`modsem`: An R Package for Estimating Latent Interactions and Quadratic Effects

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modsem

- modsem is an R package for estimating latent interaction and quadratic effects, in *Structural Equation Models* (SEMs).

Frameworks

- Product Indicator (PI) approaches
- Distribution Analytic (DA) approaches

Product Indicator (PI) Approaches

Product Indicator (PI) Approaches

- First attempt at latent interaction in SEMs (Kenny and Judd 1984)
- Creates product indicators, used as indicators for latent interaction terms.
- Has traditionally required manual model specification, and manual construction of product indicators.
- Early approaches involved complicated model constraints.
- Manual specification (partially) led to a continual simplification of constraints.

Product Indicator (PI) Approaches (History)

- Constrained Approach (orthogonal specification) (Kenny and Judd 1984)
- Constrained Approach (oblique specification) (Jöreskog and Yan 1996)
- Constrained Approach (mean-centered indicators) (Algina and Moulder 2001)
- Unconstrained Approach (constrained latent mean) (Martin and Marsh 1999)
- Resdiual Centering Approach (no constraints) (Little, Bovaird, and Widaman 2006)
- Double Centering Approach (no constraints) (Lin et al. 2010)

Product Indicator (PI) Approaches (Tools)

- `semTools` offers tools for creating the product indicators, but does not help specify the model.
- Thus the PI approaches largely require manual specification.
- `modsem` automatically handles the creation of product indicators, and model specification.
- Model specification becomes exponentially more complicated for models with more indicators, more interaction terms. Especially for the PI approaches with model constraints.

Example: Double Centering Approach, using semTools

```
model <- '
# Measurement Model
  X  =~ x1 + x2 + x3
  Z  =~ z1 + z2 + z3
  Y  =~ y1 + y2 + y3
  XZ =~ x1.z1 + x2.z1 + x3.z1 +
        x1.z2 + x2.z2 + x3.z2 +
        x1.z3 + x2.z3 + x3.z3

# Structural Model
  Y ~ X + Z + XZ

# Residual Covariances
  x1.z1 ~~ x1.z2 + x1.z3 + x2.z1 + x3.z1
  x1.z2 ~~ x1.z3 + x2.z2 + x3.z2
  x2.z1 ~~ x2.z2 + x2.z3 + x3.z1

  x1.z3 ~~ x2.z3 + x3.z3
  x2.z2 ~~ x2.z3 + x3.z2
  x3.z1 ~~ x3.z2 + x3.z3

  x2.z3 ~~ x3.z3
  x3.z2 ~~ x3.z3
'
```

Example: Double Centering Approach, using semTools

```
library(semTools)
data.prod <- indProd(data = oneInt,
                     var1 = c("x1", "x2", "x3"),
                     var2 = c("z1", "z2", "z3"),
                     match = FALSE)

fit <- sem(model, data = data.prod)
summary(fit)
```

```
Regressions:
                   Estimate  Std.Err  z-value  P(>|z|)
  Y ~
    X                 0.675    0.027   25.379    0.000
    Z                 0.561    0.026   21.606    0.000
    XZ                0.702    0.027   26.360    0.000
```

Example: Double Centering Approach, using modsem

```
library(modsem)

model <- '
# Measurement Model
  X  =~ x1 + x2 + x3
  Z  =~ z1 + z2 + z3
  Y  =~ y1 + y2 + y3

# Structural Model
  Y ~ X + Z + X:Z
'

fit <- modsem(model, data = oneInt)
summary(fit)
```

```
Regressions:
                   Estimate  Std.Err  z-value  P(>|z|)
  Y ~
    X                 0.675    0.027   25.379    0.000
    Z                 0.561    0.026   21.606    0.000
    XZ                0.702    0.027   26.360    0.000
```

