

## Lecture 9

### Empirical Research Methods IN4304

#### Psychophysical Methods Measuring sensitivity

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## Previous lecture

### Correlation coefficient

Express strength and direction of relation  
Pearson (interval level)  
Spearman (ordinal level)

### Partial correlation

Partialling out the effect of a third variable on the correlation between 2 variables

### Regression analysis

relation between interval level predictor variables and an interval level dependent variable

- $R^2$
- Collinearity
- Std Error of the Estimate

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n + e_i$$

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## Today

- Psychometric Curve (function)
- Method of Constant Stimuli
- Method of Limits
- Method of Adjustment
- Paired Comparison
- Sorting Method
- Triangle or Three-Sample Method

Based on:

Engelhard, P.G. (2000). Chapter 5: Thresholds and Just-Noticeable Differences. In *Psychometric Scaling: A Toolkit for Imaging Systems Development*. Imcotek.  
Gescheider, G.A. (1997). Chapter 3: The Classical Psychophysical Methods. In *Psychophysics: the fundamentals*, Mahwah, New York: Lawrence Erlbaum Associates.

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## Learning outcomes of this lecture

After today's lecture you should be able :

- to explain several methods to measure intensity of a stimulus
- to establish a Psychometric Curve and determine the point of subjective equality and Just Noticeable difference
- to understand the difference between measurement for sensitivity and measurement for preference

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## Psychophysical Methods

### Sensitivity

- Method of Constant Stimuli
- Method of Limits
- Method of Adjustment

### Preference

- Paired Comparison
- Sorting Method
- Triangle or Three-Sample Method

1. What is intensity of stimuli that is just visible (*absolute threshold*)?
2. What is the minimum intensity that is just perceived as different from the standard (just-noticeable difference)?

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## Sensitivity versus Preference

Sensitive thresholds:

- *Absolute threshold*: amount of a physical stimulus needed for detection (e.g. luminance, noise, blocking artefact)
- *Just-noticeable difference (JND)*: required change in physical stimulus needed to perceive a difference with a reference (e.g. colour difference, non-uniformity, geometrical deformation)

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## Method of Constant Stimuli – Absolute Thresholds - Procedure

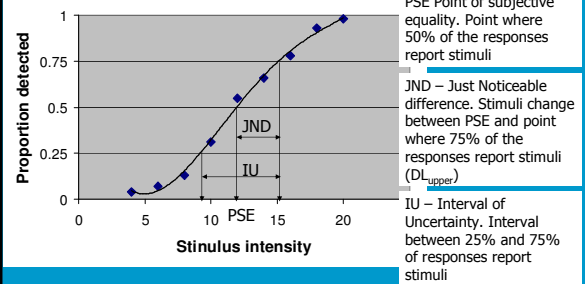
- Stimuli set of 5 to 9 different values
- 50% threshold somewhere within range of stimulus values
- Low value is almost never detected
- High value is almost always detected
- Each stimulus is presented repeatedly (e.g. 100 times) in random order
- Participant needs to indicate whether he/she perceives stimuli

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## Psychometric Curve (function)

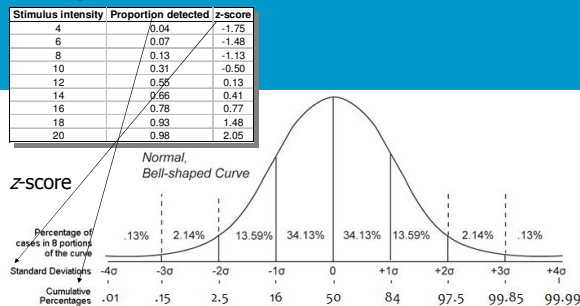


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## Psychometric Function – z-score

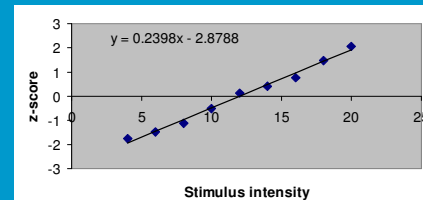


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## Psychometric Function – Expressed in z-score



- $PSE : 0 = 0.2398x - 2.8788 \rightarrow PSE = 2.8788 / 0.2398 = 12.005$
- $Norm^{-1}(0.75) = 0.67449 \rightarrow DL_{upper} = (0.67449 + 2.8788) / 0.2398 = 14.81772$
- $JND = 14.81772 - 12.005 = 2.8$

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## Method of Constant Stimuli – Just Noticeable Difference - Procedure

