

# Statistical Analysis of Factorial Designs

- ⌘ Review of Interactions
- ⌘ Interactions in Tables and Line Graphs
- ⌘ The F-tests of a Factorial ANOVA
- ⌘ Using LSD to describe the pattern of an interaction

## Interpreting Factorial Results based on “Inspection”

Now that we have the basic language we will practice examining and describing main effects and interactions based on tables, line graphs and bar graphs portraying factorial results.

Once you know how to describe the results based on “inspection” it will be a very simple task to learn how to apply NHST to the process.

As in other designs we have looked at “an effect” as a numerical difference between two “things”, in factorial analyses...

Main effects involve differences between marginal means.

Simple effects involve differences between cell means.

Interactions involve the differences between simple effects.



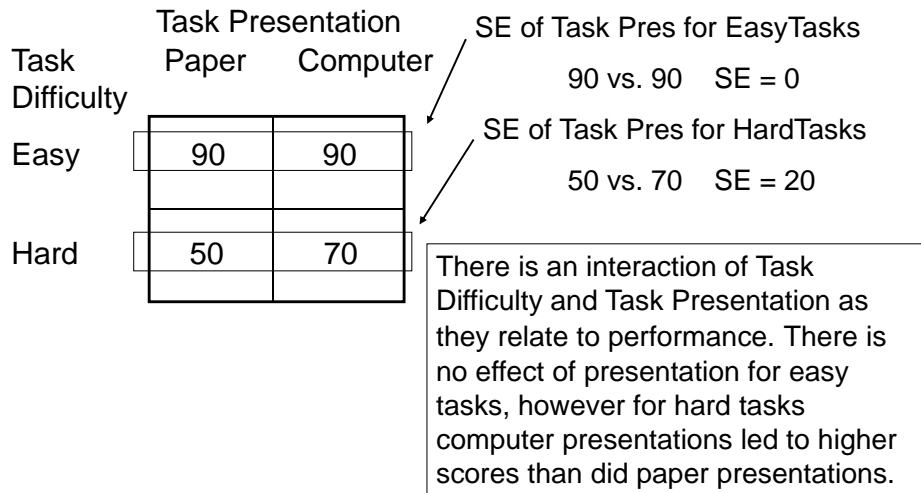
Inspecting a Table to determine simple effects & interaction...

Task Difficulty	Task Presentation	
	Paper	Computer
Easy	90	90
Hard	50	70

We'll look at describing the interaction using each set of simple effects in turn. Then we'll look at describing each main effect (and checking if each is descriptive or misleading)

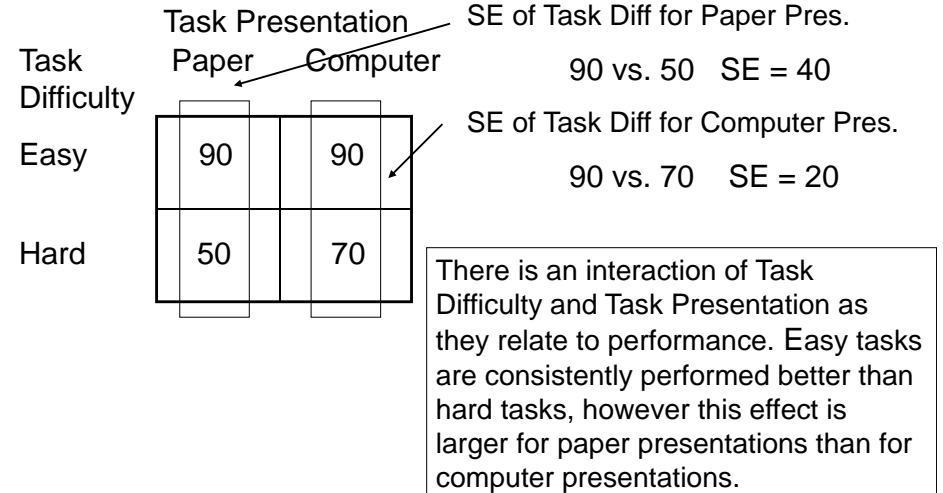
Inspecting a Table to determine simple effects & interaction...

