The background features a light gray grid on the left side. On the right, there is a large, curved, abstract graphic composed of overlapping, semi-transparent geometric shapes in various colors including orange, red, purple, blue, and green. A small orange triangle is visible on the left edge of the grid.

Practical Measurement Systems Analysis (Gage R&R) for Design

Topics

- Basics of gage R&R
- Gage R&R calculations
 - Using R
- Design Gage R&R – Gage Discrimination
- Pitfalls of Gage R&R
- Discussion



■ Rob Schubert

Reliability Consultant – Akhan Semiconductor

Reliability Engineer - Apple

Corporate Quality/Reliability Engineer - Shure Inc (13 yrs)

Quality Engineer, Six Sigma Blackbelt, Noise Vibration Engineer – Ford (13 yrs)

Certified Reliability Engineer (ASQ), Certified CMQ/OE (ASQ), Six Sigma Blackbelt (Ford)

Master's in Acoustical Engineering, Penn State

Robert.j.Schubert@gmail.com

Previous Presentations:

Overview of life testing in Minitab (Minitab insights, Accendo reliability)

2 parameter vs 3 parameter Weibull with a cable flex test (ARDC)

Practical use of the Stress-Strength models to develop specifications (ARDC, Accendo reliability)



Gage R&R – what is it?

Simple bathroom scale

Measurements listed in 0.5 lbs
Does that mean ± 0.25 lbs?



Gage R&R – what is it?



Operator effect: How do you quantify?

Gage R&R – what is it?



What is it you are trying to measure?
Large differences or small differences?



Gage R&R – what is it?

Part of **Measurement Systems Analysis**

includes:

Accuracy:

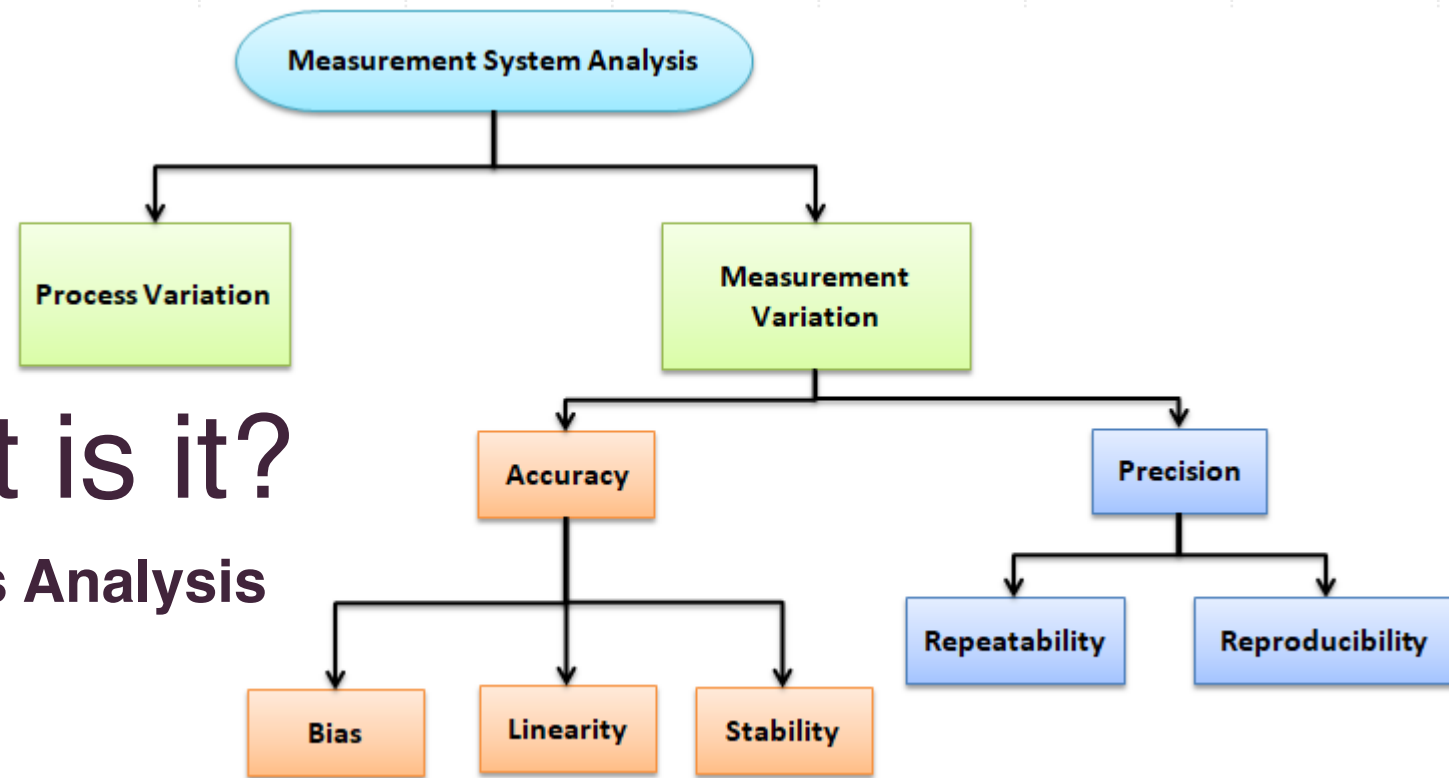
Resolution of gage

Linearity

Stability/consistency

Precision:

Gage R&R



Accuracy vs Precision



High precision, low accuracy



High accuracy, low precision

Resolution

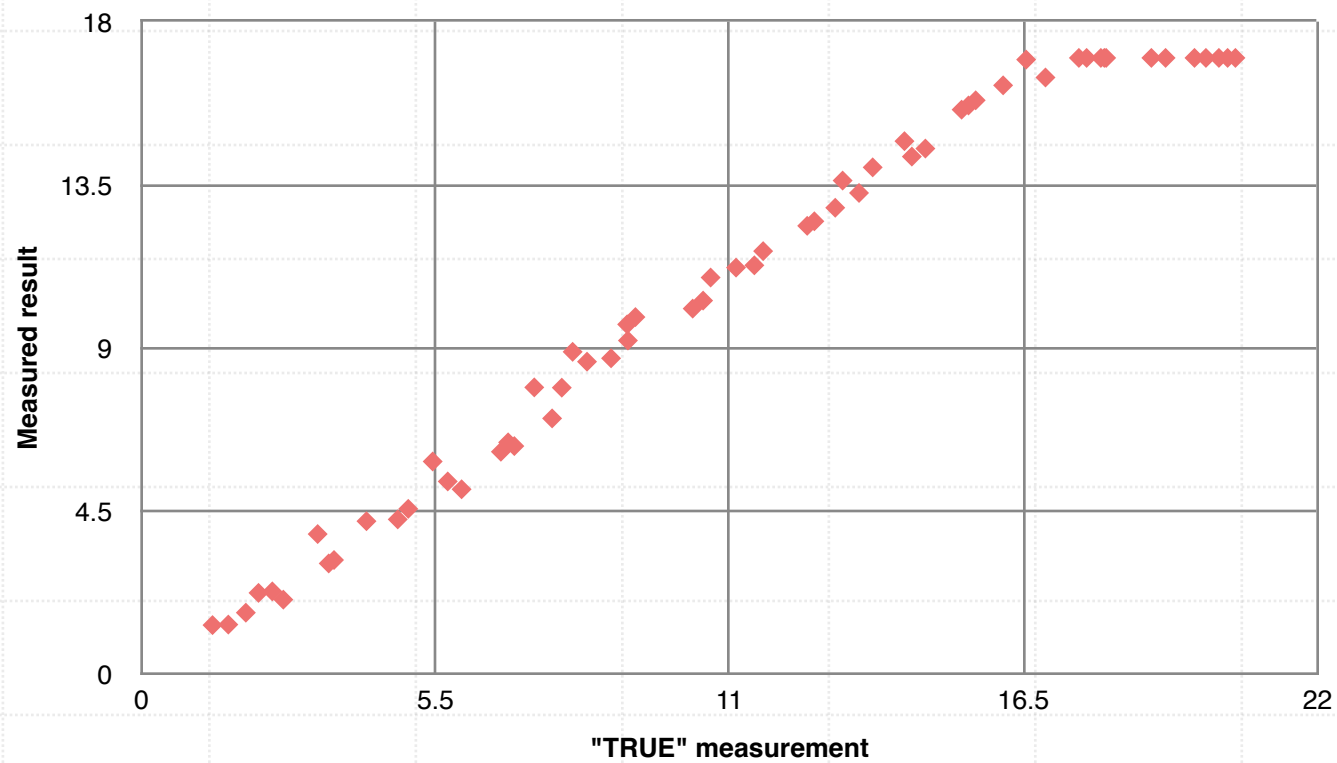
- Calipers: 0.001"



