# Making the Visible:

## Visualizing Latent Variables in Structural Equation Modeling

**Gabriel Crone**
**PSYC 6135**
**Class Presentation**

# Making the Invisible Visible:

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# Presentation Overview

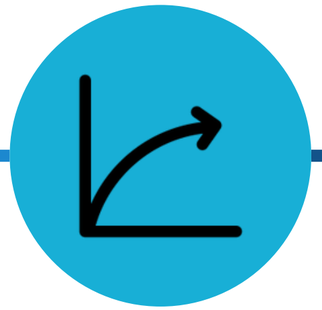
## Introduction

Definitions & Factor Score Estimation

## Visualizations for Regular SEMs

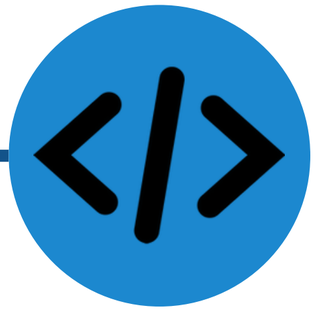
Reccomended plots & flexplavaan package

## Special Cases



Visualizing nonlinear SEMs!

## Software Demo!



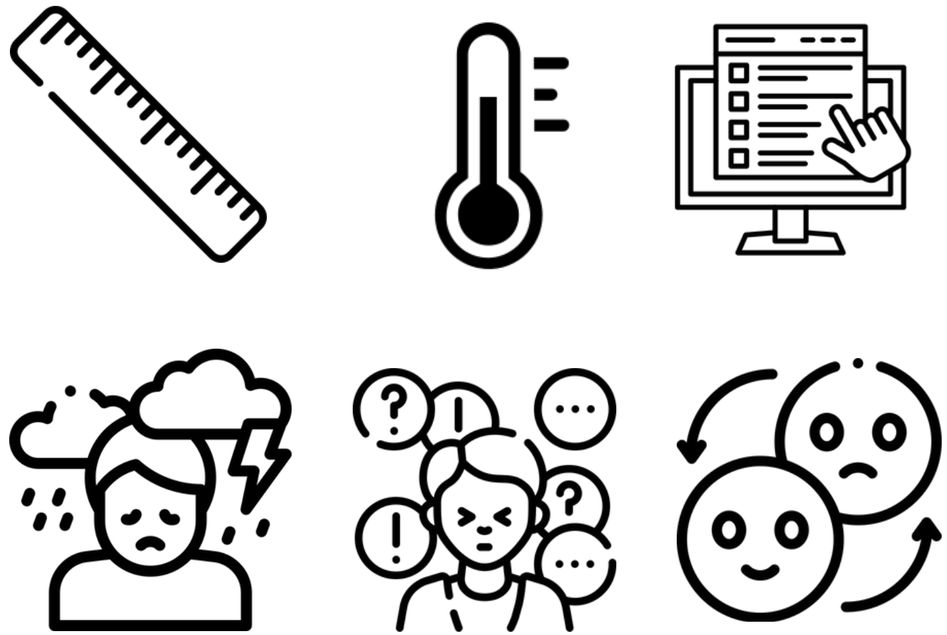
Generating Plots in R with Guided Example

# Introduction

Definitions & Factor Score Estimation

# What are Latent Variables?

- Two types of variables: those we can observe, and those we cannot
  - **Observed** = **Manifest**
    - E.g., height, weight, temperature, survey item scores, time
  - **Unobserved** = **Latent**
    - E.g., depression, anxiety, mood, boredom, life satisfaction, and many more!

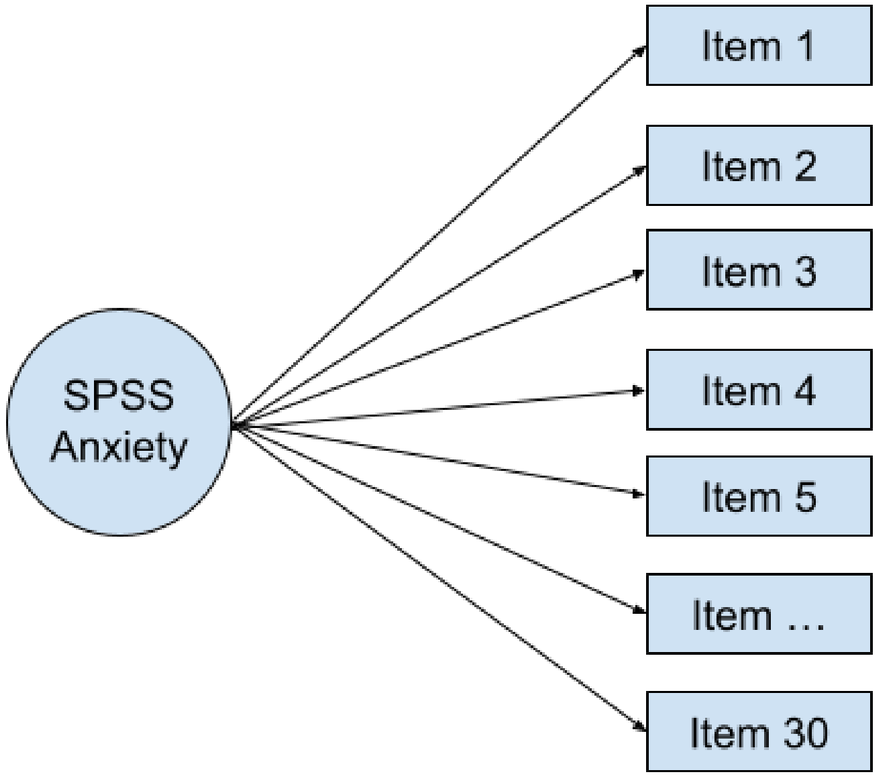


# Measuring Latent Variables

- How can we measure that which we cannot observe?

- **We define it in terms of what we can measure: manifest variables!**
  - e.g., SPSS anxiety can be measured by individual items on a scale measuring it (see right)

- **Measurement model**
  - We define latent variables (“factors”) in terms of their manifest variables (“indicators”)




**Source:**
https://stats.oarc.ucla.edu/spss/seminars/introduction-to-factor-analysis/a-practical-introduction-to-factor-analysis/