Visualizing Interaction Effects

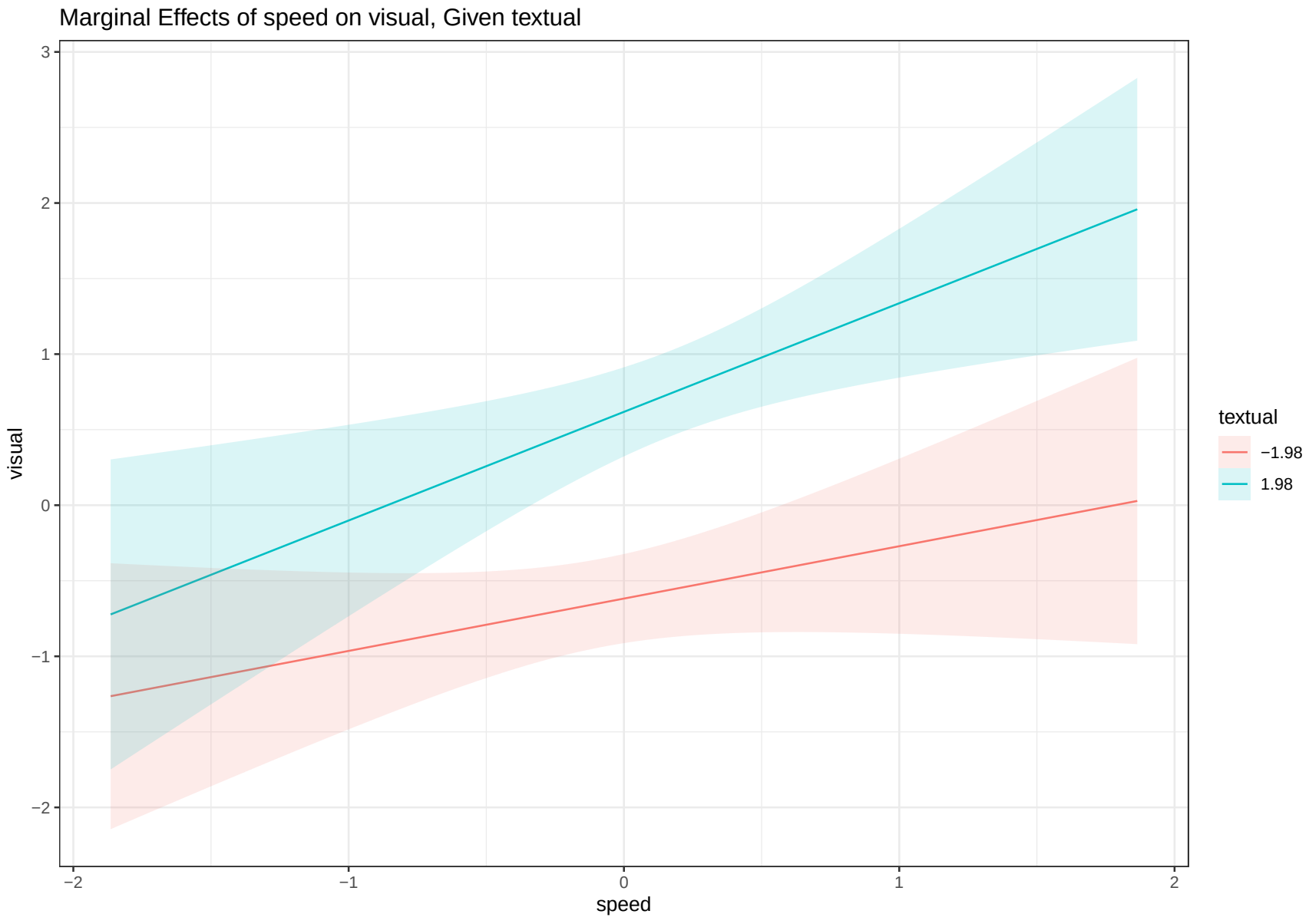
Example Model

```
model <-  '
  visual  =~ x1 + x2 + x3
  textual =~ x4 + x5 + x6
  speed   =~ x7 + x8 + x9

  visual ~ speed + textual + speed:textual
'

fit <- modsem(model, data = HolzingerSwineford1939, method = "lms")
summary(fit)
```

```
Regressions:
                   Estimate  Std.Error  z.value  P(>|z|)
  visual ~
    textual           0.312      0.076    4.107    0.000
    speed             0.533      0.158    3.366    0.001
    speed:txtl        0.094      0.093    1.016    0.309
```

