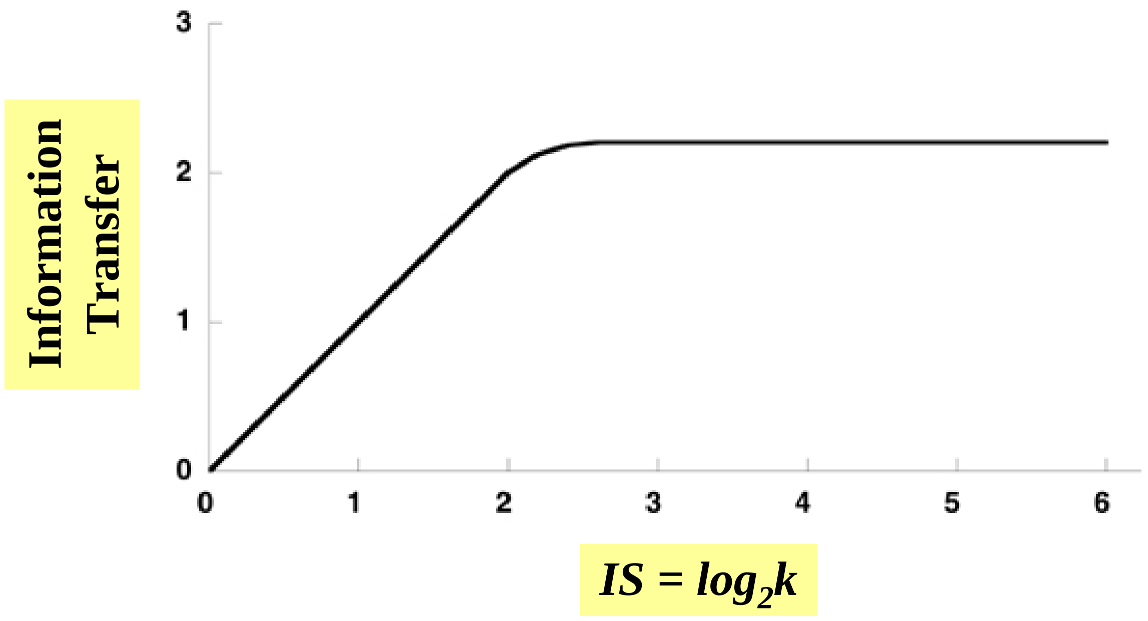


FIG. 1. Dependence of mutual information Ψ on the total sensitivity Δ' for various values of the number N of stimuli. (See text for assumptions.)

R

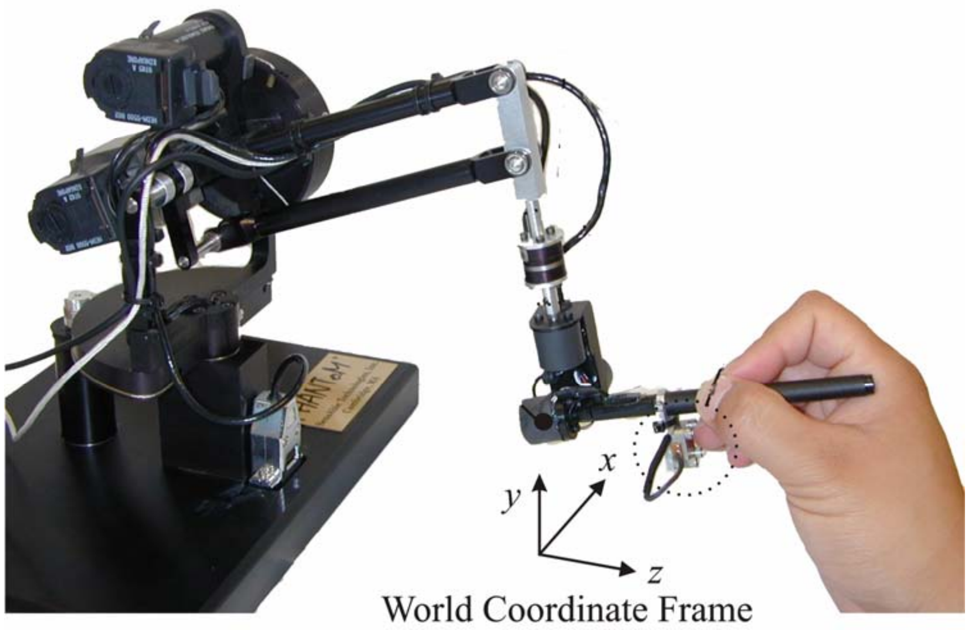
- **Problem**
  - **At small *R*, where $R = \log(I_{max}/I_{min})$, information transfer < channel capacity**
- **Strategy**
  - **Use largest possible range given the experimental setup**
- **Examples of "largest possible range"**
  - **Sound levels: AL to "too loud"**
  - **Curvature: straight line to arc of the smallest circle that can be drawn**
  - **Weight: AL to "too heavy"**