- Participant is presented with standard stimulus ( $St$ ) and comparison stimulus ( $Co$ ) and has to judge which stimulus produces a sensation of greater magnitude
- Usually equal number above and below  $St$
- Presented in random sequence
- Order or Location of  $Co$  and  $St$  counterbalance or randomised to control for time error or space error

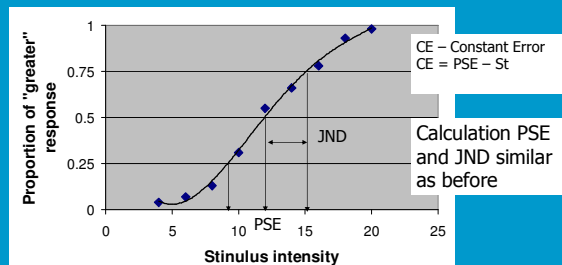


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## Method of Constant Stimuli – Just Noticeable Difference - Results



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## Method of Constant Stimuli

- Advantage
  - Collects data that can be analysed as a psychometric function
  - More precise than Method of Limits
- Limitations
  - Response error
  - Can take considerable time to conduct

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## Psychophysical Methods

### Sensitivity

- Method of Constant Stimuli V
- **Method of Limits**
- Method of Adjustment

### Preference

- Paired Comparison
- Sorting Method
- Triangle or Three-Sample Method

1. What is intensity of stimuli that is just visible (*absolute threshold*)?
2. What is the minimum intensity that is just perceived as different from the standard (just-noticeable difference)?

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## Method of Limits – Absolute Threshold - Procedure

- Start well below or above threshold
- Each step the threshold is approached by changing the intensity
- The stimuli are manipulated in ascending or descending series
- The series is continued until participant reports the presence (or absence) of the stimuli. Presentation continues however with a trail in the other direction.



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## Method of Limits – Absolute Threshold - results

- Mean threshold value = 4.1
- Std = 0.843
- JND =  $\text{Std} \cdot \text{Norminv}(0.75)$  =  $\text{Std} \cdot 0.67449$  = 0.569
- Option: after Yes present another stimulus to make sure participant actually see the stimuli

Stimulus intensity (dB)	A	D	A	D	A	D	A	D	A	D
10						Y				
9		Y				Y				Y
8		Y				Y				Y
7		Y		Y		Y				Y
6		Y		Y	Y	Y		Y		Y
5	Y	Y		Y	Y	N	Y	Y		Y
4	N	Y	Y	N	N	N	N	Y	Y	N
3	N	N		N	N	N	N	Y	N	
2	N	N		N	N	N	N	N	N	
1	N	N		N	N	N	N	N	N	
0	N	N		N	N	N	N	N	N	
-1	N		N			N	N			
-2	N					N	N			
-3	N						N			
-4	N									
-5	N									
-6	N									
-7	N									
-8	N									
-9	N									
-10	N									
Transition point	4.5	3.5	3.5	4.5	5.5	4.5	4.5	2.5	3.5	4.5

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## Method of Limits – Absolute Threshold - Errors

- Error of habituation (repeating the same response, too late directing change)
- Error of expectation (prematurely report change)
  - Therefore:
    - vary starting point
    - don't use excessively long trail series
    - Pre-training and good instructions

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## Method of Limits – Just Noticeable Difference - procedure

- Select standard stimuli (St) where stimuli intensity that can be perceived
- Select set of stimuli (Co)
- Start with stimuli intensity below standard stimuli, and each of member of stimuli set slightly increase intensity (or opposite when descending)
- Participant has to report of the sample (Co) Equal (E), is Greater (G) or Less (L) than the standard stimuli (St).
- Order or Location of Co and St counterbalance or randomised to control for time error or space error

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### Method of Limits – Just Noticeable Difference

Interval of uncertainty  
 $= IU = \text{Avg L upper} - \text{Avg L lower} = 22.00 - 17.95 = 4.05$

Difference limen  $= DL = 0.5IU = 0.5(4.05) = 2.025$

PSE  $= 0.5(\text{Avg L upper} + \text{Avg L lower}) = 0.5(22.00 + 17.95) = 19.97$