Simple Effects of Task Presentation

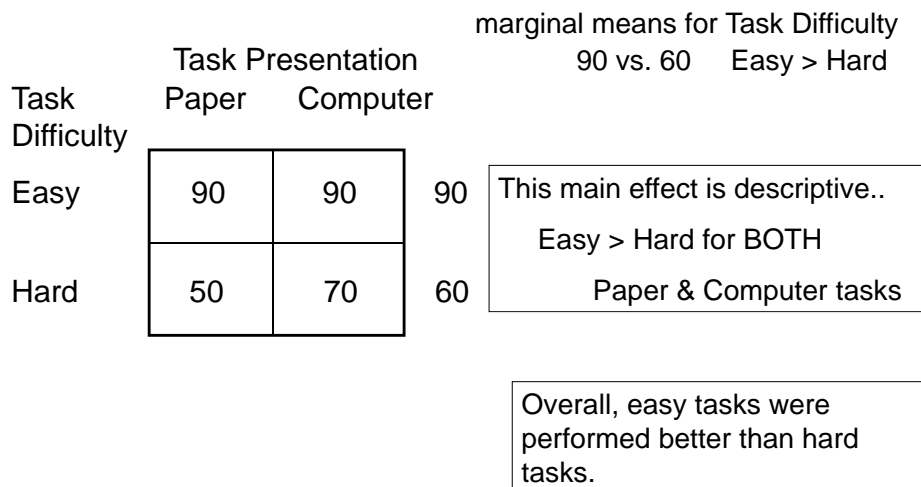


Inspecting a Table to determine simple effects & interaction...

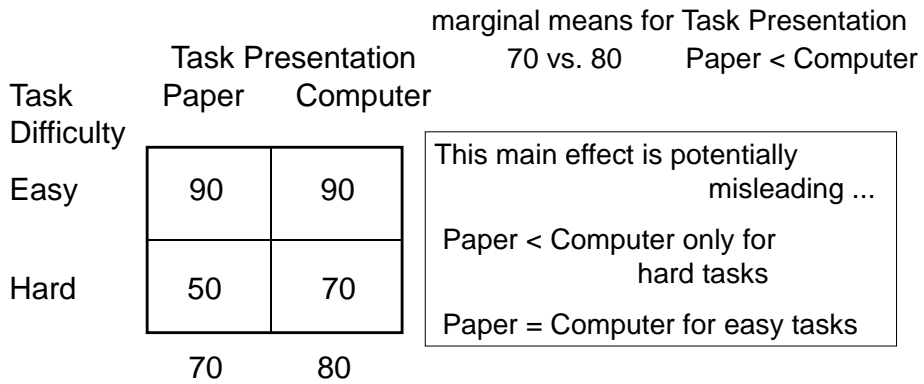
Simple Effects of Task Difficulty



Inspecting a Table to determine main effects ...



Inspecting a Table to determine main effects ...



This main effect is potentially misleading ...  
Paper < Computer only for hard tasks  
Paper = Computer for easy tasks

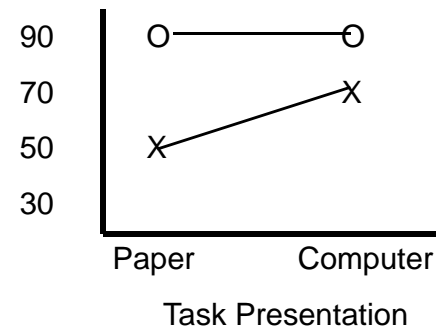
Overall, there was better performance on computer than paper tasks. However, this was not descriptive for easy tasks.

Inspecting a line graph ...

“Different differences” and “Differential Simple Effects” both translate into NONPARALLEL LINES in a figure.