- Crude ruler: Perhaps $\frac{1}{4}$ " ?



Linearity



Stability/Consistency

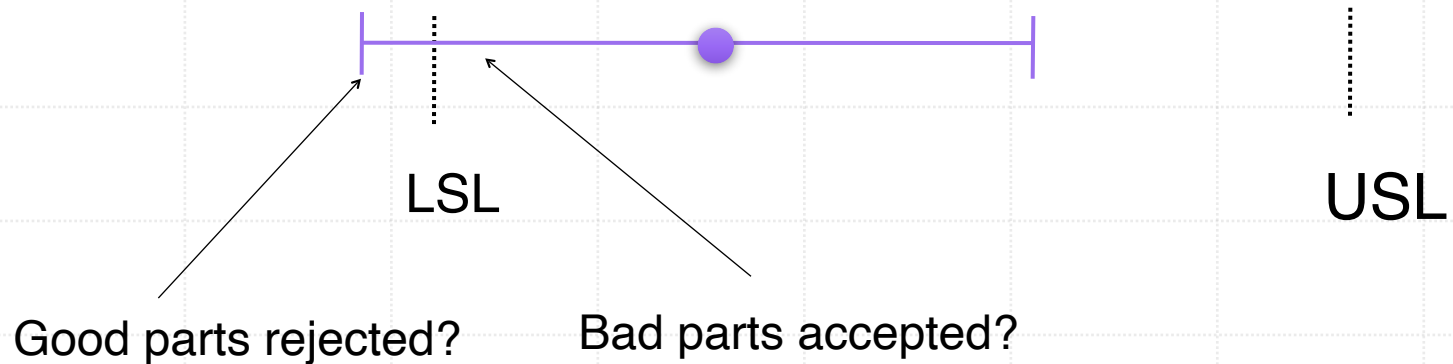
part	Op1 Run1	Op2 Run 1	Op1 Run 2	Op2 Run 2
1	10.19	10.04	10.93	10.30
2	12.02	12.08	12.85	12.16
3	5.21	5.52	5.26	5.11
4	7.36	7.14	7.41	7.07
5	9.91	10.24	11.06	19.23

Not enough cool down time?

Gage R&R – Why?

For Production, misclassification of parts means:

- unnecessary scrapping or reworking
- shipment of unacceptable product to customers



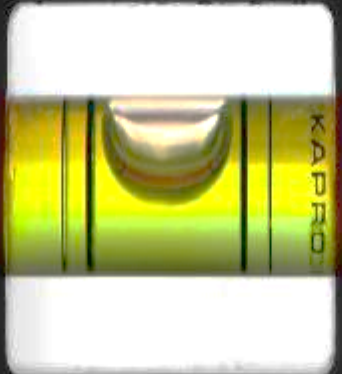
Types of Data

- **Variable (Continuous)**

- continuous scale
 - Examples: length, height, gap, thickness, torque, speed, hardness

- **Attribute (Discrete)**

- **cannot** be described on a continuous scale
 - Binary
 - Examples: Pass/Fail, Good/Bad, Go/No Go
 - Ordinal
 - Examples: Low/Med/Hi, color gradient

