

# FOUNDATIONS OF STATISTICAL DECISION MAKING

Comparing Multiple Groups

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**Aaron R. Baggett, Ph.D.**

Department of Physical Therapy  
University of Mary Hardin-Baylor  
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# OUTLINE

# Outline

- Statistical variables
- Multiple group comparisons (ANOVA)

# Recap

- Descriptive vs. inferential statistics
- The normal distribution
- Comparing groups
- Statistical/practical significance

# Resources

- Slides, data, and handouts available at:

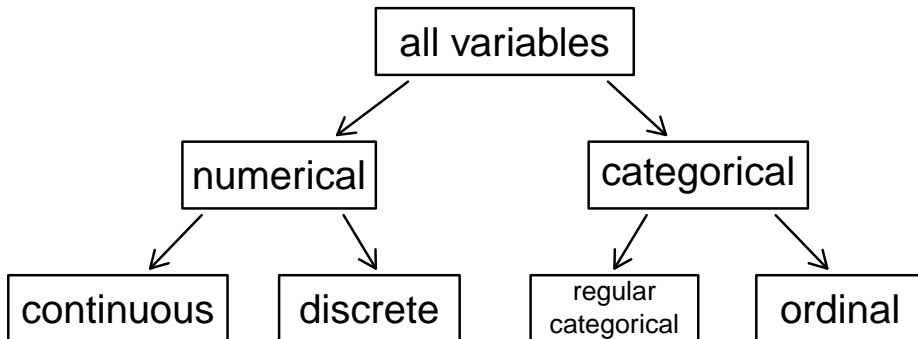
[bit.ly/umhb\\_dpt](https://bit.ly/umhb_dpt)

# STATISTICAL VARIABLES

# Statistical Variables

- Measureable, observable values or characteristics
- Vary across observations, measures
- Provide the basis for hypothesis test selection
- For example:
  - Is  $Y$  numerical?
  - Is  $X$  numerical or categorical?

# Statistical Variables





**EXAMPLE**

# Attitudes Toward Exercise Intensity

- Imagine we design an experiment to test attitudes toward different levels of exercise intensity between high- and low-fit participants

ID	Intensity	Fitness	Attitude
26	Low Intensity	High Fitness	21
10	High Intensity	High Fitness	33
14	High Intensity	Low Fitness	12
8	High Intensity	High Fitness	37
17	High Intensity	Low Fitness	12
3	High Intensity	High Fitness	46
⋮	⋮	⋮	⋮

# Attitudes Toward Exercise Intensity

- Independent variables (factors):
  1. Exercise intensity (high, low)
  2. Fitness level (high, low)
- Dependent variable (outcome):
  1. Attitude score (0-50)

# Attitudes Toward Exercise Intensity

- The current study can be thought of as a  $2 \times 2$  factorial design
- 2 IVs with 2 levels each = 4 cells
- To analyze experimental data like these, we use an  $F$ -test
- Analysis of variance (ANOVA)

# Attitudes Toward Exercise Intensity

- The current study can be thought of as a  $2 \times 2$  factorial design
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- To analyze experimental data like these, we use an  $F$ -test
- Analysis of variance (ANOVA)

	High Fitness	Low Fitness
High Intensity	$n = 10$	$n = 10$
Low Intensity	$n = 10$	$n = 10$

**ANOVA**

# ANOVA

- Multiple group comparisons (2+)
- All factors are categorical
- Mean comparison between- or within-groups
- Two types of effects are produced
  1. Main effects
  2. Interaction effects

# MAIN EFFECTS



# Main Effects

- Represent mean comparison of the levels of each factor, ignoring others
- An effect suggests a mean difference between levels of a single factor, holding all others constant

# Attitudes Toward Exercise Intensity

- Factors (IVs)
  1. Exercise intensity
  2. Fitness level

	High Fitness	Low Fitness
High Intensity	$M_1 = 36.30$	$M_2 = 11.60$
Low Intensity	$M_3 = 20.70$	$M_4 = 29.50$