Performance

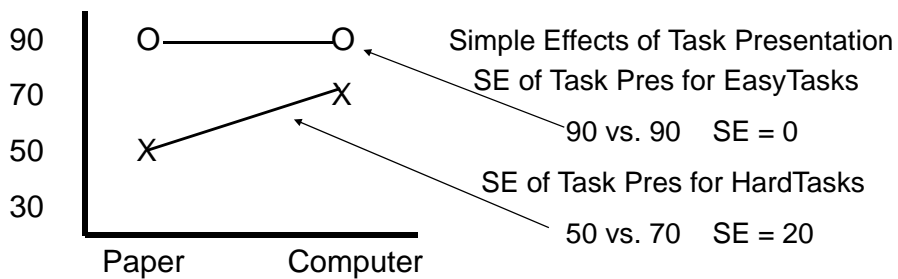
Key for Task Difficulty  
O = Easy    X = Hard



	P	C
Easy	90	90
Hard	50	70

Inspecting a line graph to determine simple effects & interaction...

Performance



Task Presentation

Key for Task Difficulty

O = Easy

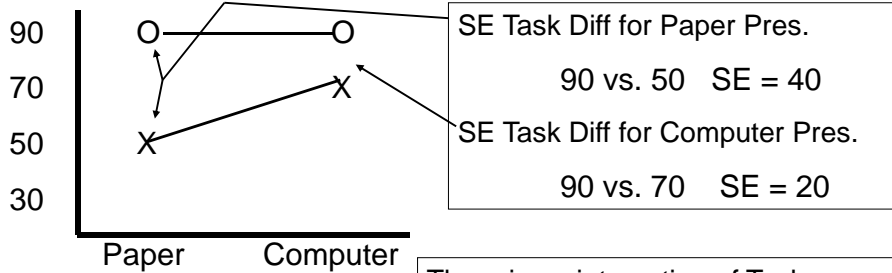
X = Hard

There is an interaction of Task Difficulty and Task Presentation as they relate to performance. There is no effect of presentation for easy tasks, however for hard tasks computer presentations led to higher scores than did paper presentations.

Inspecting a line graph to determine simple effects & interaction...

Performance

Simple Effects of Task Difficulty



SE Task Diff for Paper Pres.  
90 vs. 50 SE = 40

SE Task Diff for Computer Pres.  
90 vs. 70 SE = 20

There is an interaction of Task Difficulty and Task Presentation as they relate to performance. Easy tasks are consistently performed better than hard tasks, however this effect is larger for paper presentations than for computer presentations.

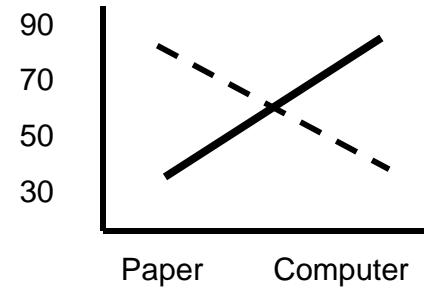
Key for Task Difficulty

O = Easy X = Hard

How ***not*** to Inspect a line drawing to determine if there is an interaction...

This is a “cross-over” interaction -- it certainly IS an interaction but it IS NOT the only kind !!

Performance



Task Presentation

Key for Task Difficulty

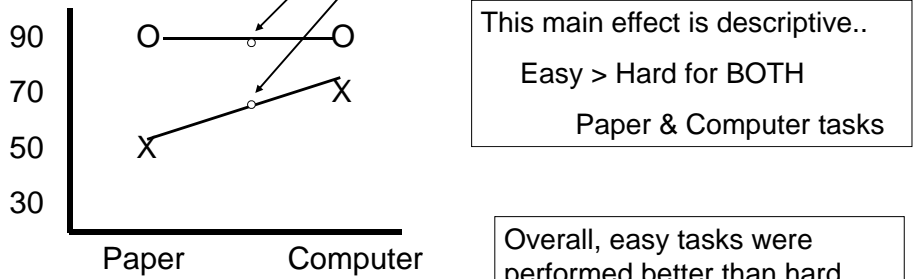
Easy      Hard

Inspecting a line graph to determine if there are main effects...