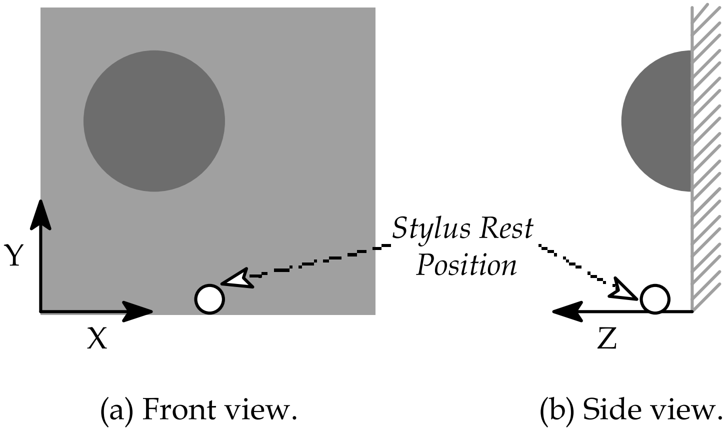
Issue #2: Number of Stimulus Alternatives (*k*)



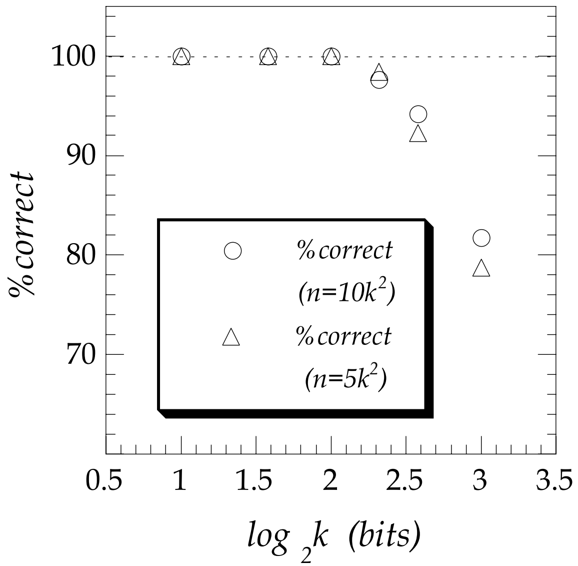
- Small *k* limits IT_{est}
- Large *k* requires too many trials
- One strategy: increase *k* until IT_{est} asymptotes