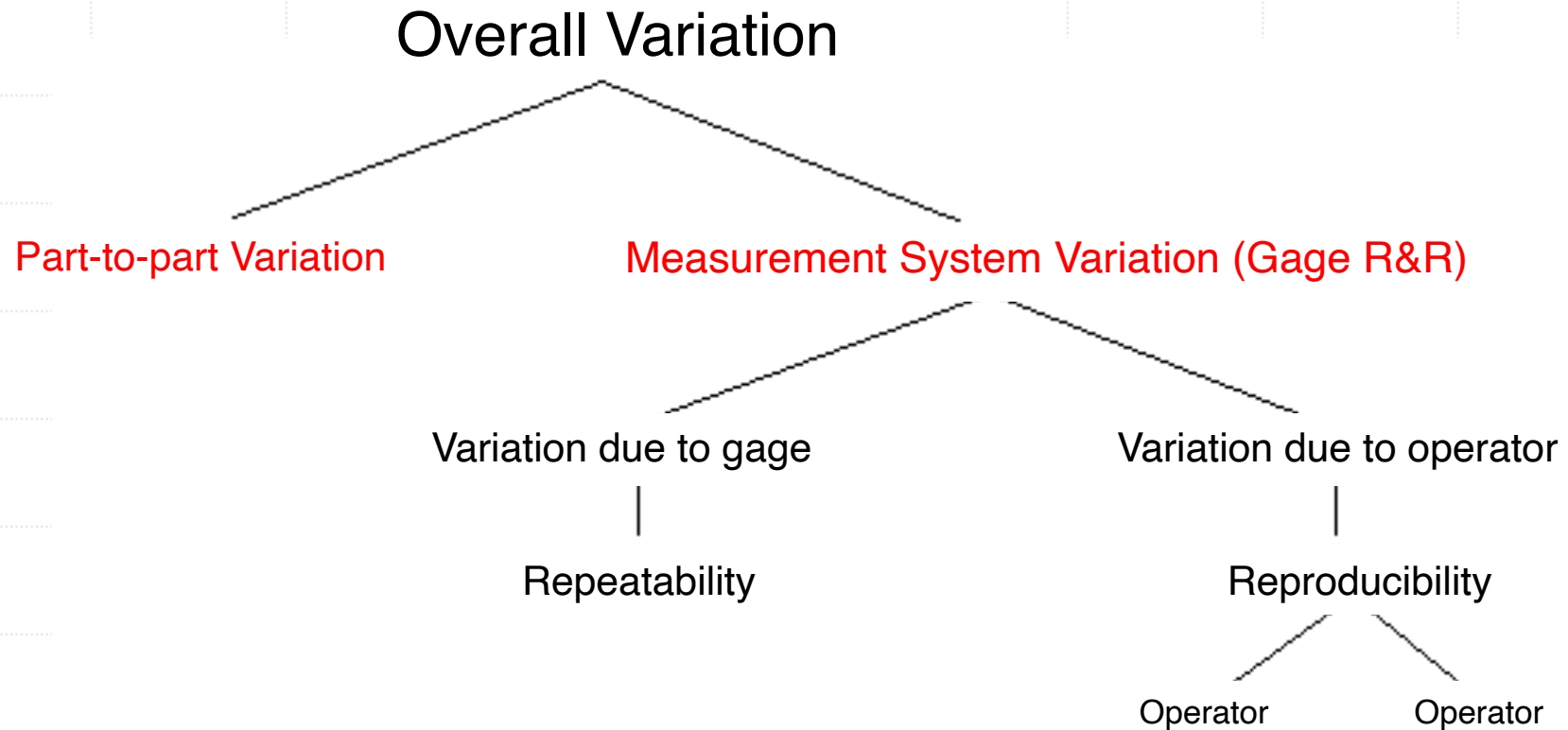


Gage R&R: Type 0, Type 1, Type 2

- Type 0 Gage R&R repeats measurements without removing the sample.
 - For example: “bed of nails” electronic board test, or Soundroom measurement
- Type 1 Gage R&R removes and replaces the part for each measurements
- Type 2 is standard: 2 or more operator, multiple parts, 2 or more measurements

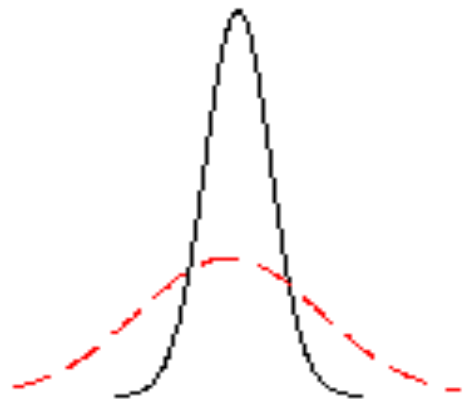


Variation contributors



Repeatability vs Reproducibility

Repeatability

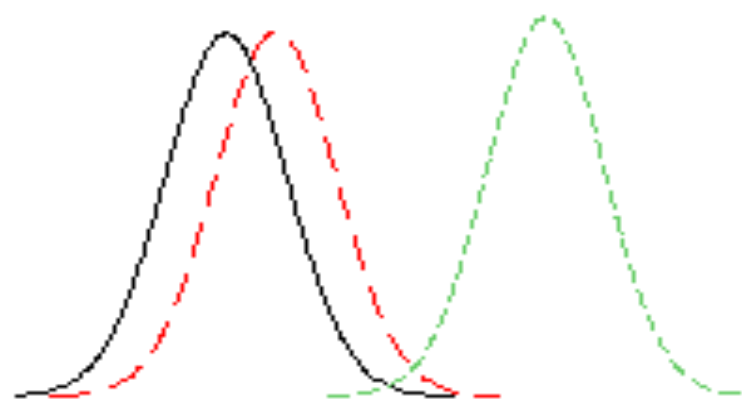


Gage A

Gage B

the variation in measurements obtained with one measurement instrument when used several times by one appraiser while measuring the identical characteristic on the same part.

Reproducibility



Appraiser 1

Appraiser 2

Appraiser 3

the variation in the average of the measurements made by different appraisers using the same measuring instrument when measuring the identical characteristic on the same part.

Sample Size and Operator Selection

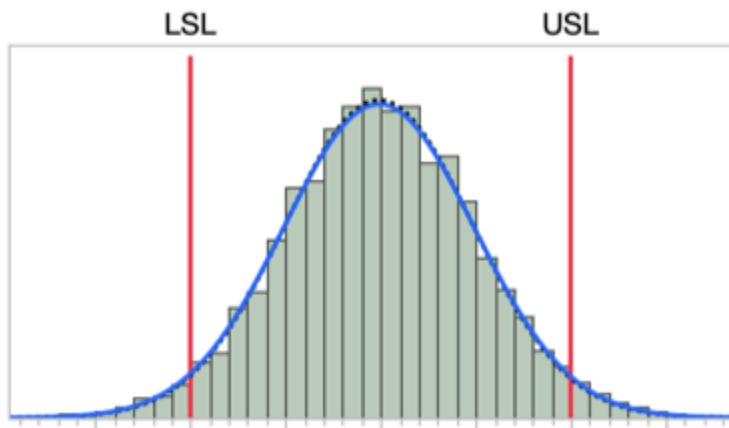
Rule of thumb

- 10+ samples
- 2+ operators
- 2+ measurements each
- 1 or (possibly) more gages
- **All environmental conditions if possible**
(number of samples x number of operators)/number of gages >15
- Operator Selection
 - people that normally take measurements
 - represent full range of experience levels



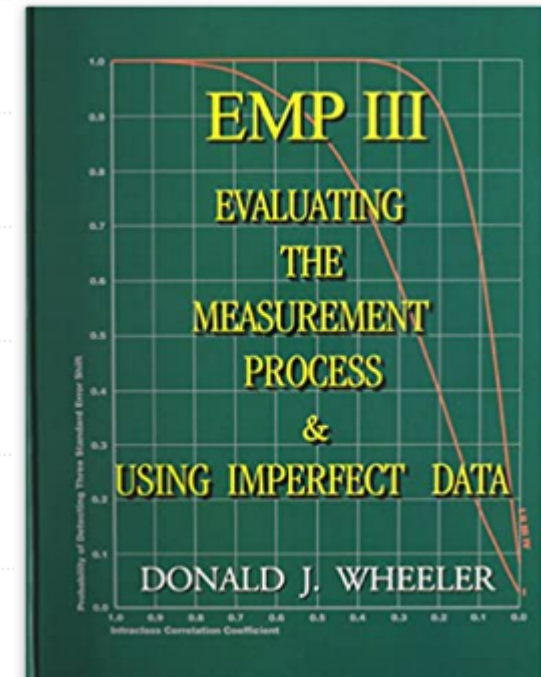
Production Gage R&R

- Automotive Industry Action Group levels:
 - <10% - Good
 - 10-30% - Marginal
- What does 10% or 30% mean?