# What is Structural Equation Modeling (SEM)?

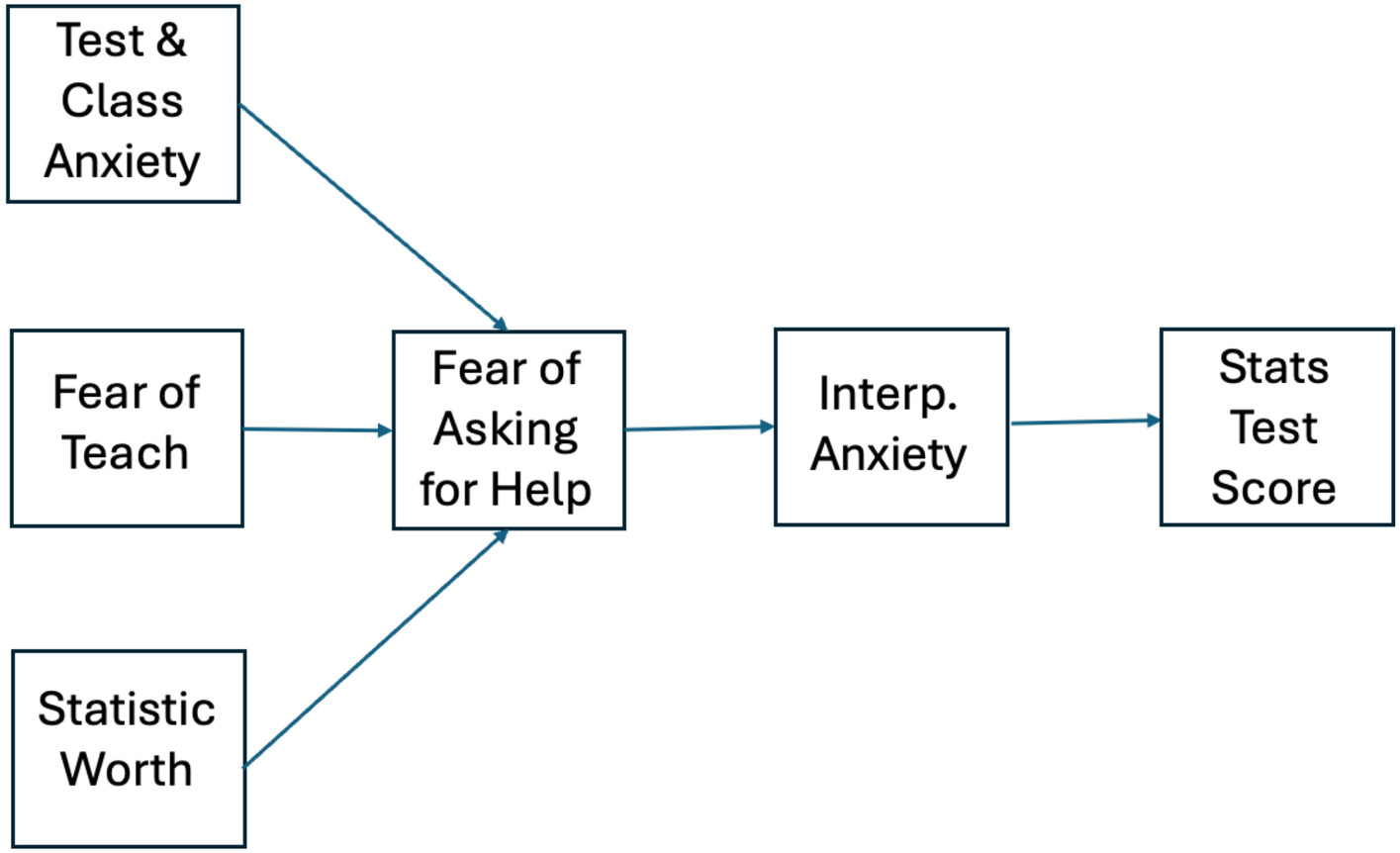
- **Structural Equation Modeling** (**SEM**) = Broad and powerful statistical modeling framework
- Different models within SEM capture relationships between different variables:
  - 3 main types:
    - **Path analysis**
    - **Factor analysis**
    - **Structural regression**