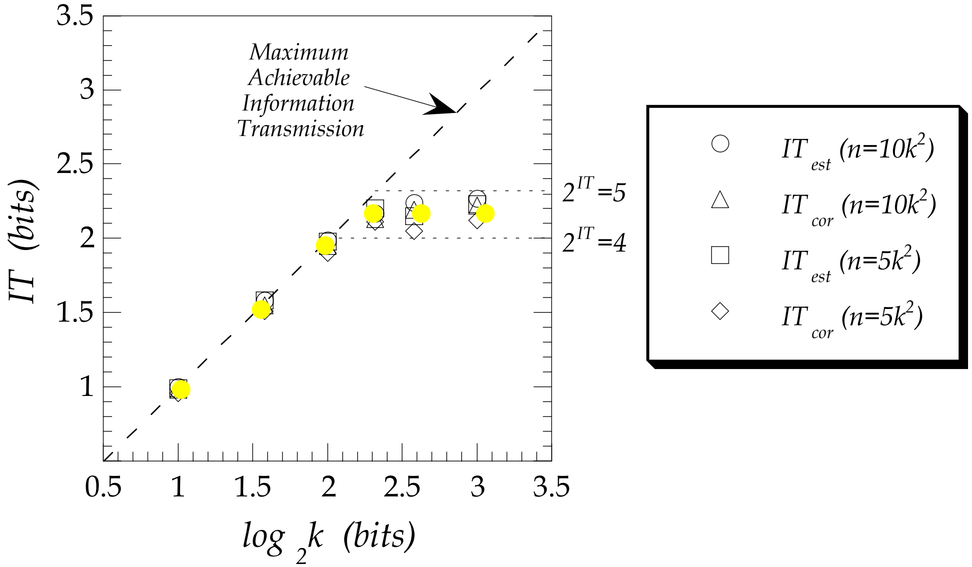
An Example (Tan, 1997)





Range of radius:
10 – 80 mm
For different numbers
Of stimulus alternatives (k)


100
90
80
70
% correct
0.5
1
1.5
2
2.5
3
3.5
log 2k (bits)
% correct
(n=10k2)
% correct
(n=5k2)

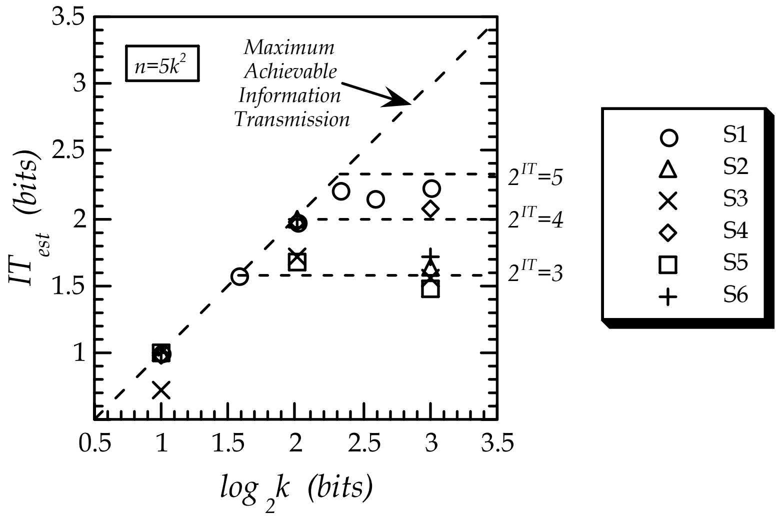

3.5
3
2.5
2
1.5
1
IT (bits)
0.5
1
1.5
2
2.5
3
3.5
log 2k (bits)
Maximum
Achievable
Information
Transmission
2IT=5
2IT=4
IT est (n=10k2)
IT cor (n=10k2)
IT est (n=5k2)
IT cor (n=5k2)

Issue #3: *Linear* or *Log* Spacing?

- **Objective**
  - **Equal perceptual distance between adjacent stimuli**
  - **If Weber's law applies, logarithmic spacing is preferred**
- **Problem**
  - **Many discrimination experiments are required before an absolute identification exp can be designed and conducted**
- **Lucky Solution**
  - **In most cases, *information transfer* is not sensitive to stimulus spacing**

An Example (Tan, 1997)

- Identification of sphere size:
  - Range of radius (fixed): 10.0 to 80.0 mm
  - Linear (e.g., *k*=3): 10.0, 45.0, 80.0 mm
  - Logarithmic (e.g., *k*=3): 10.0, 28.28, 80.0 mm



S1, S2, S3: Linear
S4, S5, S6: Log

Issue #4: How Many Trials?

