Classical Psychophysical Methods (*cont.*)

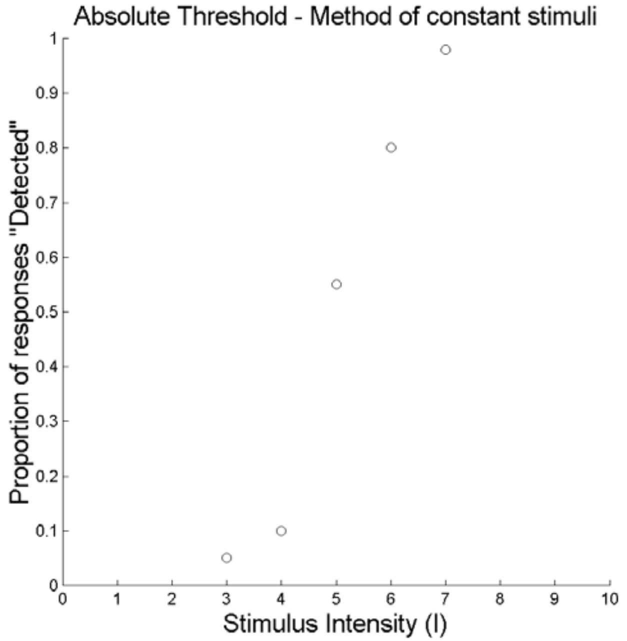
Outline

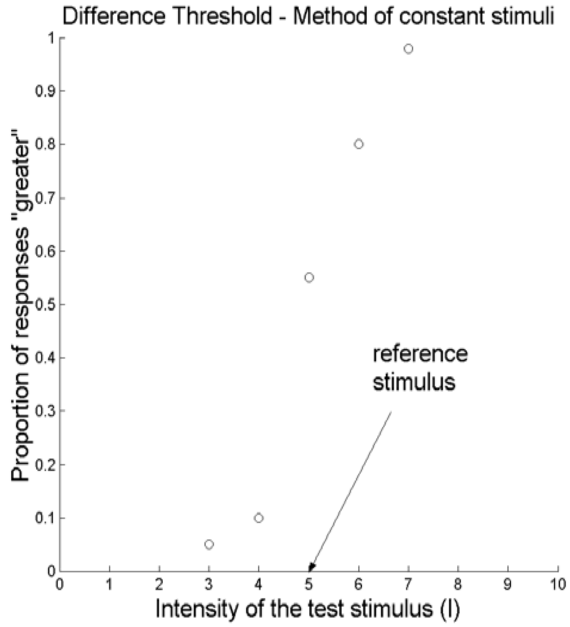
- Method of Adjustment
- Method of Limits
- Method of Constant Stimuli
- Probit Analysis

Method of Constant Stimuli

- **A set of equally spaced levels of the stimulus intensities is chosen (usually 5-9). Each level is repeated large number of times in a given session (e.g. 100). The order of presentations is randomized. The subject is asked to report whether the presented stimulus can be detected (when AL is measured), or whether the intensity of the presented test stimulus is greater than that of the reference stimulus (when DL is measured).**
- **In the case of measuring DL, again an asymmetric or symmetric design can be used.**

- **The proportion of responses (YES) for each level of stimulus intensities is recorded and plotted against the stimulus intensity. When the intensity of the stimulus is very low, this proportion is close to zero. When the intensity is high, this proportion is close to one. The graphs below show hypothetical data.**