# Some Examples!

**Path analysis can depict complex relationships between manifest variables!**

Notation:
Manifest variables are
inside boxes

**Path analysis**

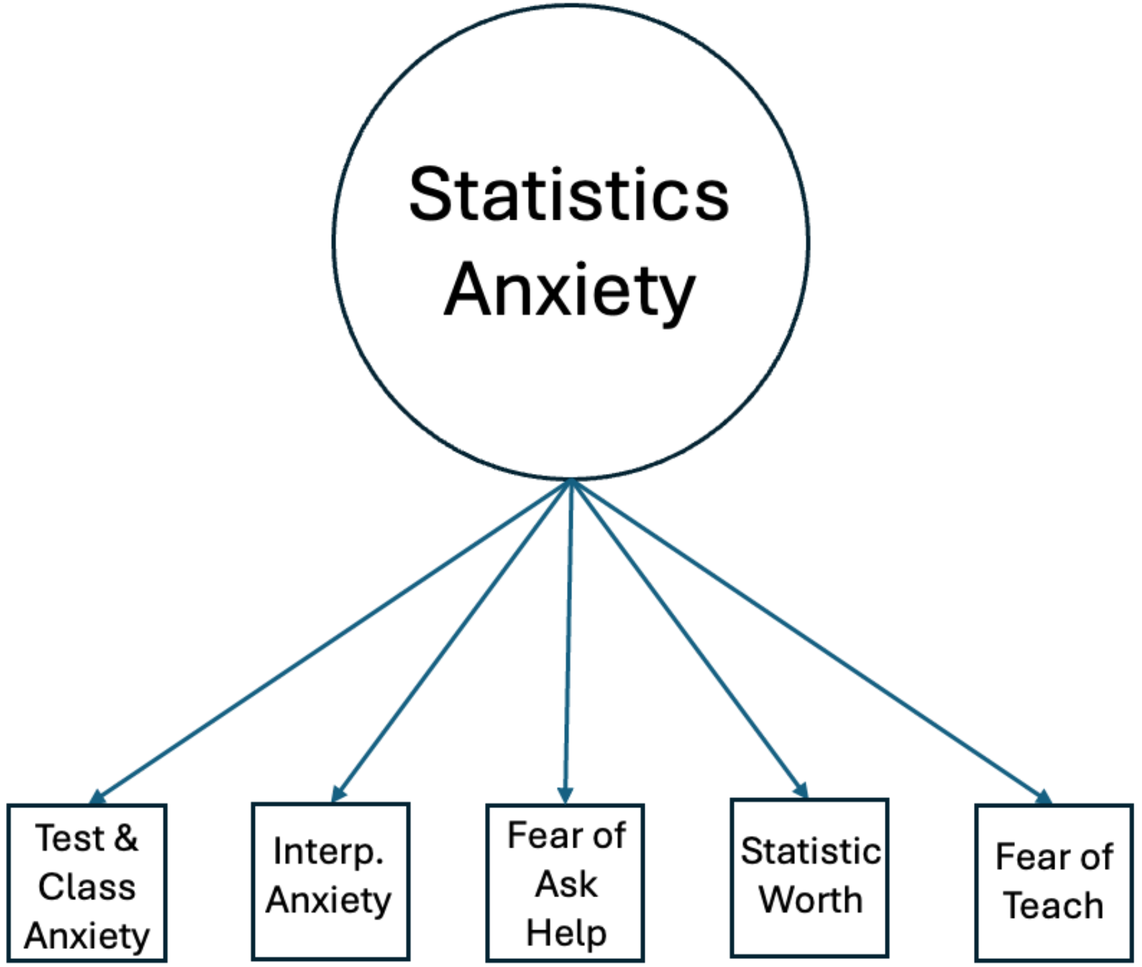


# Some Examples!

**Factor Analysis Models define latent factor in terms of (manifest) indicators.**

Notation:
Latent variables are inside circles

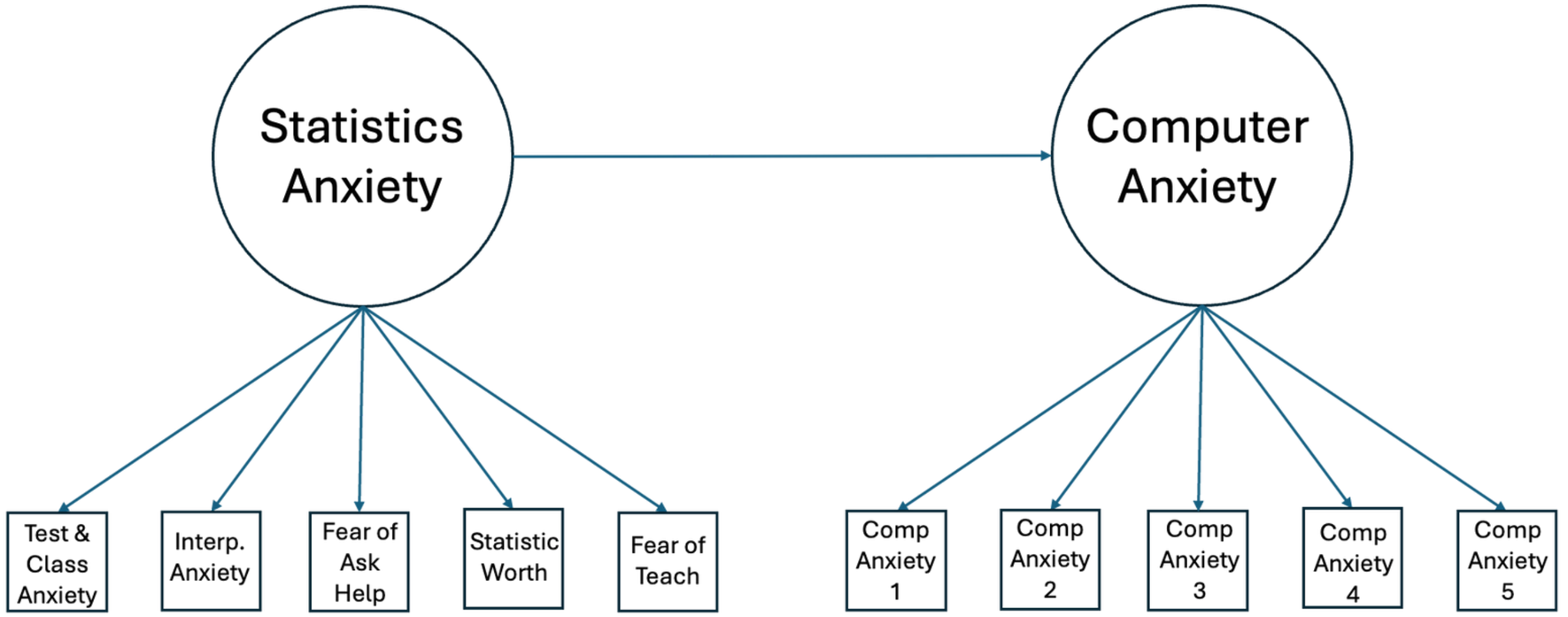
## Factor Analysis



# Some Examples!

**Structural Regression models depict linear relationships between latent factors!**

## Structural Regression

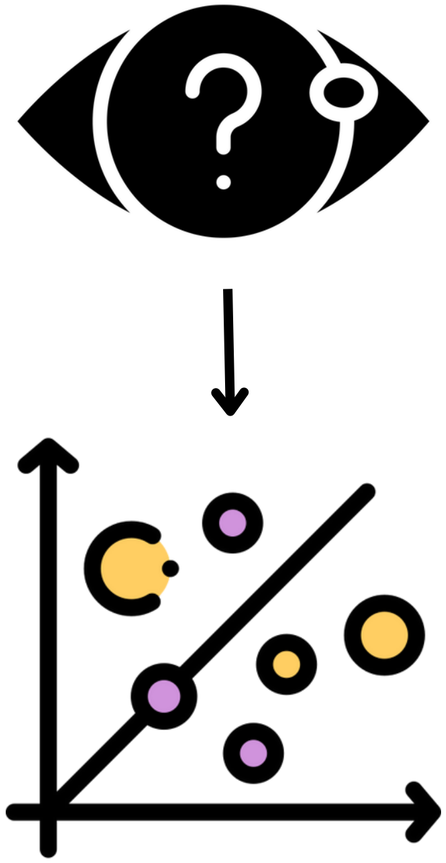


# Summary of SEM Types

| Model | Relationship between manifest variables? | Uses measurement model? | Relationship between latent variables? | Relationship between latent *and* manifest variables? |
|---|---|---|---|---|
| Path Analysis | ✓ | | | |
| Factor Analysis | | ✓ | | |
| Structural Regression | ✓ | ✓ | ✓ | ✓ |

# How can latent variables be visualized?

- If latent variables are never observed, how can they be visualized?
- The answer: **Factor Score Estimation!**
    - Statistical technique that uses an SEM model to assign latent “scores” to each participant (for details, see Grice, 2001)



# Factor Scores Explained

## e.g., Computer anxiety defined by CARS 1 & 2

| ID | CARS 1 | CARS 2 | Computer Anxiety |
|---|---|---|---|
| 1 | … | … | ??? |
| 2 | … | … | ??? |
| 3 | … | … | ??? |
| … | … | … | ??? |
| n | … | … | ??? |

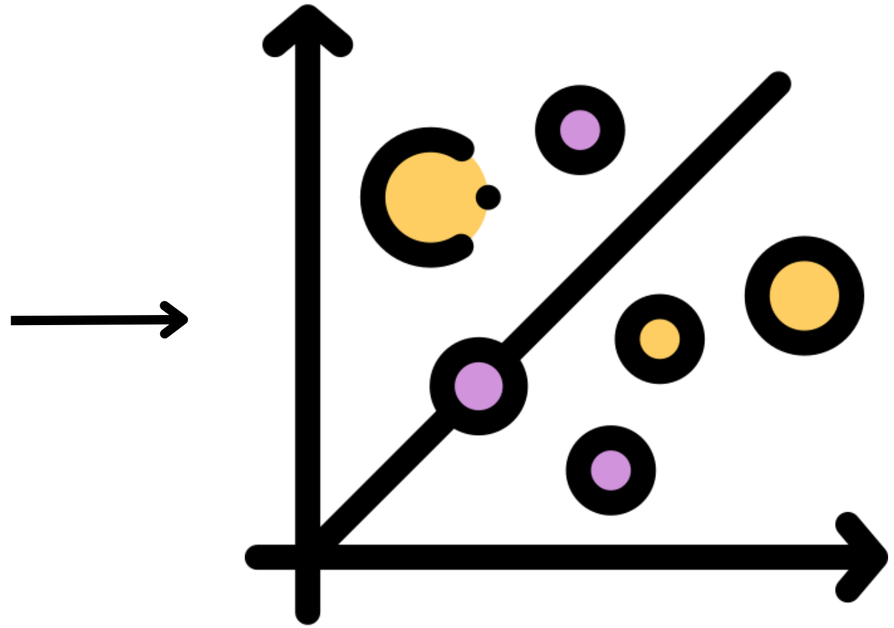
# Factor Scores Explained

| ID | CARS 1 | CARS 2 | Computer Anxiety |
|---|---|---|---|
| 1 | … | … | ??? |
| 2 | … | … | ??? |
| 3 | … | … | ??? |
| … | … | … | ??? |
| n | … | … | ??? |


| ID | Computer Anxiety |
|---|---|
| 1 | … |
| 2 | … |
| 3 | … |
| … | … |
| n | … |

# Factor Scores Explained

| ID | Computer Anxiety |
|---|---|
| 1 | ... |
| 2 | ... |
| 3 | ... |
| ... | ... |
| n | ... |



# Visualizations for Regular SEMs

Reccomended plots & flexplavaan package

# Reccomendations

- Hallgren et al. (2019) were the first to suggest using data viz in an SEM context. They suggest a couple of plots:

1. **Latent Variable Scatterplots**

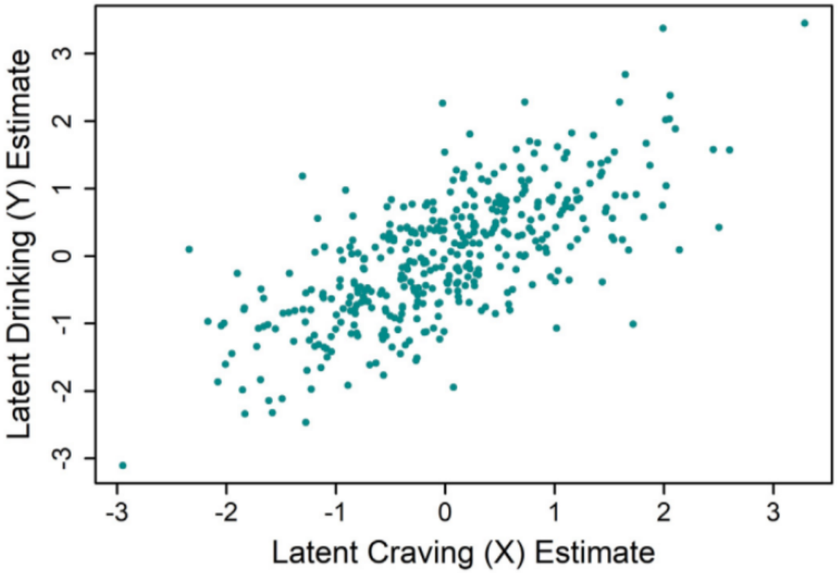



Figure 2, top panel from “Beyond path diagrams: Enhancing applied structural equation modeling research through data visualization”, p. 77

2. **Mediation effect plots**

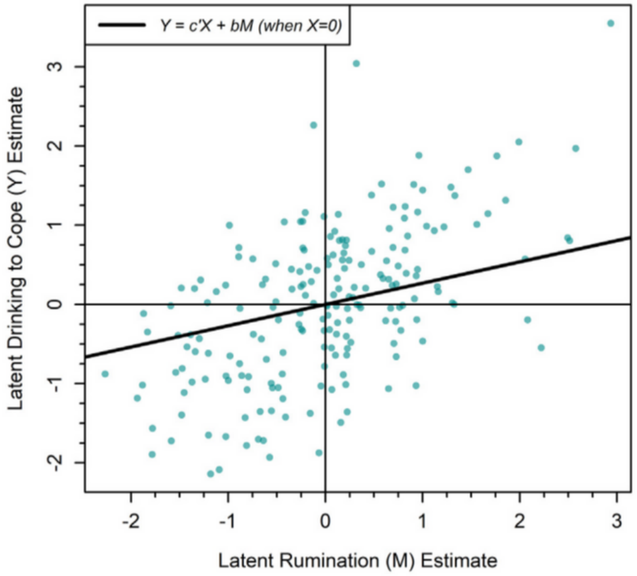



Figure 5a from “Beyond path diagrams: Enhancing applied structural equation modeling research through data visualization”, p. 80

# Reccomendations

- Fife et al. (2021) go a step further by creating several brand new plots to visualize latent variables!
  - In their (fictional) data, their **latent variables are *Force* and *Jedi***

# Measurement Plot

**Measurement plots are scatterplots between latent and manifest variables with fitted lines**

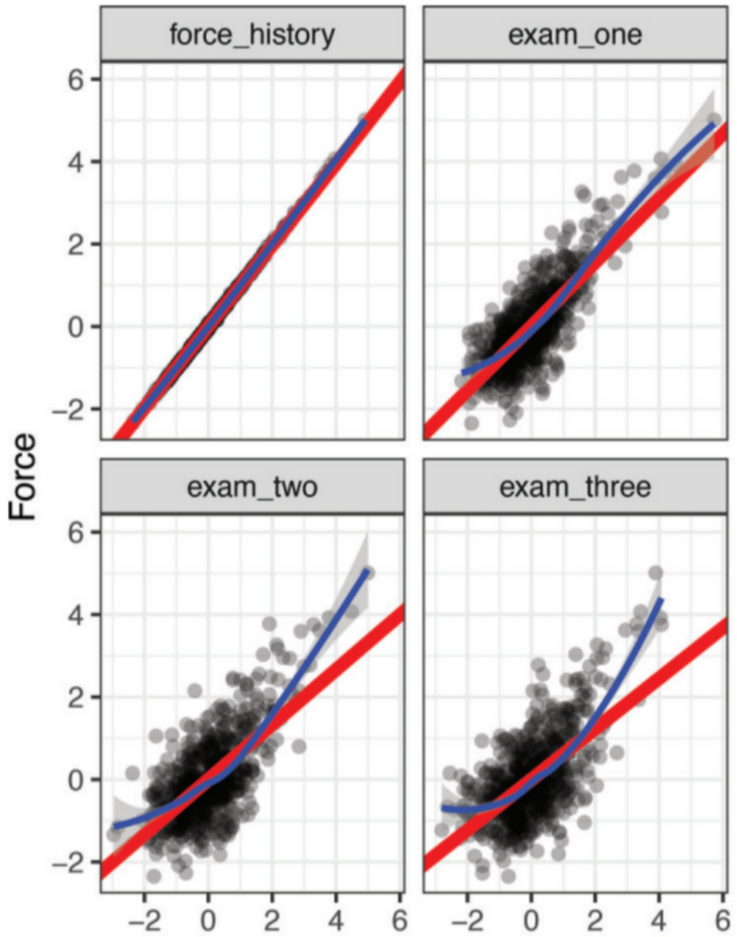
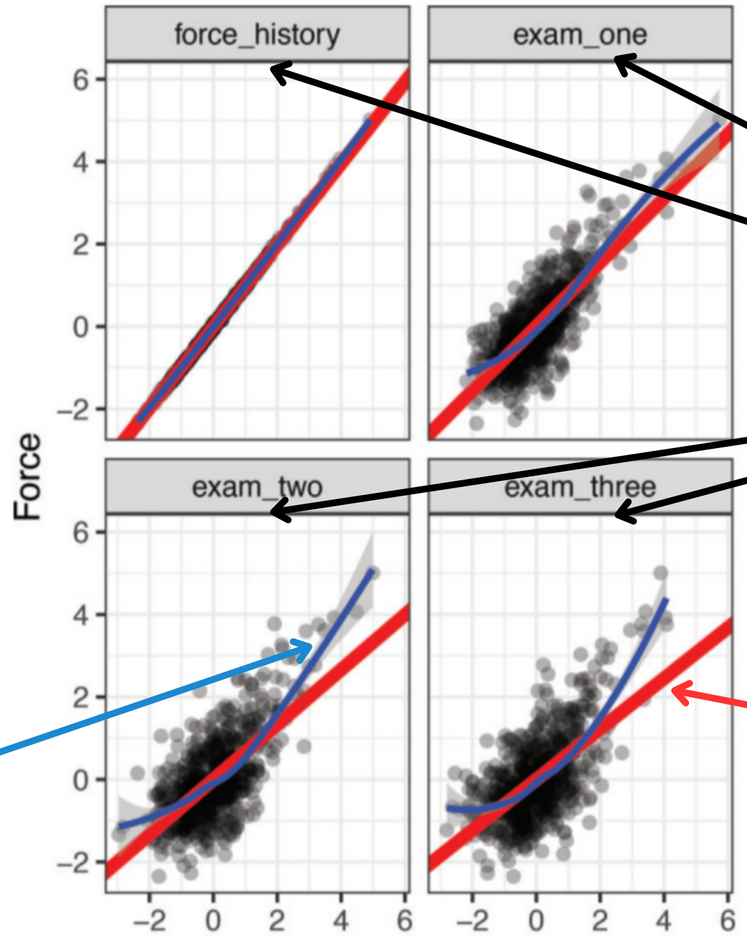