# Main Effects::Exercise Intensity

## 1. Exercise intensity:

- How do participants in the high intensity condition compare to participants in the low intensity condition, when participants' fitness level is ignored?

$$H_0 = \frac{M_1 + M_2}{2} = \frac{M_3 + M_4}{2}$$

$$H_1 = \frac{M_1 + M_2}{2} \neq \frac{M_3 + M_4}{2}$$

# Main Effects::Exercise Intensity

## 1. Exercise intensity:

- How do participants in the high intensity condition compare to participants in the low intensity condition, when participants' fitness level is ignored?

	High Fitness	Low Fitness		
High Intensity	$M_1 = 36.30$	$M_2 = 11.60$	=	<b>23.95</b>
Low Intensity	$M_3 = 20.70$	$M_4 = 29.50$	=	<b>25.10</b>

# Main Effects::Exercise Intensity

## 1. Exercise intensity:

- The typical person in a *high* intensity exercise condition has an attitude-toward-fitness score of 23.95.
- The typical person in a *low* intensity exercise condition has an attitude-toward-fitness score of 25.10.

	High Fitness	Low Fitness	
High Intensity	$M_1 = 36.30$	$M_2 = 11.60$	= <b>23.95</b>
Low Intensity	$M_3 = 20.70$	$M_4 = 29.50$	= <b>25.10</b>

# Main Effects::Fitness Level

## 2. Fitness level:

- How do highly fit participants compare to low fit participants, when exercise intensity is ignored?

$$H_0 = \frac{M_1 + M_3}{2} = \frac{M_2 + M_4}{2}$$

$$H_1 = \frac{M_1 + M_3}{2} \neq \frac{M_2 + M_4}{2}$$

# Main Effects::Fitness Level

## 2. Fitness level:

- How do highly fit participants compare to low fit participants, when exercise intensity is ignored?

	High Fitness	Low Fitness
High Intensity	$M_1 = 36.30$	$M_2 = 11.60$
Low Intensity	$M_3 = 20.70$	$M_4 = 29.50$
	<b>= 28.50</b>	<b>= 20.55</b>

# Main Effects::Fitness Level

## 2. Fitness level:

- The typical *highly fit* person has an attitude-toward-fitness score of 28.50.
- The typical *low fit* person has an attitude-toward-fitness score of 20.55.

	High Fitness	Low Fitness
High Intensity	$M_1 = 36.30$	$M_2 = 11.60$
Low Intensity	$M_3 = 20.70$	$M_4 = 29.50$
	<b>= 28.50</b>	<b>= 20.55</b>



# INTERACTION EFFECTS

# Interaction Effects

- Represent the combination, or interaction, of different levels of each IV on the DV
- Occur when the pattern of means across one level of an IV differ from the pattern across another level

# Attitudes Toward Exercise Intensity

- Factors (IVs)
  1. Exercise intensity
  2. Fitness level
- Dependent variable (DV)
  1. Attitude toward fitness score

	High Fitness	Low Fitness
High Intensity	36.30	11.60
Low Intensity	20.70	29.50

# Interaction Effects

## 1. Exercise Intensity $\times$ Fitness Level

- Does exercise intensity influence attitudes toward working out among people categorized as either high or low fit?