Production Gage R&R ratings – Wheeler method

- 1st class monitor
 - $< 20\%$ Total gage R&R
 - better than a 99% chance of detecting a shift within 10 subgroups
- 2nd class monitor
 - $< 50\%$ Total gage R&R
 - better than a 88% chance of detecting a shift within 10 subgroups



Gage R&R calculations (average and range method)

- Equipment variation - $EV = R \bar{K}_1$
(repeatability)

- Appraiser variation -
(reproducibility)

$$AV = \sqrt{(\bar{X}_{DIFF} * K_2)^2 - (EV)^2 / nr}$$

- Total Gage R&R StDev** $= \sqrt{EV^2 + AV^2}$

- Part to Part StDev - PV = Rp(K₃)**

- Total Variation** $= \sqrt{PV^2 + EV^2 + AV^2}$

Total Gage R&R
Repeatability
Reproducibility
Operator
Part-To-Part
Total Variation

StdDev	StudyVar	%StudyVar

These are used for design gage R&R

Number of district categories

- $NoDC = \frac{Part\ to\ Part\ StDev}{Total\ Gage\ RR\ StDev} * \sqrt{2}$

Gage R&R calculations

- Equipment variation - $EV = R \overline{(K_1)}$
(repeatability)

- Appraiser variation - $AV = \sqrt{(\bar{X}_{DIFF} * K_2)^2 - (EV)^2 / nr}$
(reproducibility)

- Total Gage R&R StDev** $= \sqrt{EV^2 + AV^2}$

- Part to Part StDev - PV = Rp(K₃)**

Number of district categories

- $NoDC = \frac{Part\ to\ Part\ StDev}{Total\ Gage\ RR\ StDev} * \sqrt{2}$

Example data:

Operator	Part	Trial				Range	Mean	Mean Range	Mean Mean
		1st	2nd	3rd	4th				
A	x	0.29	0.31	0.33	0.32	0.04	0.3125	0.04	0.2958
A	y	0.28	0.29	0.31	0.27	0.04	0.2875		
A	z	0.27	0.29	0.31	0.28	0.04	0.2875		
B	x	0.3	0.31	0.3	0.32	0.02	0.3075	0.02	0.2991
B	y	0.29	0.28	0.3	0.29	0.02	0.29		
B	z	0.29	0.3	0.31	0.3	0.02	0.3		
C	x	0.3	0.3	0.31	0.3	0.01	0.3025	0.01	0.2975
C	y	0.29	0.28	0.29	0.28	0.01	0.285		
C	z	0.31	0.3	0.31	0.3	0.01	0.305		

Gage R&R calculations

- $EV = \bar{R} (K_1)$
- \bar{R} is average range
 - Total mean range = $(0.04+0.02+0.01)/3 = 0.0233$

Example data:

Operator	Part	Trial				Range	Mean	Mean Range	Mean Mean
		1st	2nd	3rd	4th				
A	x	0.29	0.31	0.33	0.32	0.04	0.3125	0.04	0.2958
A	y	0.28	0.29	0.31	0.27	0.04	0.2875		
A	z	0.27	0.29	0.31	0.28	0.04	0.2875		
B	x	0.3	0.31	0.3	0.32	0.02	0.3075	0.02	0.2991
B	y	0.29	0.28	0.3	0.29	0.02	0.29		
B	z	0.29	0.3	0.31	0.3	0.02	0.3		
C	x	0.3	0.3	0.31	0.3	0.01	0.3025	0.01	0.2975
C	y	0.29	0.28	0.29	0.28	0.01	0.285		
C	z	0.31	0.3	0.31	0.3	0.01	0.305		

- EV = $\overline{R}(K_1)$

- \bar{R} is average range
 - Total mean range = $(0.04+0.02+0.01)/3 = 0.0233$
- K_1 is a constant based on the number of trials
 - $K_1 = 1/d_2$
 - Subgroup size = number of trials = 4
 - Number of combination of parts and operators (g) = 3 parts and 3 Operators = $3*3=9$
 - $d_2 = 2.080$
 - $K_1 = 1/d_2 = 1/2.080 = 0.480$
 - $EV = \bar{R} * K_1 = 0.0233 * 0.480 = 0.0112$

k	Subgroup size, n														
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	1.414	1.912	2.239	2.481	2.673	2.830	2.963	3.078	3.179	3.269	3.350	3.424	3.491	3.553	
2	1.279	1.805	2.151	2.405	2.604	2.768	2.906	3.025	3.129	3.221	3.305	3.380	3.449	3.511	
3	1.231	1.769	2.120	2.379	2.581	2.747	2.886	3.006	3.112	3.205	3.289	3.366	3.435	3.499	
4	1.206	1.750	2.105	2.366	2.570	2.736	2.877	2.997	3.103	3.197	3.282	3.358	3.428	3.492	
5	1.191	1.739	2.096	2.358	2.563	2.730	2.871	2.992	3.098	3.192	3.277	3.354	3.424	3.488	
6	1.181	1.731	2.090	2.353	2.558	2.726	2.867	2.988	3.095	3.189	3.274	3.351	3.421	3.486	
7	1.173	1.726	2.085	2.349	2.555	2.723	2.864	2.986	3.092	3.187	3.272	3.349	3.419	3.484	
8	1.168	1.721	2.082	2.346	2.552	2.720	2.862	2.984	3.090	3.185	3.270	3.347	3.417	3.482	
9	1.164	1.718	2.080	2.344	2.550	2.719	2.860	2.982	3.089	3.184	3.269	3.346	3.416	3.481	
10	1.160	1.716	2.077	2.342	2.549	2.717	2.859	2.981	3.088	3.183	3.268	3.345	3.415	3.480	
11	1.157	1.714	2.076	2.340	2.547	2.716	2.858	2.980	3.087	3.182	3.267	3.344	3.415	3.479	
12	1.155	1.712	2.074	2.3439	2.546	2.715	2.857	2.979	3.086	3.181	3.266	3.343	3.414	3.479	
13	1.153	1.710	2.073	2.338	2.545	2.714	2.856	2.978	3.085	3.180	3.266	3.343	3.413	3.478	
14	1.151	1.709	2.072	2.337	2.545	2.714	2.856	2.978	3.085	3.180	3.265	3.342	3.413	3.478	
15	1.150	1.708	2.071	2.337	2.544	2.713	2.855	2.977	3.084	3.179	3.265	3.342	3.412	3.477	

d ₂	1.128	1.693	2.059	2.326	2.534	2.704	2.847	2.970	3.078	3.173	3.259	3.336	3.407	3.472
k	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Subgroup size, n														

Gage R&R calculations

$$AV = \sqrt{(\bar{X}_{DIFF} * K_2)^2 - (EV)^2 / nr}$$

- \bar{X}_{diff} is the range of means = $0.2991 - 0.2958 = 0.0033$
- n = number of parts = 3
- r = number of trials = 4

Example data:

Operator	Part	Trial				Range	Mean	Mean Range	Mean Mean
		1st	2nd	3rd	4th				
A	x	0.29	0.31	0.33	0.32	0.04	0.3125	0.04	0.2958
A	y	0.28	0.29	0.31	0.27	0.04	0.2875		
A	z	0.27	0.29	0.31	0.28	0.04	0.2875		
B	x	0.3	0.31	0.3	0.32	0.02	0.3075	0.02	0.2991
B	y	0.29	0.28	0.3	0.29	0.02	0.29		
B	z	0.29	0.3	0.31	0.3	0.02	0.3		
C	x	0.3	0.3	0.31	0.3	0.01	0.3025	0.01	0.2975
C	y	0.29	0.28	0.29	0.28	0.01	0.285		
C	z	0.31	0.3	0.31	0.3	0.01	0.305		

$$AV = \sqrt{(\bar{X}_{DIFF} * K_2)^2 - (EV)^2 / nr}$$

- \bar{x}_{diff} is the range of means = $0.2991 - 0.2958 = 0.0033$
- n = number of parts = 3
- r = number of trials = 4

$$\mathbf{K}_2 = 1/d_2$$

But this time we use
number of parts = 3

And

Number of combination of parts and operators (g) = 3 parts and 3 Operators = $3 \times 3 = 9$