Figure 10 from “Seeing the Impossible: Visualizing Latent Variable Models With Flexplavaan”, p. 1465

# Measurement Plot

**Measurement plots are scatterplots between latent and manifest variables with fitted lines**




**4 plots total, one for each manifest variable**

Blue lines are loess lines representing observed relationships

Red lines are model-implied linear trend lines

Figure 10 from “Seeing the Impossible: Visualizing Latent Variable Models With Flexplavaan”, p. 1465

# Structural (“Crosshair”) Plot

**“Crosshair” plots are scattertplots with extra goodies! :)**

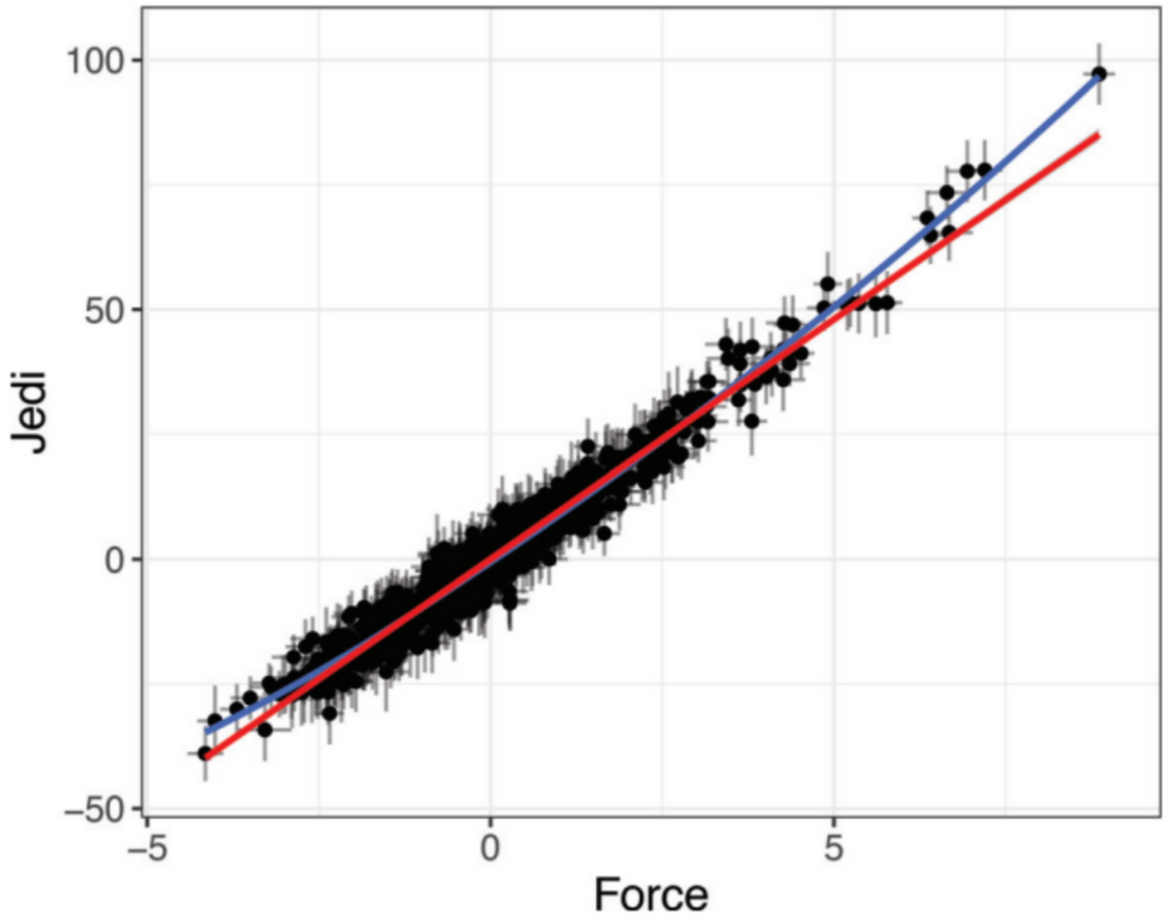
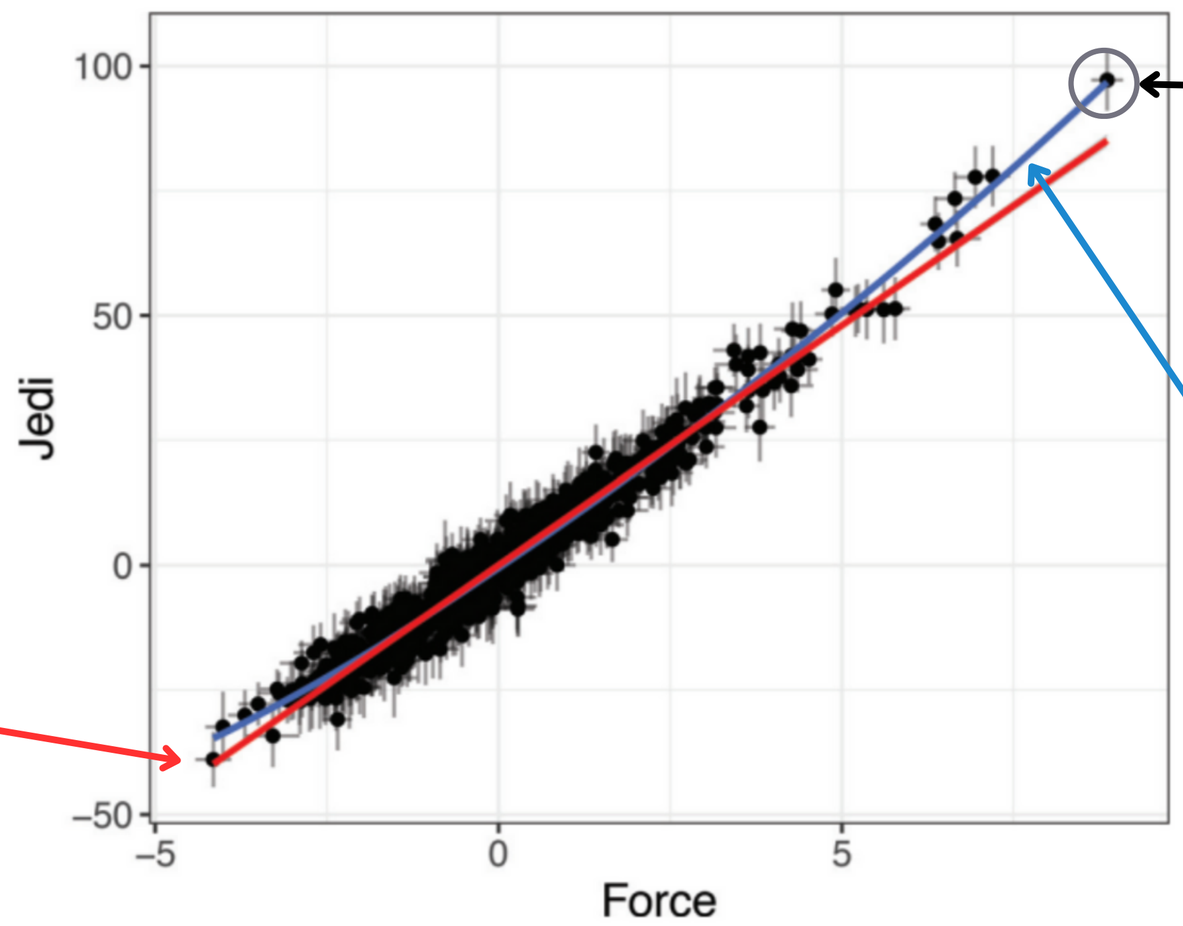