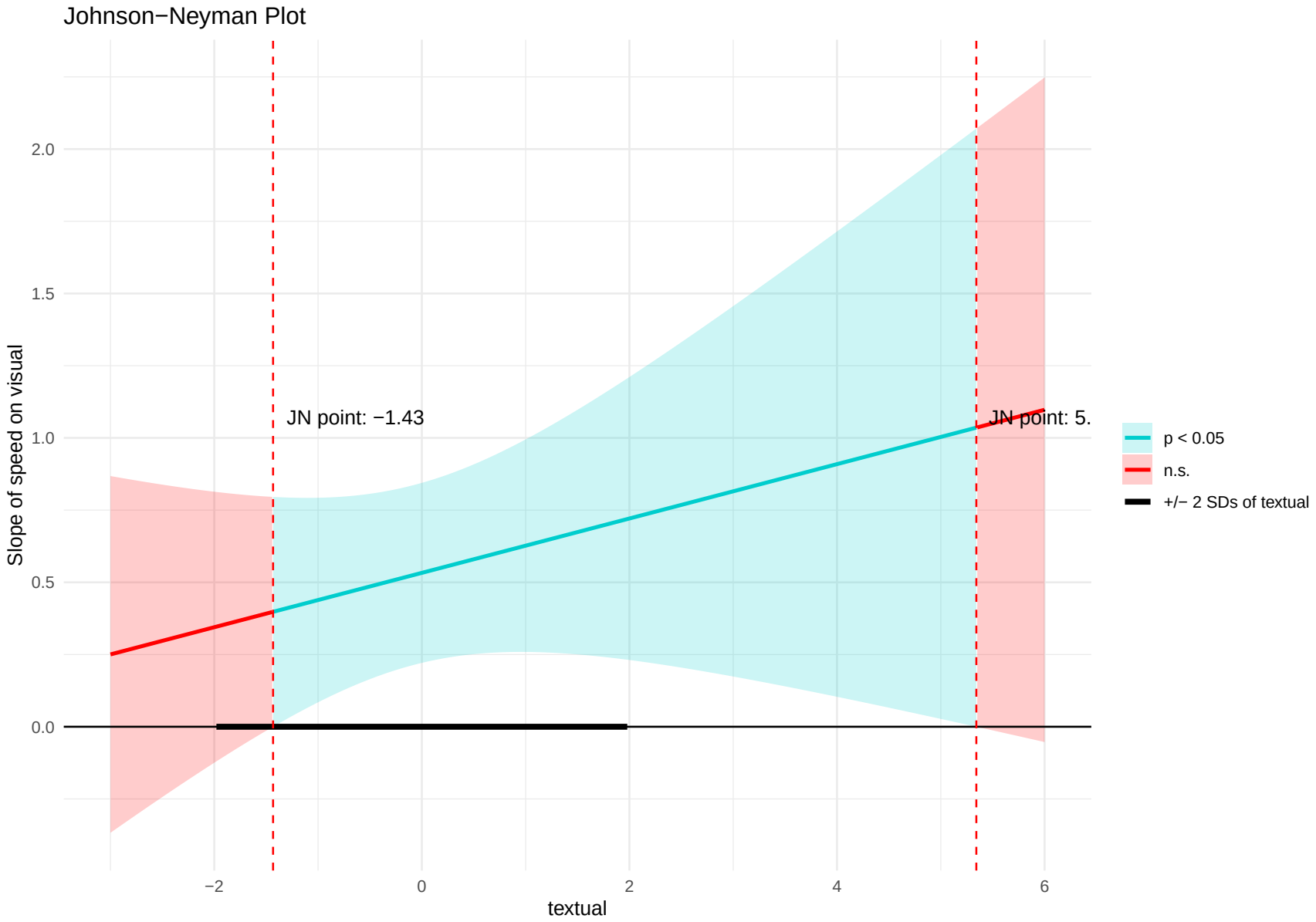
Plotting Margins (Simple Slopes)

```
plot_interaction(x = "speed", z = "textual", y = "visual", model = fit, vals_z
```