So $K_2 = 1/d_2 = 1/1.718 = 0.582$

k	Subgroup size, n													
	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.414	1.912	2.239	2.481	2.673	2.830	2.963	3.078	3.179	3.269	3.350	3.424	3.491	3.553
2	1.279	1.805	2.151	2.405	2.604	2.768	2.906	3.025	3.129	3.221	3.305	3.380	3.449	3.513
3	1.231	1.769	2.120	2.379	2.581	2.747	2.886	3.006	3.112	3.205	3.289	3.366	3.435	3.499
4	1.206	1.750	2.105	2.366	2.570	2.736	2.877	2.997	3.103	3.197	3.282	3.358	3.428	3.492
5	1.191	1.739	2.096	2.358	2.563	2.730	2.871	2.992	3.098	3.192	3.277	3.354	3.424	3.488
6	1.181	1.731	2.090	2.353	2.558	2.726	2.867	2.988	3.095	3.189	3.274	3.351	3.421	3.486
7	1.173	1.726	2.085	2.349	2.555	2.723	2.864	2.986	3.092	3.187	3.272	3.349	3.419	3.484
8	1.168	1.721	2.082	2.346	2.552	2.720	2.862	2.984	3.090	3.185	3.270	3.347	3.417	3.482
9	1.164	1.718	2.080	2.344	2.550	2.719	2.860	2.982	3.089	3.184	3.269	3.346	3.416	3.481
10	1.160	1.716	2.077	2.342	2.549	2.717	2.859	2.981	3.088	3.183	3.268	3.345	3.415	3.480
11	1.157	1.714	2.076	2.340	2.547	2.716	2.858	2.980	3.087	3.182	3.267	3.344	3.415	3.479
12	1.155	1.712	2.074	2.3439	2.546	2.715	2.857	2.979	3.086	3.181	3.266	3.343	3.414	3.478
13	1.153	1.710	2.073	2.338	2.545	2.714	2.856	2.978	3.085	3.180	3.266	3.343	3.413	3.478
14	1.151	1.709	2.072	2.337	2.545	2.714	2.856	2.978	3.085	3.180	3.265	3.342	3.413	3.478
15	1.150	1.708	2.071	2.337	2.544	2.713	2.855	2.977	3.084	3.179	3.265	3.342	3.412	3.477

d_2	1.128	1.693	2.059	2.326	2.534	2.704	2.847	2.970	3.078	3.173	3.259	3.336	3.407	3.472
k	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Gage R&R calculations

$$AV = \sqrt{(\bar{X}_{DIFF} * K_2)^2 - (EV)^2 / nr}$$

$$= \sqrt{(0.033 * 0.582)^2 - \frac{(0.0112)^2}{3 * 4}} = \sqrt{-0.00000672} = 0$$

Example data:

■ Total Gage R&R Standard deviation

$$= \sqrt{EV^2 + AV^2}$$

$$= \sqrt{(0.0112)^2 + (0)^2} = 0.0112$$

Operator	Part	Trial				Range	Mean	Mean Range	Mean Mean
		1st	2nd	3rd	4th				
A	x	0.29	0.31	0.33	0.32	0.04	0.3125	0.04	0.2958
A	y	0.28	0.29	0.31	0.27	0.04	0.2875		
A	z	0.27	0.29	0.31	0.28	0.04	0.2875		
B	x	0.3	0.31	0.3	0.32	0.02	0.3075	0.02	0.2991
B	y	0.29	0.28	0.3	0.29	0.02	0.29		
B	z	0.29	0.3	0.31	0.3	0.02	0.3		
C	x	0.3	0.3	0.31	0.3	0.01	0.3025	0.01	0.2975
C	y	0.29	0.28	0.29	0.28	0.01	0.285		
C	z	0.31	0.3	0.31	0.3	0.01	0.305		

Gage R&R calculations

- Part to part Standard Deviation - $PV = R_p(K_3)$

$$R_p = \bar{X}_{\text{Part Max}} - \bar{X}_{\text{Part Min}}$$

- $R_p = 2.991 - 2.958 = 0.033$

Example data:

Operator	Part	Trial				Range	Mean	Mean Range	Mean Mean
		1st	2nd	3rd	4th				
A	x	0.29	0.31	0.33	0.32	0.04	0.3125	0.04	0.2958
A	y	0.28	0.29	0.31	0.27	0.04	0.2875		
A	z	0.27	0.29	0.31	0.28	0.04	0.2875		
B	x	0.3	0.31	0.3	0.32	0.02	0.3075	0.02	0.2991
B	y	0.29	0.28	0.3	0.29	0.02	0.29		
B	z	0.29	0.3	0.31	0.3	0.02	0.3		
C	x	0.3	0.3	0.31	0.3	0.01	0.3025	0.01	0.2975
C	y	0.29	0.28	0.29	0.28	0.01	0.285		
C	z	0.31	0.3	0.31	0.3	0.01	0.305		

Gage R&R calculations

- Part to part Standard Deviation - $PV = R_p(K_3)$

$$R_p = \bar{X}_{\text{Part Max}} - \bar{X}_{\text{Part Min}}$$

- $R_p = 2.991 - 2.958 = 0.033$
- $K_3 = 1/d_2$
- But this time we use only number of parts = 3
- $K_3 = 1/1.912 = 0.523$
- $PV = 0.033 * 0.523 = 0.0173$

k	Subgroup size, n														
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	1.414	1.912	2.239	2.481	2.673	2.830	2.963	3.078	3.179	3.269	3.350	3.424	3.491	3.553	
2	1.279	1.805	2.151	2.405	2.604	2.768	2.906	3.025	3.129	3.221	3.305	3.380	3.449	3.513	
3	1.231	1.769	2.120	2.379	2.581	2.747	2.886	3.006	3.112	3.205	3.289	3.366	3.435	3.499	
4	1.206	1.750	2.105	2.366	2.570	2.736	2.877	2.997	3.103	3.197	3.282	3.358	3.428	3.492	
5	1.191	1.739	2.096	2.358	2.563	2.730	2.871	2.992	3.098	3.192	3.277	3.354	3.424	3.488	
6	1.181	1.731	2.090	2.353	2.558	2.726	2.867	2.988	3.095	3.189	3.274	3.351	3.421	3.486	
7	1.173	1.726	2.085	2.349	2.555	2.723	2.864	2.986	3.092	3.187	3.272	3.349	3.419	3.484	
8	1.168	1.721	2.082	2.346	2.552	2.720	2.862	2.984	3.090	3.185	3.270	3.347	3.417	3.482	
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10	1.160	1.716	2.077	2.342	2.549	2.717	2.859	2.981	3.088	3.183	3.268	3.345	3.415	3.480	
11	1.157	1.714	2.076	2.340	2.547	2.716	2.858	2.980	3.087	3.182	3.267	3.344	3.415	3.479	
12	1.155	1.712	2.074	2.3439	2.546	2.715	2.857	2.979	3.086	3.181	3.266	3.343	3.414	3.479	
13	1.153	1.710	2.073	2.338	2.545	2.714	2.856	2.978	3.085	3.180	3.266	3.343	3.413	3.478	
14	1.151	1.709	2.072	2.337	2.545	2.714	2.856	2.978	3.085	3.180	3.265	3.342	3.413	3.478	
15	1.150	1.708	2.071	2.337	2.544	2.713	2.855	2.977	3.084	3.179	3.265	3.342	3.412	3.477	

d ₂	1.128	1.693	2.059	2.326	2.534	2.704	2.847	2.970	3.078	3.173	3.259	3.336	3.407	3.472	
k	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
	Subgroup size, n														