Figure 11 from “Seeing the Impossible: Visualizing Latent Variable Models With Flexplavaan”, p. 1465

# Structural (“Crosshair”) Plot

**“Crosshair” plots are scattertplots with extra goodies! :)**




**“Crosshairs”** represent **95% prediction intervals**

Red line is **model-implied fit line**

Blue line represents **regression line** between two variables

Figure 11 from “Seeing the Impossible: Visualizing Latent Variable Models With Flexplavaan”, p. 1465

# *flexplavaan* Package

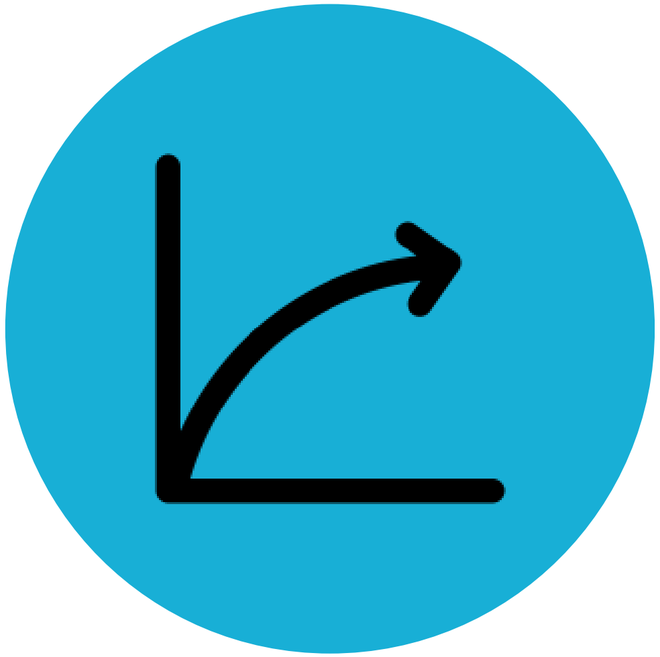
- Fife et al. (2021) not only pioneered several data viz methods for latent vars., but they also created an R package to help!

- ***Flexplavaan*** = *flexplot* (easy model plotting) + *lavaan* (latent var. modeling)
    - *Flexplavaan* takes SEM models (specified with *lavaan* syntax) and allows one to create beautiful plots!

Dennis Fife, author of *flexplavaan*

**Source:**
https://www.amazon.com/stores/author/B014PYL9OC

# Special Cases

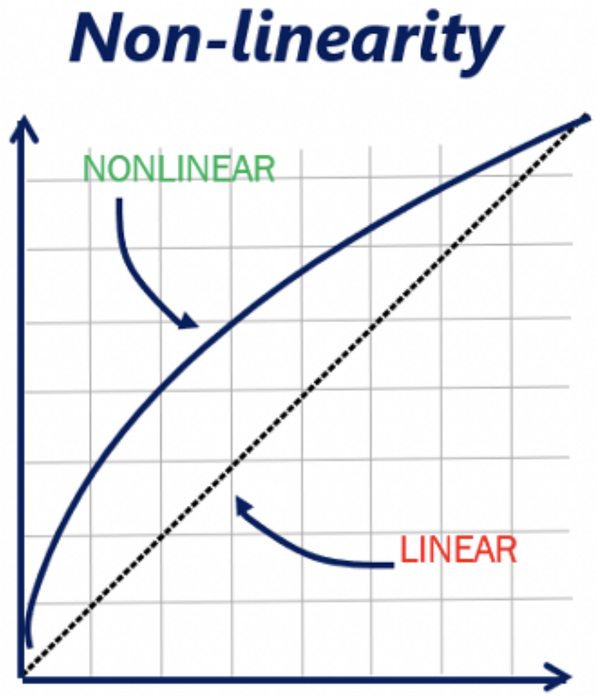


Visualizing
nonlinear SEMs!

# Not all SEMs are alike…

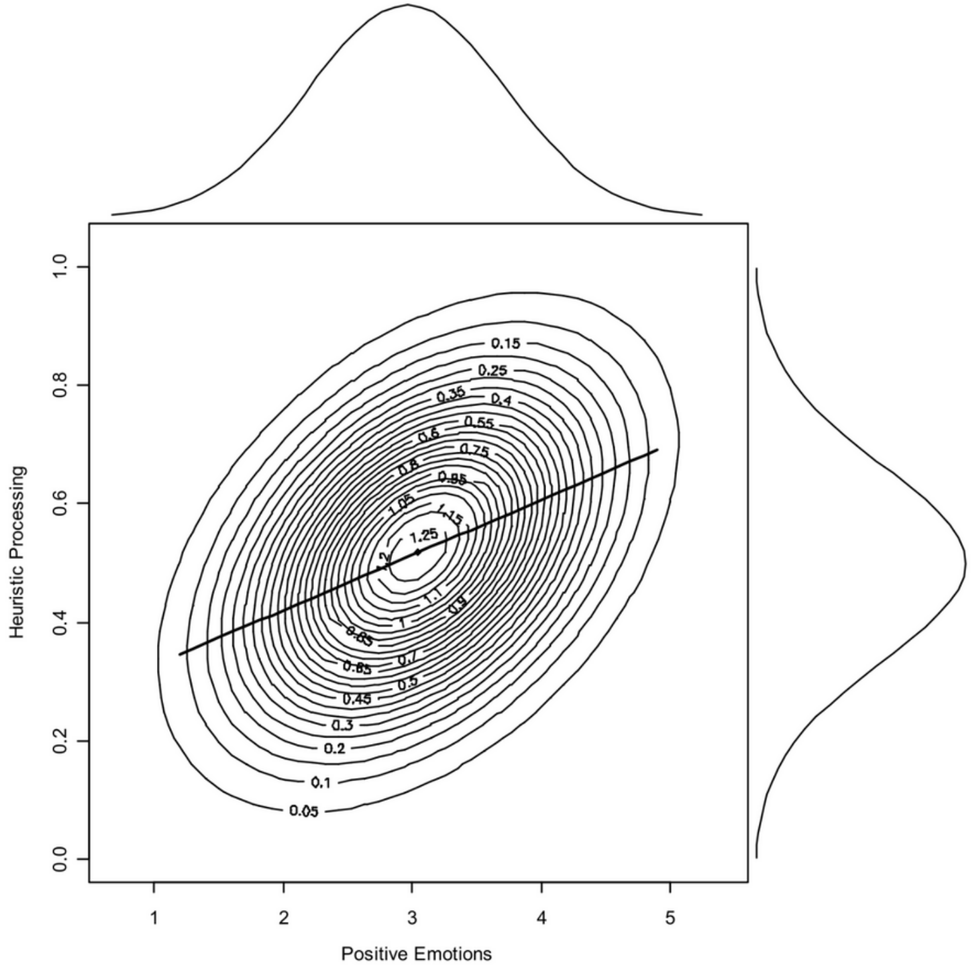
- Regular SEMs assume that relationships between variables are *linear* in nature.
  - If data are *nonlinear*, need to use another estimation method!

- Pek et al. (2009) devized a **semiparametric** (**SEMM**) **approach** to estimate and visualize nonlinear relationships among latent variables!