- **The issue:**
  - IT_{est} **is subject to statistical fluctuations**
  - IT_{est} **is biased (**$E[IT_{est}] > IT$**)**
  - **bias > sampling errors**
- **Need sufficient number of trials to overcome bias and sampling errors**

Miller's (1954) Formula

- IT_{est} **is an over-estimate of** IT

$$E[IT_{est}] - IT = \underbrace{\frac{\log_2 e}{2n}(k-1)^2}_{\Delta} + O\left(\frac{1}{n^2}\right) > 0$$

- **With large** n **(> 5k²), Δ is small (0.14 *bit*)**
- **With small** n**, Δ can over-correct**

i.e., $IT_{est} - \Delta < IT$

Miller's (1954) Formula (*cont.*)

- **When performance level is high, Δ over-corrects**

25	0	0	0
0	25	0	0
0	0	25	0
0	0	0	25

P(C) = 100%
IS = IR = IT_{est} =IT= 2 *bits*
yet $\Delta \neq 0$

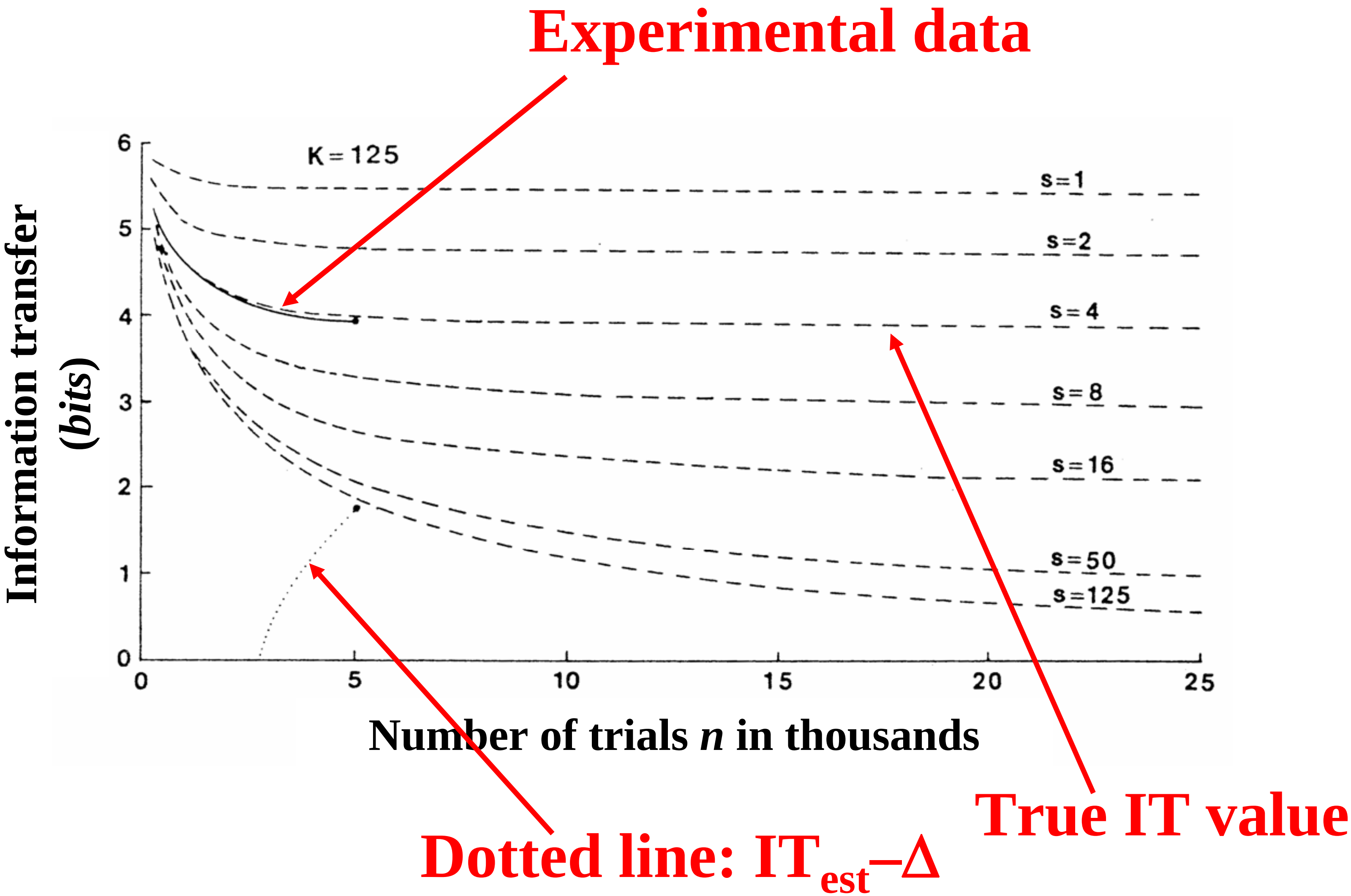
- **Bottom line: $n>=5k^2$ is needed.**

An Experiment where *k*=125 (Rabinowitz et al., *JASA*, 1987)

- **For *k* = 125, 5k^2 = 78,125 total trials!!**
- **3-D stimulus set — pulsed sinusoidal vibration**
  - **Five values of intensity**
  - **Five values of contact area**
  - **Five values of frequency**
- **One-interval AI paradigm with feedback**
- **3-tuplets as responses (e.g., 111, 254, etc.)**
- **Data: 125-by-125 confusion matrix!!**

Houtsma's Computer Simulation (JASA, 1983)

- **Assumption**
  - **1-D experiment with k=125**
- **Procedure**
  - **Randomly pick an S from 1-125; $S \in [1, 125]$**
  - $R_{raw} = S + noise\ (\pm s)$
  - **R is reset to 1 or 125 if R_{raw} is too small or too large; $R \in [1, 125]$**
  - **Collect enough number of "trials", n**
  - **Estimate IT_{est} as a function of n**
- **The value of s is used to control the asymptotic value of IT_{est}**


Experimental data
K = 125
s = 1
s = 2
s = 4
s = 8
s = 16
s = 50
s = 125
Information transfer (*bits*)
Number of trials *n* in thousands
0
1
2
3
4
5
6
0
5
10
15
20
25