- Number of distinct categories =

$$\text{NoDC} = \frac{\text{Part to Part StDev}}{\text{Total Gage RR StDev}} * \sqrt{2} = \frac{0.0173}{0.0112} * \sqrt{2} = 2.18$$

Design vs production gage R&R

Design:

No Specification

Goal: determine difference between designs
=different part selection

Final measurement: Gage Discrimination



Design Gage R&R – Gage Discrimination

1) Calculate the number of distinct categories (without truncation):

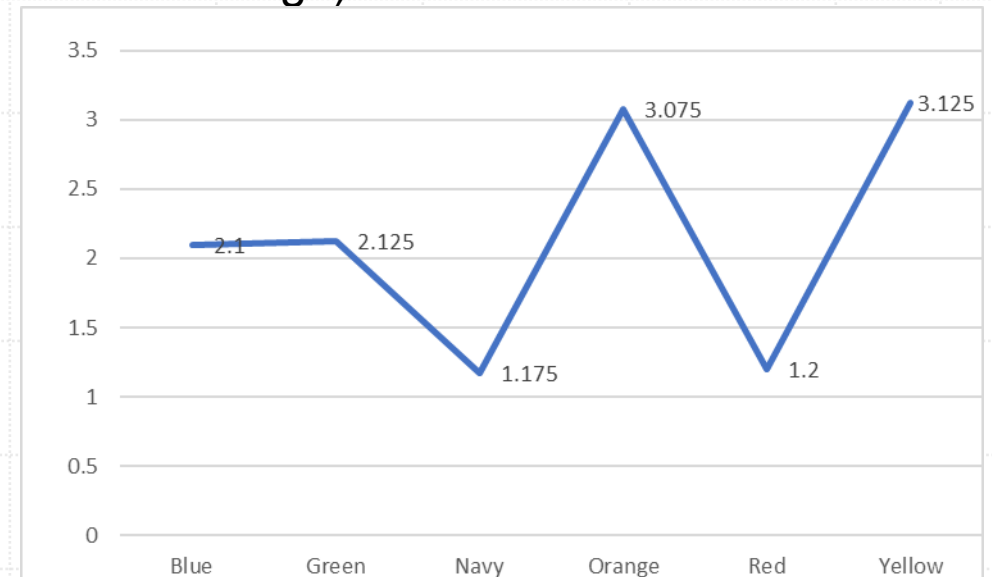
$$\text{NoDC} = \frac{\text{Part to Part StDev}}{\text{Total Gage RR StDev}} * \sqrt{2} \text{ or } \sqrt{2 * \frac{\text{Part to Part Variance}}{\text{Total Gage RR Variance}}}$$

2) Calculate the range

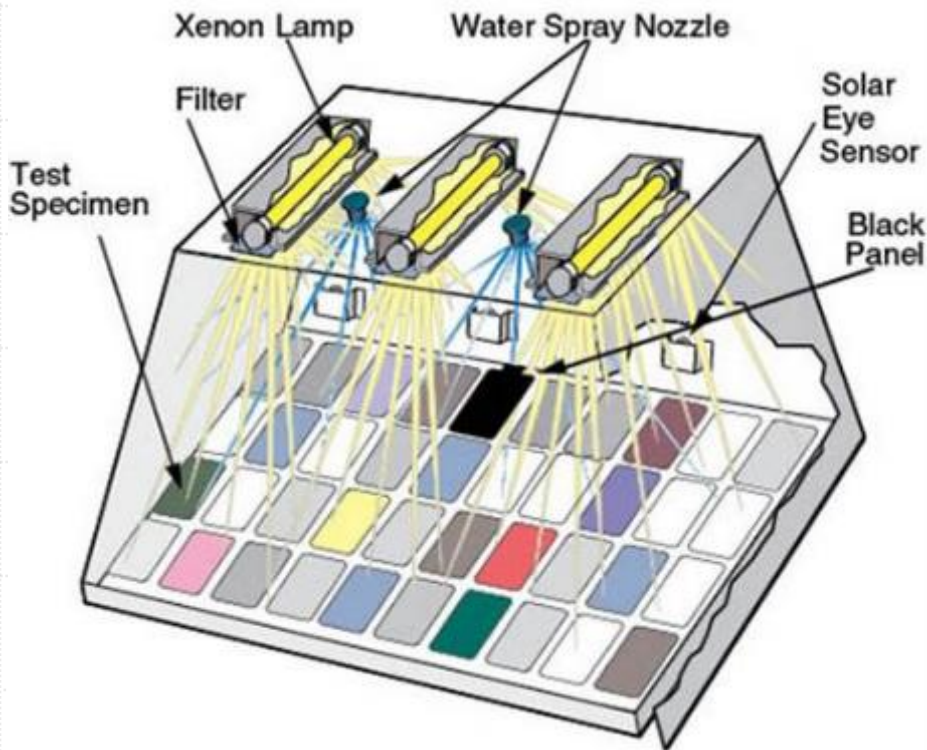
$$\text{Rng} = (\text{Maximum measurement average}) - (\text{Minimum measurement average})$$

3) Divide Range by Number of distinct categories.

$$\frac{\text{Rng}}{\text{NoDc}} = \text{Gage Discrimination}$$

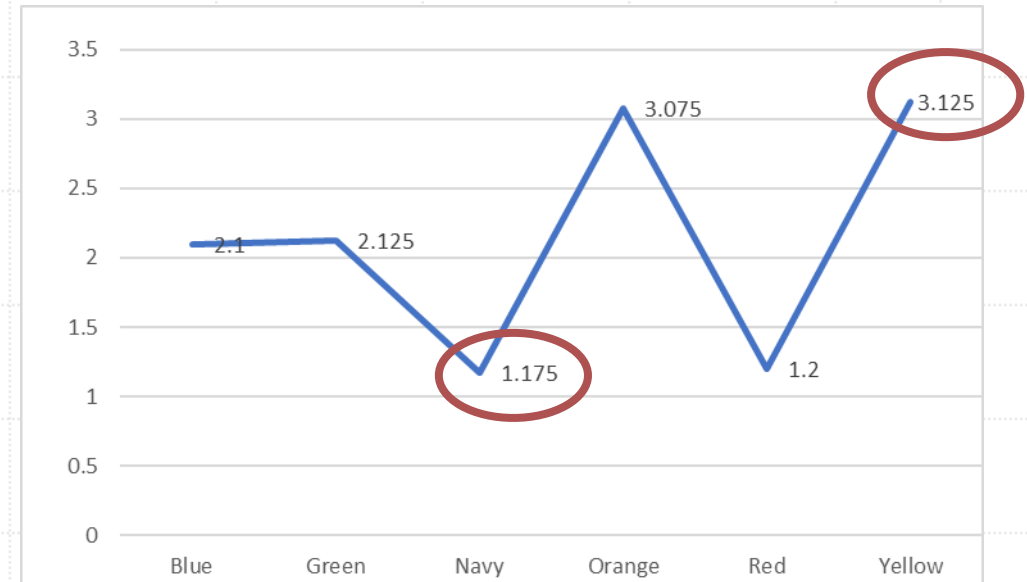


Design Gage R&R – Gage Discrimination Example



Part (color)	Operator	DE94
yellow	1	3.1
yellow	2	3
yellow	1	3.3
yellow	2	3.1
blue	1	2.1
blue	2	2.1
blue	1	2
blue	2	2.2
red	1	1.1
red	2	1.2
red	1	1.2
red	2	1.3
orange	1	3
orange	2	3
orange	1	3.2
orange	2	3.1
green	1	2.1
green	2	2.2
green	1	2
green	2	2.2
navy	1	1.1
navy	2	1.1
navv	1	1.2
nav		1.3