**Source:** https://rahsoft.com/2021/04/23/non-linearity-and-its-effects-in-rf-system/

# Marginal Desnity Plot

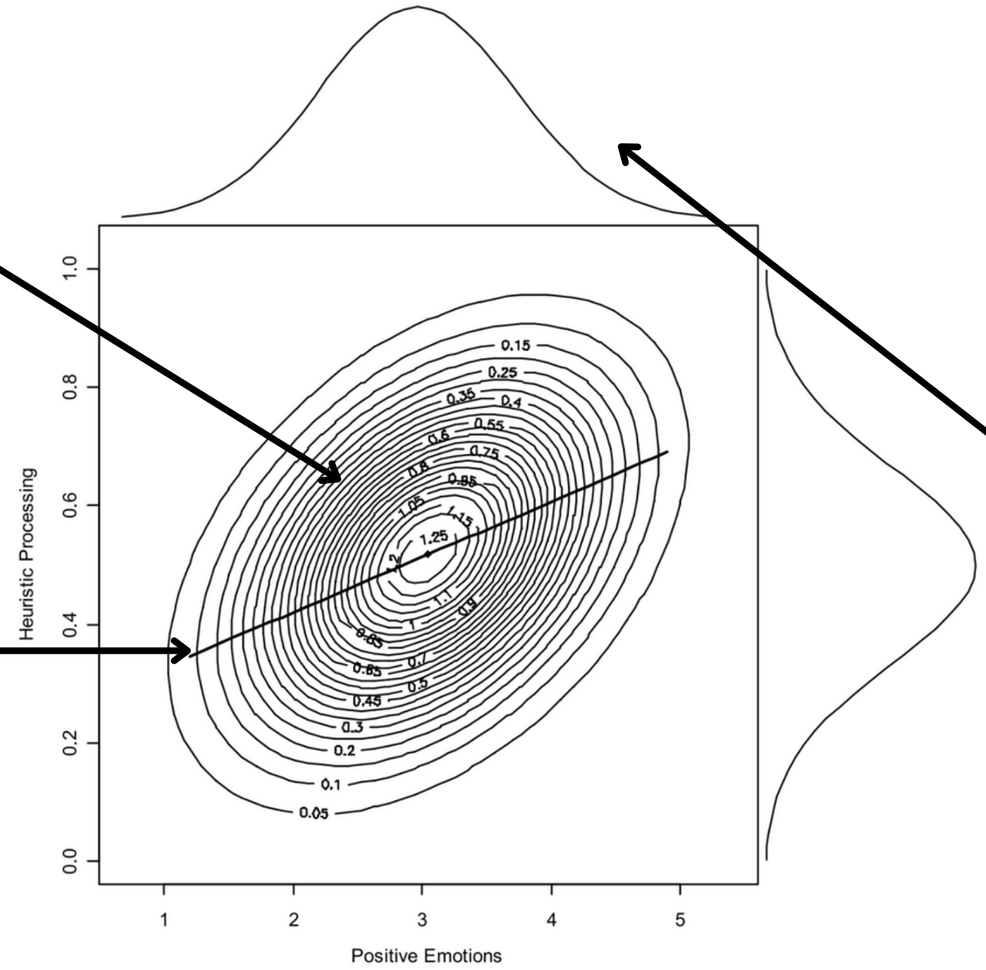



**Marginal Desnity Plots are 3 plots in one! They heavily draw on the model (the SEMM).**

# Marginal Desnity Plot

Model-implied bivariate contour plot

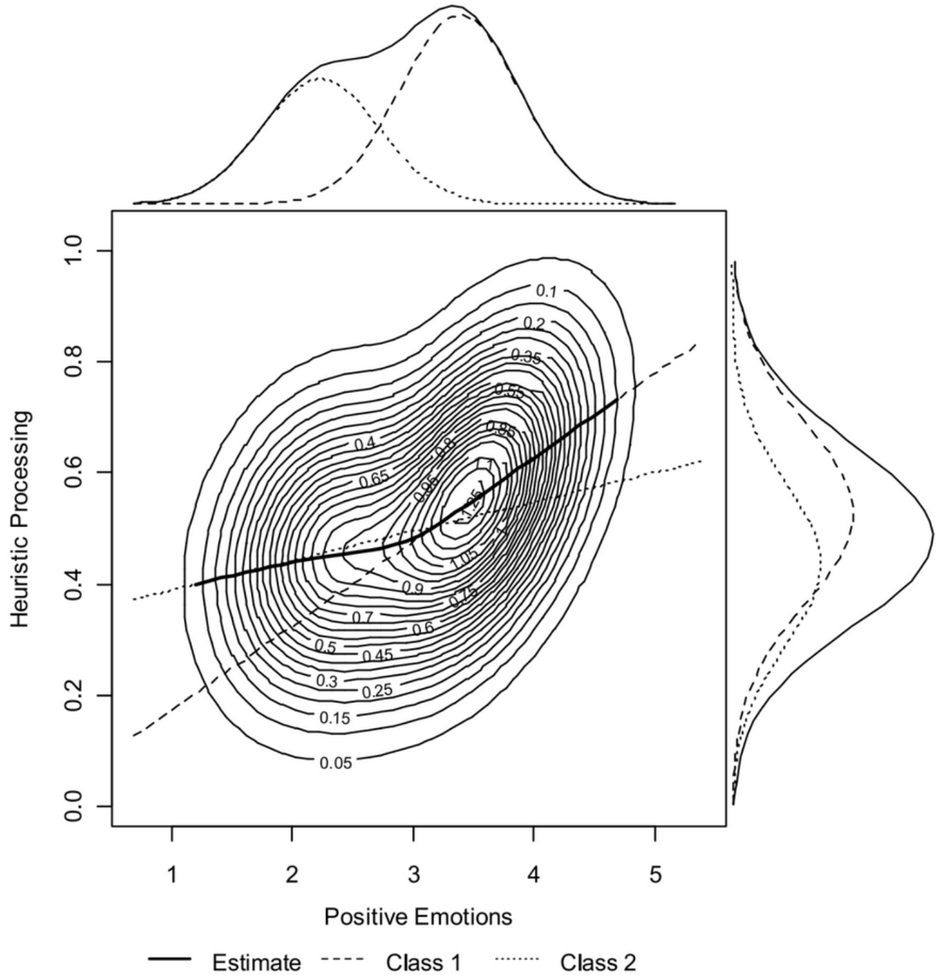
Regression Line (can be nonlinear, but is not in this case)




**Marginal Desnity Plots are 3 plots in one! They heavily draw on the model (the SEMM).**

Density Plots (1 per latent variable)