Performance

marginal means for Task Difficulty

90 vs. 60 Easy > Hard



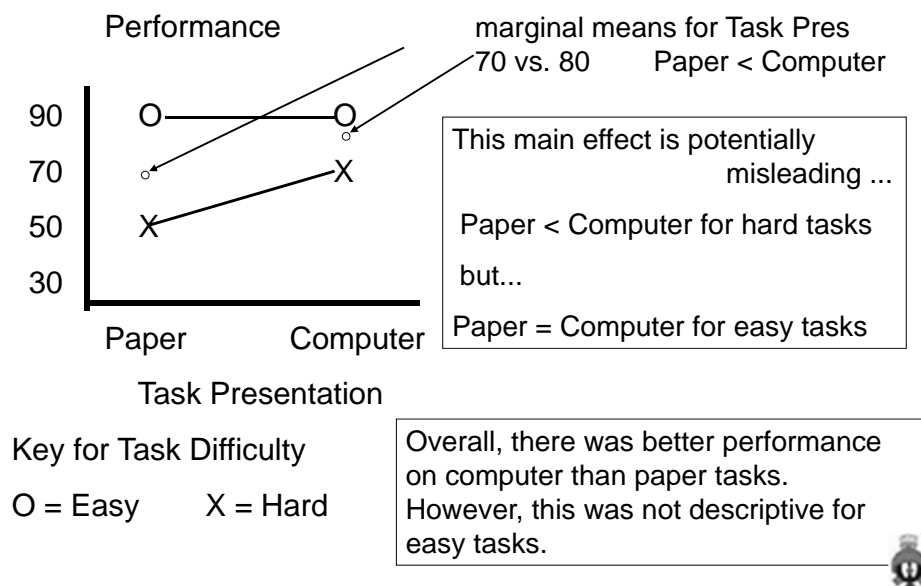
This main effect is descriptive..  
Easy > Hard for BOTH  
Paper & Computer tasks

Overall, easy tasks were performed better than hard tasks.

Key for Task Difficulty

O = Easy X = Hard

Inspecting a line graph to determine if there are main effects...



## Statistical Analysis of 2x2 Factorial Designs

Like a description of the results based upon inspection of the means, formal statistical analyses of factorial designs has five basic steps:

1. Tell IVs and DV
2. Present data in table or figure
3. Determine if the interaction is significant
  - if it is, describe it in terms of one of the sets of simple effects.
4. Determine whether or not the first main effect is significant
  - if it is, describe it
  - determine if that main effect is descriptive or misleading
5. Determine whether or not the second main effect is significant
  - if it is, describe it
  - determine if that main effect is descriptive or misleading

## Interpreting Factorial Effects

Important things to remember:

- main effects and the interaction are 3 separate effects each must be separately interpreted -- three parts to the "story"
  - most common error -- "interaction is different main effects"
  - best thing -- be sure to carefully separate the three parts of the story and tell each completely
- Be careful of "causal words" when interpreting main effects and interactions (only use when really appropriate).
  - caused, effected influenced, produced, changed ....
- Consider more than the "significance"
  - consider effect sizes, confidence intervals, etc. when describing the results

## Statistical Analysis of a 2x2 Design

Task Difficulty (b)	Task Presentation (a)		SE of Presentation for Easy Tasks
	Paper	Computer	
Easy	90	70	80
Hard	40	60	50
	65	65	SE for Presentation for Hard Tasks

Presentation Main Effect	Difficulty Main Effect	Interaction Effect
$F_{\text{Presentation}}$	$F_{\text{Difficulty}}$	$F_{\text{Interaction}}$
65 vs. 65	80 vs. 50	$SE_{\text{Easy}}$ vs. $SE_{\text{Hard}}$

## Statistical Analyses Necessary to Describe Main Effects of a 2x2 Design

In a 2x2 Design, the Main effects F-tests are sufficient to tell us about the relationship of each IV to the DV...

- since each main effect involves the comparison of two marginal means -- the corresponding significance test tells us what we need to know ...
- whether or not those two marginal means are "significantly different"
- Don't forget to examine the means to see if a significant difference is in the hypothesized direction !!!

## Statistical Analyses Necessary to Describe the Interaction of a 2x2 Design

However, the F-test of the interaction only tells us whether or not there is a "statistically significant" interaction...