Stimulus intensity (dB)	A	D	A	D	A	D	A	D	A	D
24.5						G				
24.0			G					G		
23.5			G					G		G
23.0			G		G			G		G
22.5		G	G		G		G	G		G
22.0	G	E	E	G	E	G	E	G	G	E
21.5	E	E	E	E	E	E	G	E	E	E
21.0	E	E	E	E	E	E	E	E	E	E
20.5	E	E	E	E	E	E	E	E	E	E
20.0	E	E	E	E	E	E	E	E	E	E
19.5	E	E	E	E	E	E	E	E	E	E
19.0	E	E	E	E	E	E	E	E	E	E
18.5	E	L	E	E	E	E	E	E	E	E
18.0	E	L	E	L	E	L	E	L	E	E
17.5	L	L	L	L	E	L	L	L	L	L
17.0	L	L	L	L	L	L	L	L	L	L
16.5	L	L	L	L	L	L	L	L	L	L
16.0	L	L	L	L	L	L	L	L	L	L
15.5	L	L	L	L	L	L	L	L	L	L
Upper limen	21.75	22.25	22.25	21.75	22.75	21.25	22.25	21.75	21.75	22.25
Lower limen	17.75	18.75	17.75	18.25	17.25	18.25	17.75	18.25	17.75	17.75

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### Method of Limits – Procedure Issue

- Where to start the stimuli sequence?
  - Start near the threshold of JND, need pilot study
- Initial step size?
  - Too small -> great number of trials
  - Too large -> no precision in estimation threshold
- When to stop collecting data?
  - Set stop criteria expressed in number of response changes
- Modification of step sizes
  - Initial step large, and near threshold interval decrease

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### Method of Limits

- Advantage
  - Is more efficient than Method of Constant Stimuli
  - Could be used as pilot study to collect values to be used in Method of Constant Stimuli
- Limitations
  - Less precise than the method of Constant Stimuli

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### Variations of the Method of Limits – Staircase Method

- Same as the Method of Limits however the starting point of series was the end point of the previous series
- Quick converges towards threshold
- Variation is double staircase (2 parallel sequence, one descending one increasing, randomly switch between) to avoid bias of a less-than-honest participant

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### Psychophysical Methods

#### Sensitivity

- Method of Constant Stimuli V
- Method of Limits V
- Method of Adjustment**

#### Preference

- Paired Comparison
- Sorting Method
- Triangle or Three-Sample Method

- What is intensity of stimuli that is just visible (*absolute threshold*)?
- What is the minimum intensity that is just perceived as different from the standard (just-noticeable difference)?

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### Method of Adjustment – Absolute Threshold - Procedure

- Participants control the changes in stimulus
- Start point stimulus is set far below or far above threshold
- Participants have to increase (or decrease) stimuli until sensation is just perceptible (or disappears)
- Stimuli is often continuously variable
- Often a participant is asked a large number of ascendings and descendings
- Active participation helps to prevent boredom
- Important to randomise starting points to avoid error of expectation and habituation

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## Method of Adjustment – Just Noticeable Difference

- (method of average error)
- Participant is asked to adjust the stimuli to match a standard stimuli (St)
- In large set, it is expected that sometime underestimate and sometimes overestimate the St
- PSE = Mean value
- Constant Error = PSE – St
- Std as indication of JND



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## Limitation Constant stimuli, Limits, and method of adjustment

- Might fail to provide true measurement of sensitivity
- Because of
  - Response bias such as the less-than-honestly participant "how can one be sure that the thresholds of some observers are very low because they are extraordinarily sensitive or because of their tendencies to report the presence of stimuli that are below their thresholds of awareness" (Gescheider, 1997, p.63)
  - Forced-choice methods address this issue

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## Psychophysical Methods

### Sensitivity

- Method of Constant Stimuli V
- Method of Limits V
- Method of Adjustment V

### Preference

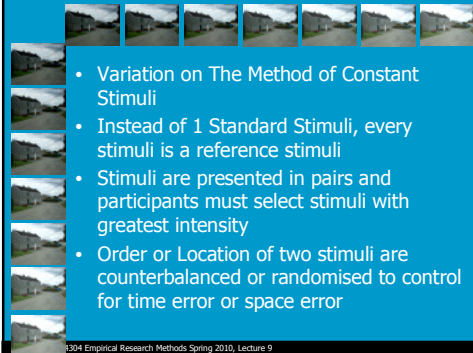
- Paired Comparison
- Sorting Method
- Triangle or Three-Sample Method

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## Paired Comparison - Procedure



- Variation on The Method of Constant Stimuli
- Instead of 1 Standard Stimuli, every stimuli is a reference stimuli
- Stimuli are presented in pairs and participants must select stimuli with greatest intensity
- Order or Location of two stimuli are counterbalanced or randomised to control for time error or space error

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## Paired Comparison - Results