# Marginal Mixture Density Plot

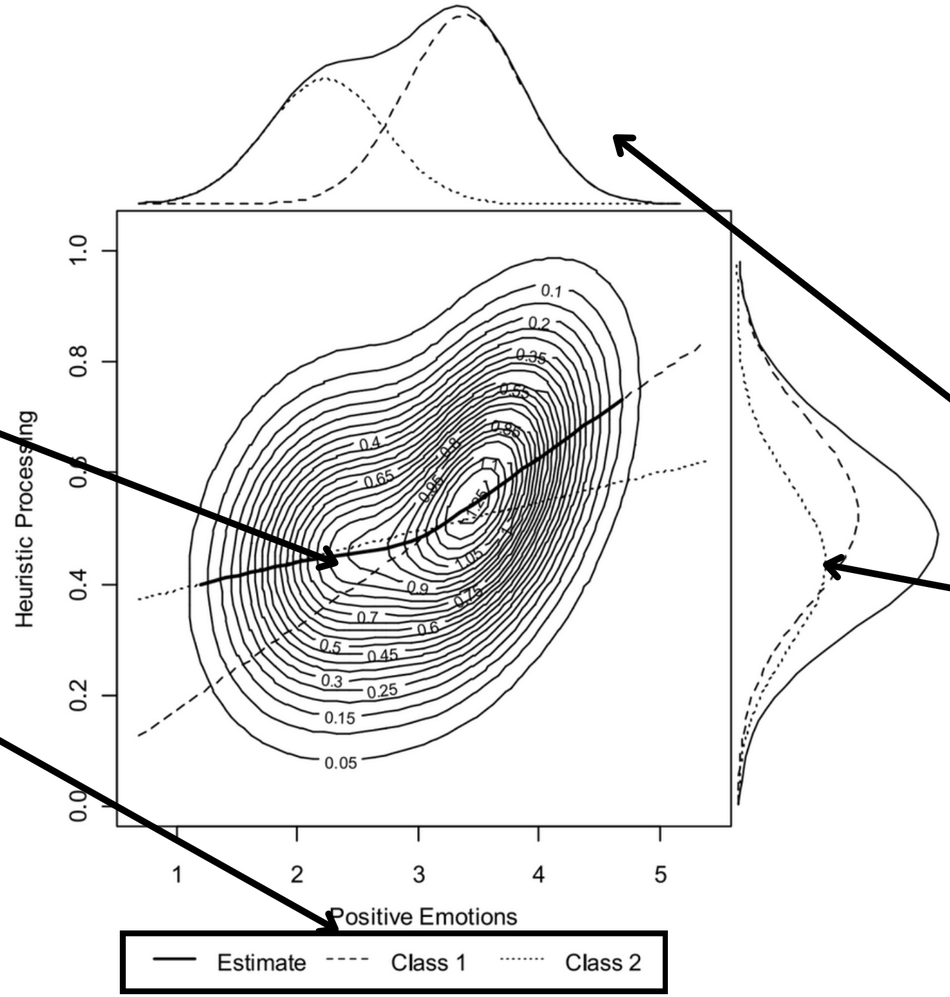



**Marginal Density Plots showing effects across levels of a the latent predictor.**

# Marginal Mixture Density Plot

Regression lines (including main [curved!] line)

Breakdown of plots:
1 for overall estimate, 2 for levels of latent predictor




**Marginal Density Plots showing effects across levels of a the latent predictor.**

6 density plots! (3 per latent variable)

# Software Demo!

Generating plots in R with Guided Example

# SEM Guiding Example

- **Statistics anxiety** and **computer anxiety** tend to negatively affect students' ability to understand statistics and run statistical analyses with software.

- **Situation:** A researcher wants to understand:

1. How statistics anxiety is related to its (STARS) indicators,
2. How computer anxiety is related to its (CARS) indicators, and
3. How computer and stats anxiety are related to each other!

Source: http://www.mtllabfsu.com/lab-news/new-open-access-article-about-math-anxiety-published

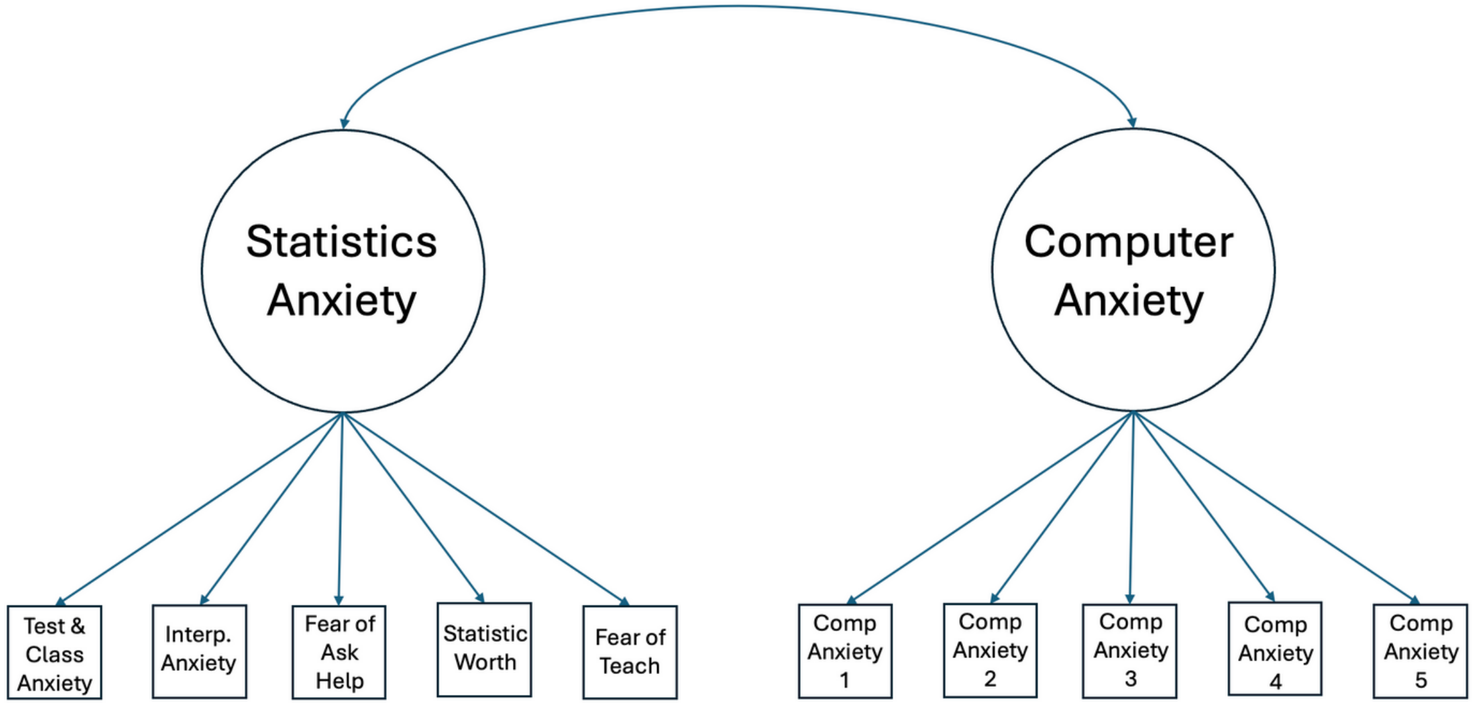
# SEM Guiding Example

- **2 Latent Variables:**

1. Statistics Anxiety (measured by STARS)
2. Computer anxiety (measured by CARS)

- **10 Manifest Variables:** 5 STARS and 5 CARS items

- **Sample**: 500 Introductory Statistics Students Learning R. (Data is fictional!)



# Demo Time!

(Note: All R Code & Output can be found here)

# References


- Fife, D. A., Brunwasser, S. M., & Markle, E. C. (2023). Seeing the impossible: Visualizing latent variable models with flexplavaan. *Psychological Methods*, *28*(6), 1456-1477. https://doi.org/10.1037/met0000468
- Hallgren, K. A., McCabe, C. J., King, K. M., & Atkins, D. C. (2019). Bayond path diagrams: Enhancing applied structural equation modeling research through data visualization. *Addictive Behaviours*, *94*, 74-82. https://doi.org/10.1016/j.addbeh.2018.08.030
- Pek, J., Sterba, S. K., Kok, B. E., & Bauer, D. J. (2009). Estimating and visualizing nonlinear relations among latent variables: A semiparametric approach. *Multivariate Behavioural Research*, *44*, 407-436. https://doi.org/10.1080/00273170903103290

SCAN ME!


I CAN'T THINK OF A SINGLE THING TO PAINT
JUST LEAVE THE CANVAS BLANK AND CALL IT "INVESTIGATION INTO THE MEANING OF NOTHING"
CHRIS MADDEN

# Thank you! :)

SCAN ME!