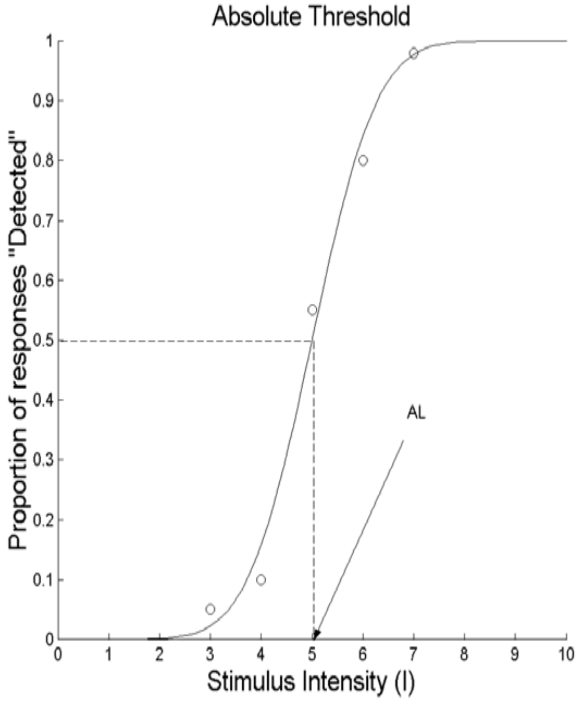


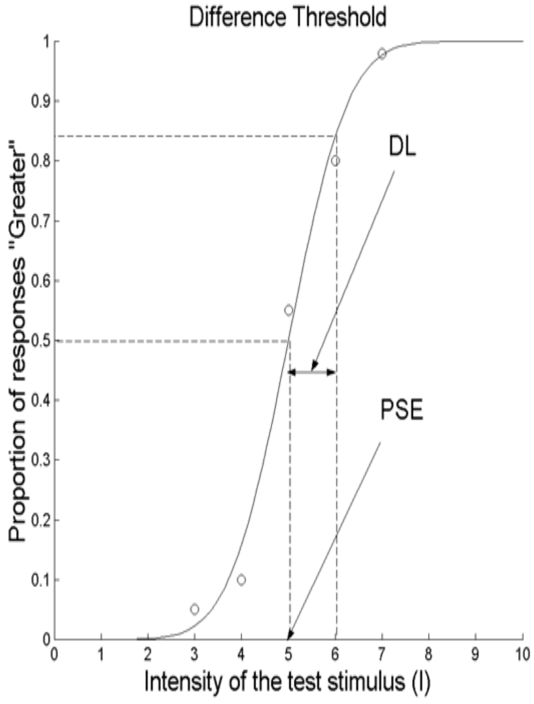


- **The data points are fitted by a theoretical curve. Often, the cumulative Gaussian distribution is used as a model. The two parameters of the Gaussian (mean and standard deviation) are estimated by the maximum likelihood method (Probit Analysis, Finney, 1971 - see SAS). AL is estimated by the mean value of the Gaussian, whereas DL (in the symmetric design) is estimated by the standard deviation. The mean value in the symmetric design is an estimate of the Point of Subjective Equality (PSE).**

Examples of the Psychometric Functions

The psychometric functions for the detection and discrimination experiment are shown below.





Exp. 5: Method of constant stimuli applied to curvature detection

- **On each trial the subject is shown a dotted line whose curvature is randomly selected from a set of values. This set includes curvature of zero (straight line - catch trial). The subject's task is to respond whether the line is curved or straight. The subject should try to obtain close to perfect performance on catch trials. After each trial a feedback is given about the accuracy of the response.**
- **The proportion of responses "detected" is plotted against curvature. A cumulative Gaussian is fitted using the least squares method. The mean and standard deviation are estimated.**

Probit Analysis

- Let X_i be the i-th stimulus level (i=1,…,k)
- Let r_i be the number of responses, out of n_i trials representing level X_i, in which the subject "detected" the stimulus.
- $P(r_i) = n_i!/[r_i!(n_i-r_i)!] \cdot p_i^{r_i} \cdot (1-p_i)^{(n_i-r_i)}$
- Exercise: find the maximum likelihood estimate of p_i
- $l=\log[P(p)]=c+r\log(p)+(n-r)\log(1-p)$
- $dl/dp=r/p-(n-r)/(1-p)=0$
- $p'=r/n$ = maximum likelihood estimator of p.

Probit Analysis

- **We assume that p for all data points come from the same cumulative Gaussian distribution**
- $l = c + \Sigma r_i \log(p_i) + \Sigma (n_i - r_i) \log(1 - p_i)$
- **If l=max then:**

  $\partial l / \partial \mu = 0$ **and** $\partial l / \partial \sigma = 0$
- **There is no analytical solution. The optimal values are found by performing statistical optimization.**

Probit Analysis (cont.)

- The fit is evaluated by a χ^2 statistic:

  $\chi^2 = \Sigma (r_i - n_i p_i)^2 / (n_i p_i q_i)$

  where $q_i = 1 - p_i$
- Expected value: $E\{\chi^2\} = df = k-2$
- If the value of χ^2 is small, the fit is good: one may conclude that the cumulative Gaussian is an adequate model and the sampling error is the only source of variability.