True IT value
Dotted line: $IT_{est} - \Delta$

So How Many Trials are Enough?

- **Collect $n >= 5k^2$ trials if possible**
- **For one-dimensional stimuli, *k* is usually reasonable (7±2).**
- **For multi-dimensional stimuli,**
  - **Additivity: $IT(multi\text{-}D) = \Sigma IT(ID)$?**
    Usually, $IT(A,F) < IT(A) + IT(F)$
  - **A general additivity law (Durlach *et al*., 1989)**

Issue #5: Training

- Training is usually needed for AI paradigms
- Criterion for termination of training

References

- **H. Z. Tan, "Identification of sphere size using the PHANToM™: Towards a set of building blocks for rendering haptic environment," in *Proceedings of the ASME Dynamic Systems and Control Division*, vol. 61. Dallas, TX: American Society of Mechanical Engineers, 1997, pp. 197–203.**
- **G. A. Miller, "Note on the bias of information estimates," in *Information Theory in Psychology*, H. Quastler (Ed.), 1954, pp. 95-100.**

References (cont.)

- **W. M. Rabinowitz, A. J. M. Houtsma, N. I. Durlach, and L. A. Delhorne, "Multidimensional tactile displays: Identification of vibratory intensity, frequency, and contactor area,"** ***Journal of the Acoustical Society of America*****, vol. 82, pp. 1243-1252, 1987.**
- **A. J. M. Houtsma, "Estimation of mutual information from limited experimental data,"** ***Journal of the Acoustical Society of America*****, vol. 74, pp. 1626–1629, 1983.**

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- N. I. Durlach, H. Z. Tan, N. A. MacMillan, W. M. Rabinowitz, and L. D. Braida, "Resolution in one dimension with random variations in background dimensions," *Perception & Psychophysics*, vol. 46, pp. 293-296, 1989.
- N. I. Durlach and L. D. Braida, "Intensity perception I. Preliminary theory of intensity resolution," *The Journal of the Acoustical Society of America*, vol. 46, pp. 372–383, 1969.