	Mean
DE94	2.133333
part[blue]	2.1
part[green]	2.125
part[navy]	1.175
part[orange]	3.075
part[red]	1.2
part[yellow]	3.125



$$Rng = 3.125 - 1.175 = 1.95$$

Design Gage R&R – Gage Discrimination

R
4.2.1

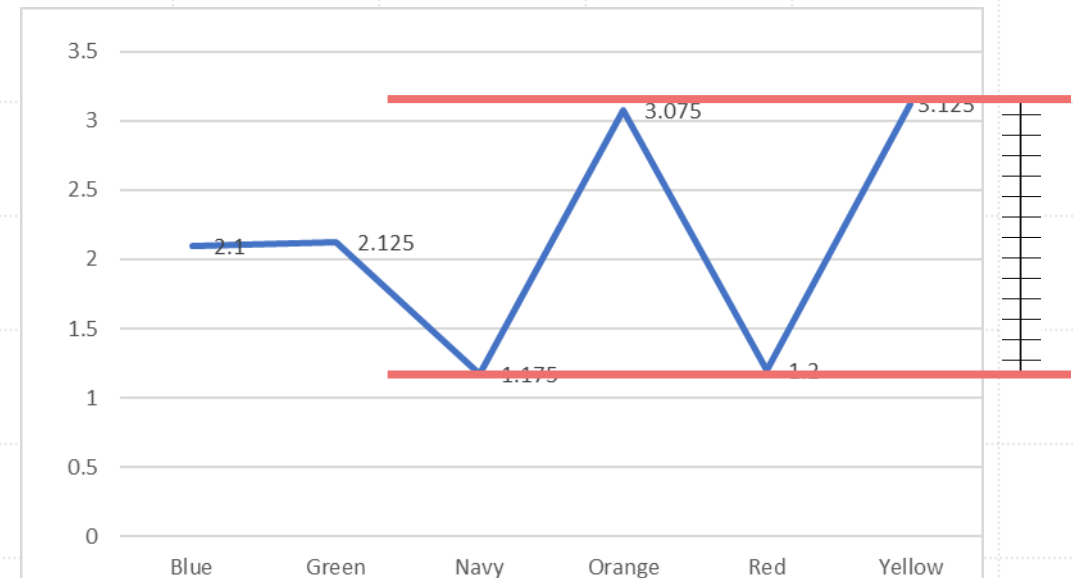
	StdDev	StudyVar	%StudyVar
Total Gage R&R	0.09801961	0.5881176	11.40
Repeatability	0.09801961	0.5881176	11.40
Reproducibility	0.00000000	0.00000000	0.00
Operator	0.00000000	0.00000000	0.00
Part-To-Part	0.85426267	5.1255760	99.35
Total Variation	0.85986775	5.1592065	100.00

$$\text{NoDC} = \frac{\text{Part to Part StDev}}{\text{Total Gage RR StDev}} * \sqrt{2}$$

$$\text{NoDC} = \frac{0.854}{0.0980} * \sqrt{2} = 12.43$$

$$\text{Gage Discrimination} = \frac{R_{ng}}{NoDc} = \frac{1.95}{12.43} = 0.156$$

Meaning: any measurement within **0.156 DE94** is the same measurement





Using R

<https://www.r-project.org/>

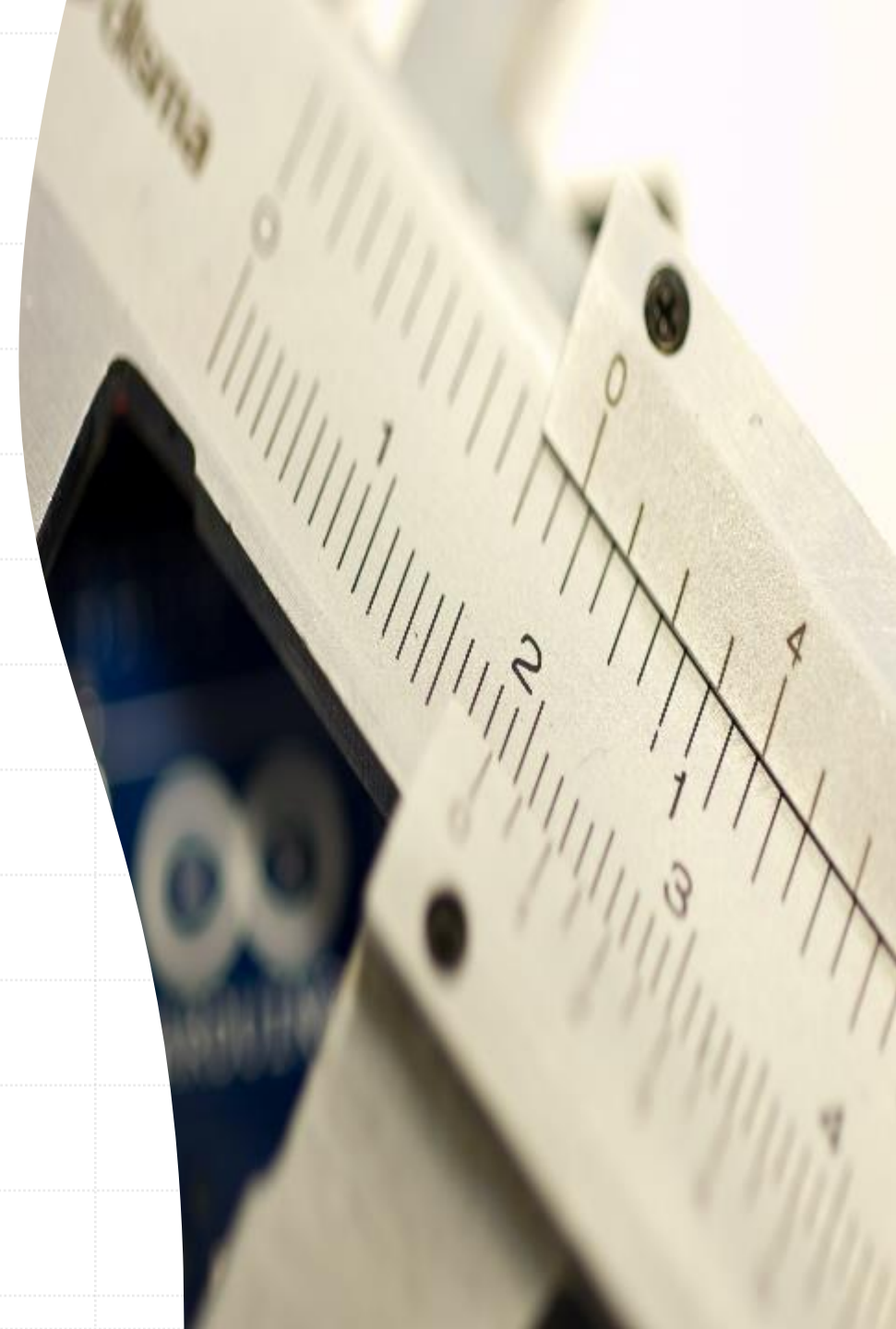
Download R, install

Type in console window:

```
setRepositories()
```

Select all repositories

```
install.packages("SixSigma")  
install.packages("dplyr")
```