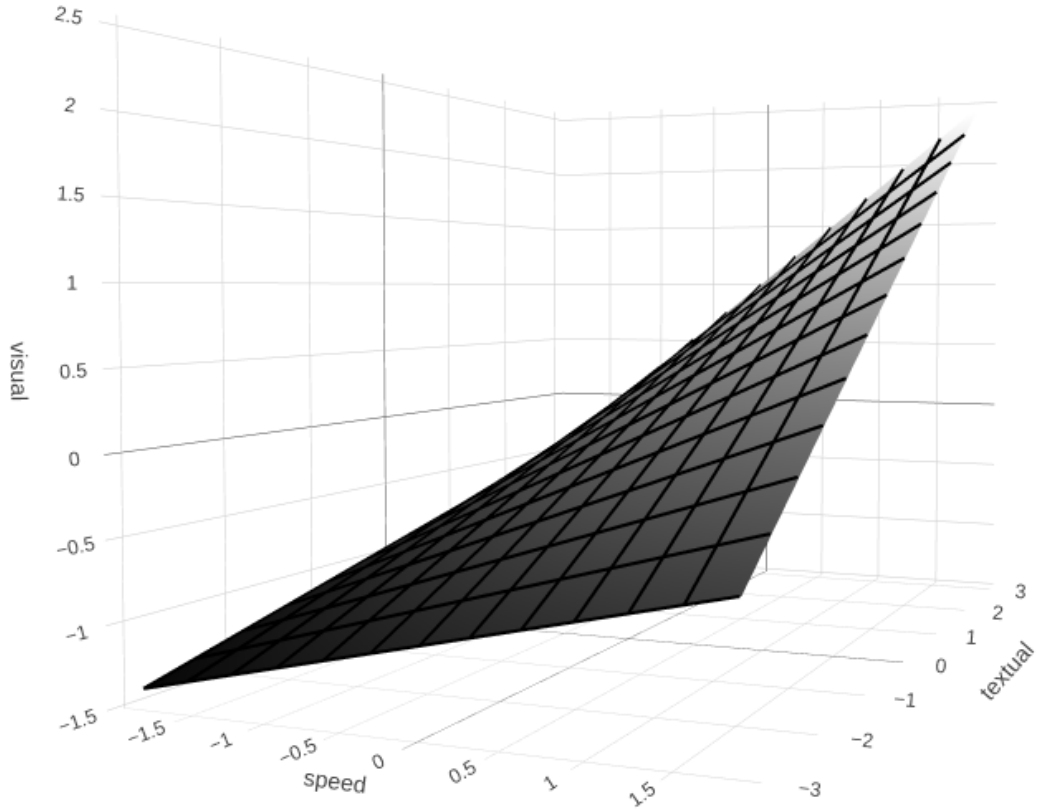
Johnson-Neyman Plot

```
plot_jn(x = "speed", z = "textual", y = "visual", model = fit, max_z = 6)
```



Surface Plot

```
plot_surface(x = "speed", z = "textual", y = "visual", model = fit,
             colorscale = "Greys", grid = TRUE, grid_color = "black")
```