Probit Analysis (cont.)

- **Sampling error refers to the random variability of $p' = r/n$ due to the fact that the sample size is finite ($n < \infty$).**
- **Large value of χ^2 suggests that either the cumulative Gaussian is not an adequate model, or that there is an additional source of variability (e.g., response criterion was not constant, the data points come from averaging proportions across several subjects).**

Strengths and Weaknesses of the Method of Constant Stimuli

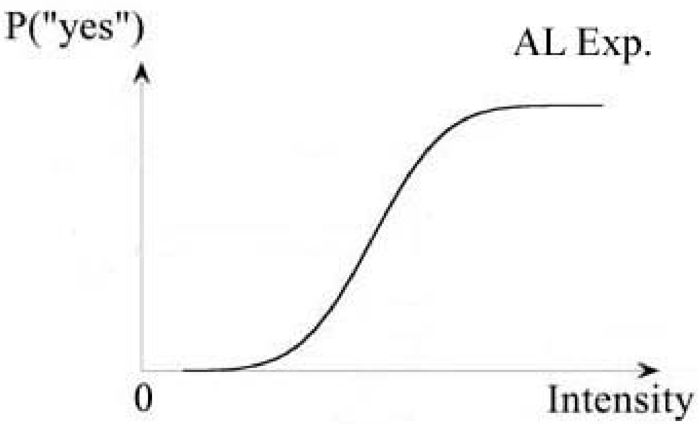
- **The method of constant stimuli provides more reliable estimates of the thresholds, as compared to the method of adjustment and the method of limits.**
- **The experimenter has to know the threshold at least approximately in order to choose the levels of the stimulus intensity appropriately. The lowest level should produce about 5% of responses YES, and the highest level should produce about 95% of responses YES.**

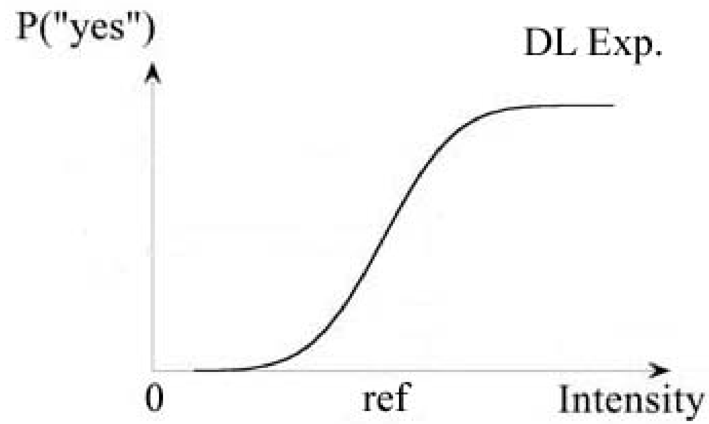
- **When applied to AL, or to DL using an asymmetric design, the method of constant stimuli confounds the percept with response bias. One solution is to introduce “catch trials” in which the intensity of the stimulus is zero. The subject is expected to produce small proportion of errors on these trials. Another solution is to use the Method of Signal Detection.**

Exp. 6: Method of constant stimuli applied to line-length discrimination

- On each trial the subject is shown the test and reference line. The length of the reference line is constant throughout the entire session. The length of the test line is randomly selected from a set of values. The subject's task is to respond whether the test line is longer or shorter than the reference line.
- The proportion of responses "longer" is plotted against the length of the test line. A cumulative Gaussian is fitted using the least squares method. The mean and standard deviation are estimated.

AL vs. DL





- = vs. >
- **Biased easily**
- **AL is estimated as the 50th percentile point**

- < vs. >
- **Bias has weaker effect**
- **DL is estimated as the standard deviation of the psychometric function**

Discussion of the discrimination results from the three methods

- The method of constant stimuli produces more reliable and accurate estimates of the the threshold (AL, DL) and PSE, as compared to the other two classical methods.
- The method of adjustment and limits are often used to provide initial estimates of threshold and PSE. These estimates are then used to design the experiment using the method of constant stimuli.
- Probit Analysis gives not only estimates of the mean and standard deviation. It also gives the estimates of standard errors.