R Script

```
# Import packages
library(SixSigma)
library("dplyr")

# remove previous data (if it exists)
rm(DTA)

# Read from CSV
DTA=read.csv("C:/Users/heada/Documents/demoDATA.csv")

# View the data in a table
View(DTA)

# run gage R&R - Console window shows numbers we are
interested in
my.rr <- ss.rr(var = DE94,
               part = Color,
               appr = Operator,
               data = DTA)
```

```
NoDC = (my.rr$studyVar[5.1]/my.rr$studyVar[1,1])*sqrt(2) #calculate NoDC
```

```
RngDta <- DTA %>%
  group_by(Color) %>%
  summarise_at(vars(DE94),
               list(name = mean))
# Specify data frame
# Specify group indicator
# Specify column
# Specify function
```

```
mx=max(RngDta$name)
mn=min(RngDta$name)
Rng=mx-mn
```

```
GageDisc=Rng/NoDC
```

```
csvf<-c("NoDC",NoDC,"Min (avg)",mn,"Max (avg)",mx,"Range = Max -
Min",Rng,"Gage discrimination",GageDisc)
Csvfle<-matrix(csvf,nrow=5,ncol=2,byrow=TRUE)
colnames(Csvfle) <- c("parameter", "value")
```

```
write.csv(Csvfle, "output.csv", row.names = FALSE)
file.show("output.csv")
```



“Don’ts” for Gage R&R

- You cannot run a gage R&R on an environmental chamber – this does conditioning, and you will evaluate a sample before and after this chamber test <- that measurement will need a gage R&R
- Gage R&R is fairly specific to a tool and a set of samples – for a design gage R&R, you can sometimes use a gage discrimination on a different product, but be aware some do not translate. <-be careful.
- If it’s a Go-no-Go gage – that is an attribute gage R&R, do not use a variable Gage R&R

Non-Destructive vs Destructive

Non-destructive

- Has repeats
- Uses Crossed Gage R&R

Destructive

- no repeats (since destroyed)
- Uses Nested Gage R&R

NOTE: All variation part to part is captured in the gage R&R as repeatability

Most Reliability Testing is destructive



Destructive Gage R&R – Gage Discrimination

Create parts with defects

Example

Glue joint:

- left half glued
- right half glued
- all glued
- no glue

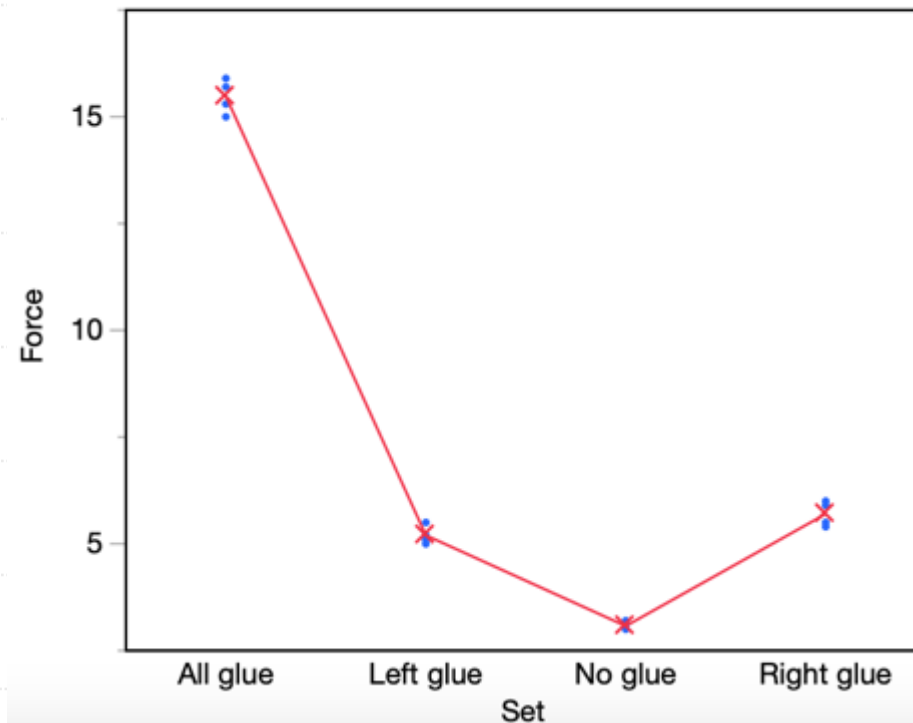
Note! You can use different trial runs
you may wish to find ones with low variability



Destructive Gage R&R – Gage Discrimination Example

Force	Operator	Set	Part
5	1	Left glue	1
5.1	2	Left glue	2
5.5	1	Left glue	3
5.2	2	Left glue	4
6	1	Right glue	5
5.9	2	Right glue	6
5.4	1	Right glue	7
5.5	2	Right glue	8
15	1	All glue	9
15.7	2	All glue	10
15.3	1	All glue	11
15.9	2	All glue	12
3	1	No glue	13
3	2	No glue	14
3.2	1	No glue	15
3.1	2	No glue	16

Mean of Force by Set



Level	Number	Mean
All glue	4	15.4750
Left glue	4	5.2000
No glue	4	3.0750
Right glue	4	5.7000

$$Rng = 15.475 - 3.075 = 12.4$$

Destructive Gage R&R – Gage Discrimination



	StdDev	StudyVar	%StudyVar
Total Gage R&R	0.2783882	1.670329	5.03
Repeatability	0.2783882	1.670329	5.03
Reproducibility	0.0000000	0.000000	0.00
Operator	0.0000000	0.000000	0.00
Part-To-Part	5.5250189	33.150113	99.87
Total Variation	5.5320280	33.192168	100.00

$$\text{NoDC} = \frac{\text{Part to Part StDev}}{\text{Total Gage RR StDev}} * \sqrt{2}$$

$$\text{NoDC} = \frac{5.525}{0.278} * \sqrt{2} = 28.03$$

$$\text{Gage Discrimination} = \frac{R_{ng}}{NoDc} = \frac{12.4}{28.03} = 0.44 \text{ lbs}$$

Meaning: any measurement within <0.44 lbs is the same measurement*

Caveat: this includes part to part variation – impossible to remove due to the destructive nature

Destructive Gage R&R

What are the assumptions?



Destructive Gage R&R

- One part - 3 locations of damage – repeatable measurements at each location
 - Is this destructive?





Take-Aways

- Production: Use Wheeler's method
- Design: Calculate Gage Discrimination
- Destructive: Create intentional defects

Destructive over-estimates gage discrimination
Assumes normal distribution

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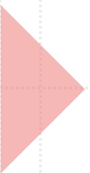
Previous Presentations:

Overview of life testing in Minitab (Minitab insights, Accendo reliability)

2 parameter vs 3 parameter Weibull with a cable flex test (ARDC)

Practical use of the Stress-Strength models to develop specifications (ARDC, Accendo reliability)





Questions?

Discussion