Relative Frequency of greater intensity

Intensity	10	20	30	40	50
	S1	S2	S3	S4	S5
S1	0.5	0.6	0.7	0.8	0.9
S2	0.4	0.5	0.6	0.7	0.8
S3	0.3	0.4	0.5	0.6	0.7
S4	0.2	0.3	0.4	0.5	0.6
S5	0.1	0.2	0.3	0.4	0.5

Z-score, psychometric function for each sample (stimuli)

Intensity	10	20	30	40	50	Intercept	slope	PSE	DL(upper)	JND	CE
S1	0.00	0.25	0.52	0.84	1.28	-0.37	0.032	11.59	32.99	21.40	1.59
S2	-0.25	0.00	0.25	0.52	0.84	-0.54	0.027	19.93	44.78	24.85	-0.07
S3	-0.52	-0.25	0.00	0.25	0.52	-0.78	0.026	30.00	55.90	25.90	0.00
S4	-0.84	-0.52	-0.25	0.00	0.25	-1.09	0.027	40.07	64.91	24.85	0.07
S5	-1.28	-0.84	-0.52	-0.25	0.00	-1.53	0.032	48.41	69.81	21.40	-1.59

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## Psychophysical Methods

### Sensitivity

- Method of Constant Stimuli V
- Method of Limits V
- Method of Adjustment V

### Preference

- Paired Comparison V
- Sorting Method
- Triangle or Three-Sample Method

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## Sorting Method - Procedure



- **Absolute threshold:** Participant sorts a set of stimuli into 2 piles according to whether the stimuli is perceivable or not.
- **JND:** Participant sorts a set of stimuli into 2 piles according to whether they have an intensity greater than the standard



Standard stimuli

- This process has to be repeated many times, or performed once by many observers

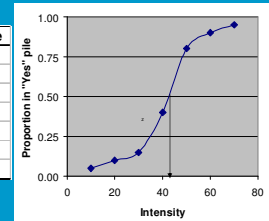
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## Sorting Method - Results

Stimuli	Intensity	Proportion in "Yes" pile
S1	10	0.05
S2	20	0.10
S3	30	0.15
S4	40	0.40
S5	50	0.80
S6	60	0.90
S7	70	0.95



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## Psychophysical Methods

### Sensitivity

- Method of Constant Stimuli V
- Method of Limits V
- Method of Adjustment V

### Preference

- Paired Comparison V
- Sorting Method V
- Triangle or Three-Sample Method

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## Triangle or Three-Sample Method - Procedure



- Can be used when the type of stimuli is difficult to define (e.g. some distortion in an image)
- Participants have to select the odd one out of 3 stimuli whereby 2 similar and one different.
- Threshold: two out of 3 stimuli do not have perceivable intensity
- JND: two stimuli reference stimuli
- Order or Location of two stimuli are counterbalanced or randomised to control for time error or space error
- Important: it should be possible to create 2 identical stimuli

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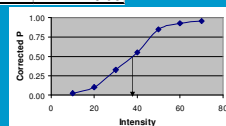


## Triangle or Three-Sample Method - Result

Stimuli	Intensity	Proportion correct response	Corrected P
S1	10	0.35	0.02
S2	20	0.40	0.10
S3	30	0.55	0.33
S4	40	0.70	0.55
S5	50	0.90	0.85
S6	60	0.95	0.93
S7	70	0.97	0.96

$$P'_{js} = \frac{3P_{js} - 1}{2}$$

Correction of guessing



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## Direct scaling

reference image



stimulus



less contract



more contract

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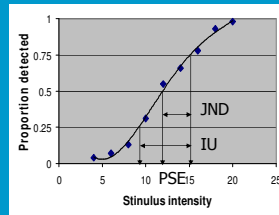
## Summary

### Methods to measure sensitivity of stimuli

- Method of Constant Stimuli
- Method of Limits
- Method of Adjustment

### Methods to measure preference

- Paired Comparison
- Sorting Method
- Triangle or Three-Sample Method



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## This week in practicum

### Week 4.2

- Working on project coursework (one-way ANOVA, two-way ANOVA)
- Working on project coursework (ANOVA with repeated measure)

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## Next time

### Week 4.3 Qualitative oriented research

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## References

- Engel drum, P.G. (2000). Chapter 5: Thresholds and Just-Noticeable Differences. In *Psychometric Scaling: A Toolkit for Imaging Systems Development*. Imcotek.
- Gescheider, G.A. (1997). Chapter 3: The Classical Psychophysical Methods. In *Psychophysics: the fundamentals*, Mahwah, New York: Lawrence Erlbaum Associates.

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