No interaction effect:  $M_1 - M_2 = M_3 - M_4$

Interaction effect:  $M_1 - M_2 \neq M_3 - M_4$

# Attitudes Toward Exercise Intensity

- Let's test our hypotheses using a factorial ANOVA

$$F = \frac{MS_{BG}}{MS_{WG}}$$

# Results

Table 1: Two-Way Analysis of Variance Results

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>p</i>	$\omega^2$
Intensity	1	13.22	13.22	0.56	0.46	0.00
Fitness	1	632.02	632.02	26.80	<.01	0.14
Intensity $\times$ Fitness	1	2805.63	2805.63	118.95	<.01	0.64
Total	36	849.10	23.59			

# Results::Main Effects

- No main effect for exercise intensity was observed,  $F(1, 36) = 0.56, p > .05$ 
  - Attitude-toward-fitness scores did not differ between participants in either the high- or low-intensity exercise conditions
- A main effect for participant fitness level was observed,  $F(1, 36) = 26.79, p < .01, \omega^2 = .14$ 
  - People who are highly fit demonstrate higher attitude-toward-fitness scores, on average, compared to people who are considered low fit

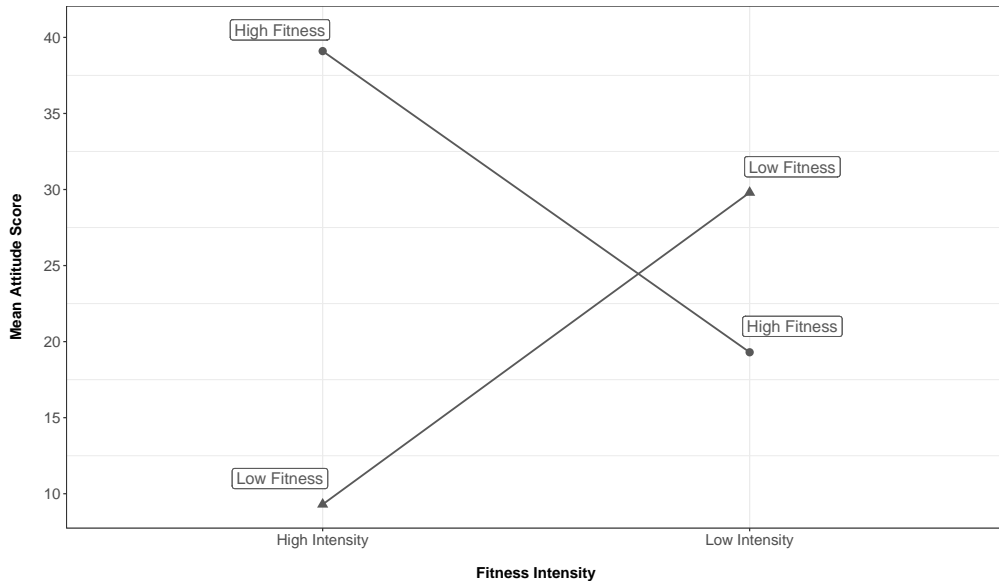
# Results::Interaction Effects

- A significant Intensity  $\times$  Fitness level interaction effect was observed,  $F(1, 36) = 118.95, p < .01, \omega^2 = .64$ 
  - High fitness::High intensity  $>$  High fitness::Low intensity
  - Low fitness::High intensity  $<$  Low fitness::Low intensity

	High Fitness	Low Fitness
High Intensity	$M_1 = 36.30$	$M_2 = 11.60$
Low Intensity	$M_3 = 20.70$	$M_4 = 29.50$



# Results::Interaction Effects



# Results::Effect Sizes

- Intensity: N/A
- Fitness:  $\omega^2 = .14$ 
  - Participant fitness level explains approximately .14  $\rightarrow$  14% of the variability in attitude-toward-fitness scores
- Intensity  $\times$  Fitness:  $\omega^2 = .64$ 
  - The Intensity  $\times$  Fitness interaction explains approximately .64  $\rightarrow$  64% of the variability in attitude-toward-fitness scores

**RECAP**

# Recap

- All variables are either numerical or categorical
- ANOVA allows for multiple group comparisons
- Main effects represent differences between levels of a single variable, ignoring others
- Interaction effects occur when the pattern of means across one level of an IV differ from the pattern across another level

# Next Time

- Foundations of relationships and prediction
  - Correlating variables
  - Predicting outcomes (Regression)