Visualizing Models With Quadratic Effects

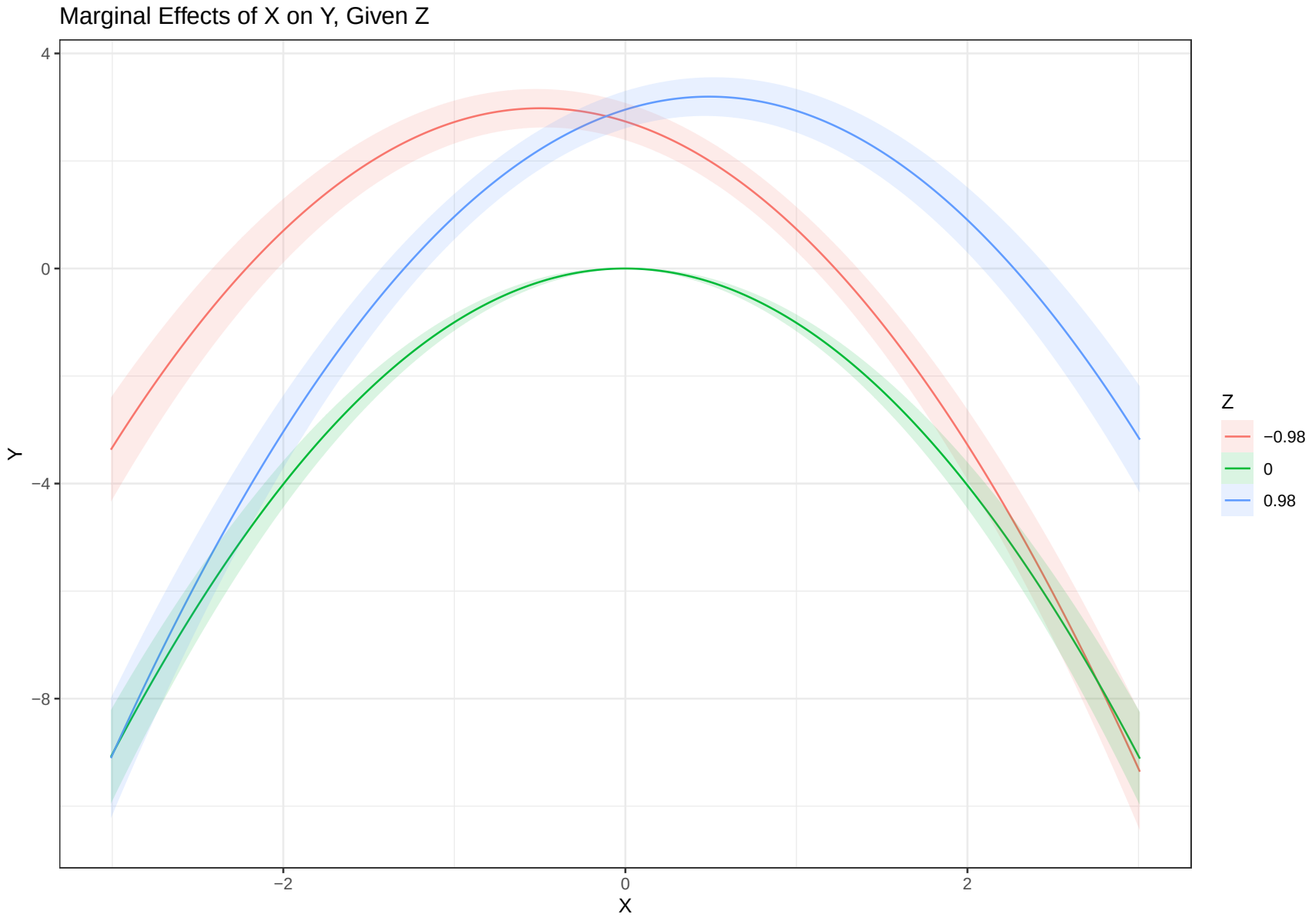
Example Model

```
model <- '
  X =~ x1 + x2 + x3
  Z =~ z1 + z2 + z3
  Y =~ y1 + y2 + y3

  Y ~ X + Z + X:X + Z:Z + X:Z
'

fit <- modsem(model, data = data.quadratic, method = "qml")
summary(fit)
```

```
Regressions:
                   Estimate  Std.Error  z.value  P(>|z|)
  Y ~
    X                -0.005      0.067   -0.081    0.935
    Z                 0.113      0.163    0.693    0.488
    X:X              -1.006      0.044  -23.040    0.000
    X:Z               1.011      0.080   12.571    0.000
    Z:Z               2.969      0.079   37.362    0.000
```