- it does not tell use the pattern of that interaction
- to determine the pattern of the interaction we have to compare the simple effects
- to describe each simple effect, we must be able to compare the cell means

we need to know how much of a cell mean difference is "statistically significant"

## Using LSD to Compare cell means to describe the simple effects of a 2x2 Factorial design

- LSD can be used to determine how large of a cell mean difference is required to treat it as a “statistically significant mean difference”
- Will need to know three values to use the computer
  - $df_{error}$  -- look on the printout or use  $N - 4$
  - $MS_{error}$  – look on the printout
  - $n = N / 4$  -- use the decimal value – do not round to the nearest whole number!

**Remember – only use the lsdmmd to compare cell means. Marginal means are compared using the main effect F-tests.**

## Applying $lsd_{mmd}$ to 2x2 BG ANOVA

Task Difficulty	Task Presentation	
	Paper	Computer
Easy	60	90
Hard	60	70

for the interaction  
 $F(1,56) = 6.5$ ,  $Mse = 300$ ,  
 $p = .023$

Is there an Interaction? Based on what? Yes! F-test of Int

What info do we need to compute the  $LSD_{mmd}$ ?

$k = 4$  groups  
 $n = (df + k) / k = (56 + 4) / 4 = 15$   
 $MSe = 6.5$   
 $df_{error} = 56$  (round down to 50)

$k = 4$  groups  
 $n = (df + k) / k = (56 + 4) / 4 = 15$   
 $MSe = 6.5$   
 $df_{error} = 56$  (round down to 50)

Remember to set the  $df_{error}$  using the drop-down menu!

LSD & HSD Minimum Mean Difference	
Enter k (number of conditions in the effect) =>	4
Enter n (average number of data points upon which each mean is based - $N/k$ ) =>	15
Enter MSe (Mean Square Error) =>	300
Select dferror (error degrees of freedom - use "next smallest" if no exact match) =>	50
LSD minimum mean difference =	12.70

With an  $LSD_{mmd} = 12.7$

Simple effect of Task Presentation

SE of Task Presentation for Easy Tasks	30	>
SE of Task Presentation for Hard Tasks	10	=

Simple effects of Task Difficulty

SE of Task Difficulty for Paper Pres.	0	
SE of Task Difficulty for Comp. Pres.	20	v

### Applying $l_{sd_{mmd}}$ to 2x2 BG ANOVA

Task Difficulty	Task Presentation		ME	for Difficulty ME $F(1,56) = 4.5, p = .041$
	Paper	Computer		
Easy	60	90	75	$l_{sd_{mmd}} = 12.7$
Hard	60	70	65	

Is there a Task Difficulty main effect? Based on what?

Yes! F-test of ME

Is main effect descriptive (unconditional) or potentially misleading (conditional)?

Simple effects of Task Difficulty

SE of Task Difficulty for Paper Pres.	0	
SE of Task Difficulty for Comp. Pres.	20	v

Descriptive only for Computer presentation; misleading for Paper presentations.

### Applying $l_{sd_{mmd}}$ to 2x2 BG ANOVA

Task Difficulty	Task Presentation		ME	for Presentation ME $F(1,56) = 7.2, p = .011$
	Paper	Computer		
Easy	60	90	80	$l_{sd_{mmd}} = 12.7$
Hard	60	70		

Is there a Task Difficulty main effect? Based on what?

Yes! F-test of ME

Is main effect descriptive (unconditional) or potentially misleading (conditional)?

Simple effects of Task Difficulty

SE of Task Presentation for Easy Tasks	30	<
SE of Task Presentation for Hard Tasks	10	=

Descriptive only for Easy tasks; misleading for Difficult tasks.

### Effect Sizes for 2x2 BG Factorial designs

For Main Effects & Interaction (each w/  $df=1$ )

$$r = \sqrt{[F / (F + df_{error})]}$$

For Main Effects & Simple Effects

$$d = (M_1 - M_2) / \sqrt{M_{error}}$$

$$r = \sqrt{\left[ \frac{d^2}{d^2 + 4} \right]} \quad (\text{This is an "approximation formula"})$$