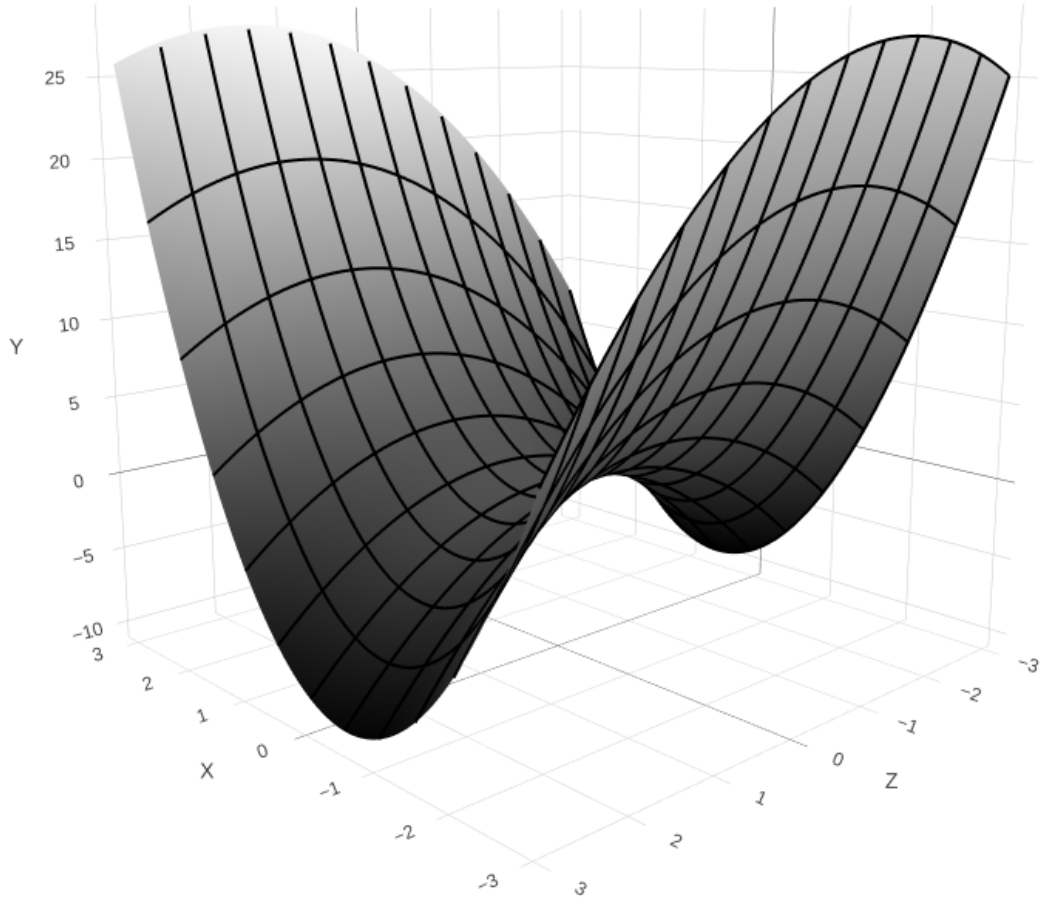
2D Plot

```
plot_interaction(x = "X", z = "Z", y = "Y", model = fit, vals_z = c(-1, 0, 1))
```



3D (Response Surface) Plot

```
plot_surface(x = "X", z = "Z", y = "Y", model = fit,
             colorscale = "Greys", grid = TRUE, grid_color = "black")
```



References

Algina, James, and Bradley C. Moulder. 2001. "A Note on Estimating the Jöreskog-Yang Model for Latent Variable Interaction Using LISREL 8.3." *Structural Equation Modeling* 8 (1): 40–52. https://doi.org/10.1207/S15328007SEM0801_3.

Jöreskog, Karl Gustav, and Fan Yan. 1996. "Nonlinear Structural Equation Models: The Kenny-Judd Model With Interaction Effects."

Kenny, David A., and Charles M. Judd. 1984. "Estimating the Nonlinear and Interactive Effects of Latent Variables." *Psychological Bulletin* 96 (1): 201–10. https://doi.org/10.1037/0033-2909.96.1.201.

Lin, Guan-Chyun, Zhonglin Wen, Herbert W. Marsh, and Huey-Shyan Lin. 2010. "Structural Equation Models of Latent Interactions: Clarification of Orthogonalizing and Double-Mean-Centering Strategies." *Structural Equation Modeling: A Multidisciplinary Journal* 17 (3): 374–91. https://doi.org/10.1080/10705511.2010.488999.