Final Project

```
This is lavaan 0.6-19
lavaan is FREE software! Please report any bugs.


Attaching package: 'dplyr'


The following objects are masked from 'package:stats':

    filter, lag


The following objects are masked from 'package:base':

    intersect, setdiff, setequal, union


Loading required package: Matrix


Welcome to emmeans.
Caution: You lose important information if you filter this package's results.
See '? untidy'
```

Possible questions:

- Are initial levels of anxiety/depression/beliefs/flexibility correlated with the rate of change in insomnia/depression/anxiety/beliefs symptoms over time?
- Do individuals who start with high levels of X show a slower/steeper decline in insomnia severity?
- Are initial levels of dysfunctional beliefs associated with change in insomnia severity? Does that change differ between therapy assignment?

https://gabriellajg.github.io/EPSY-579-R-Cookbook-for-SEM/lavaan-lab-16-latent-growth-models.html

https://longitudinalanalysis.com/mixture-latent-growth-models-r-a-step-by-step-guide/

https://tdjorgensen.github.io/SEM-in-Ed-compendium/ch27.html

Mixture Latent Growth Mixture Model introduces a categorical variable that accounts for subgroup membership

I will answer three questions:

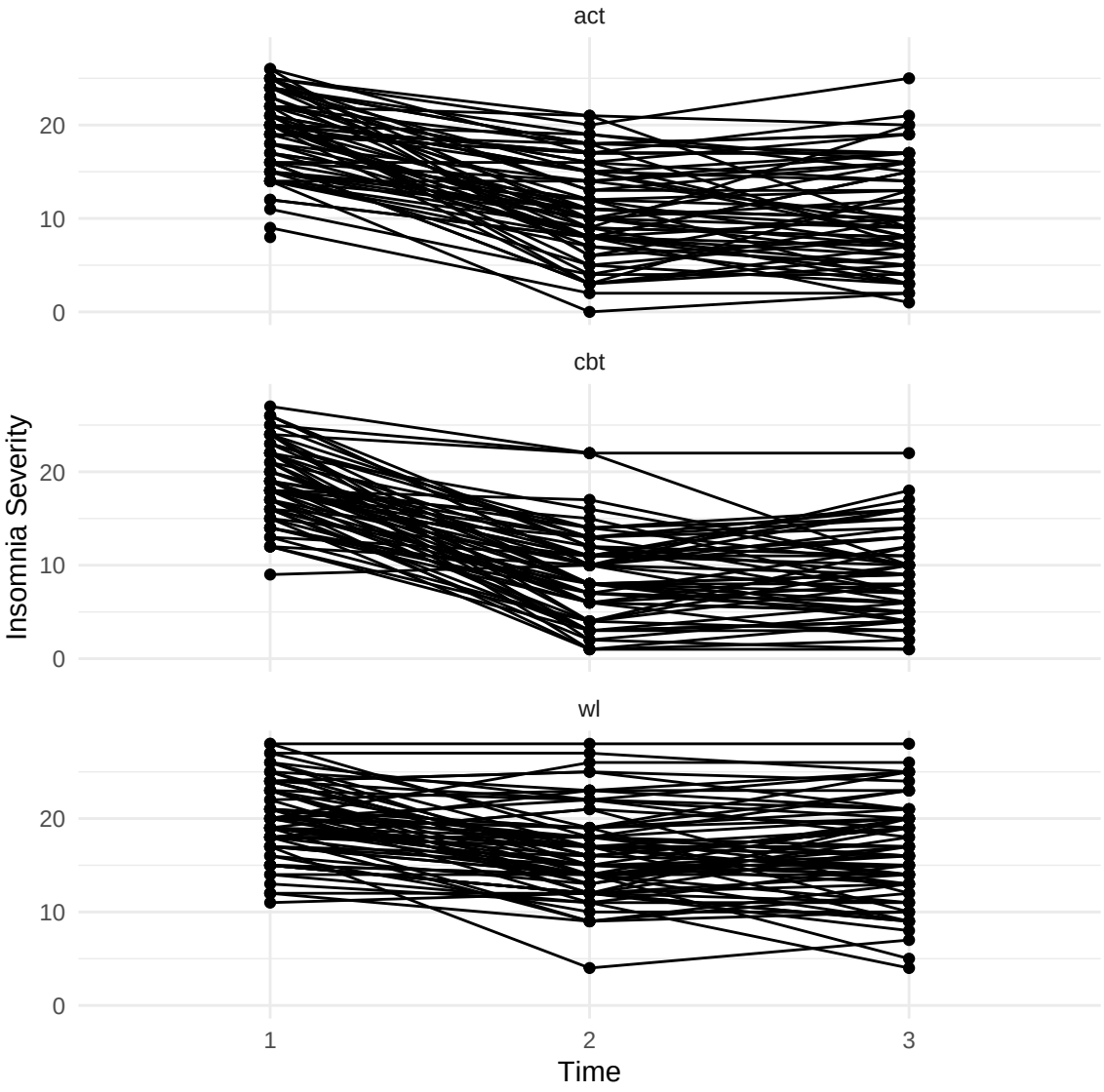
1. Treatment Efficacy: Start with the Linear Mixed-Effects Model on your primary outcome (ISI) to see if and how the treatments worked compared to the waitlist and each other.
2. Secondary Analysis (Predictors): Move to Latent Growth Curve Models to see if baseline characteristics (Anxiety, DBAS, etc.) can predict who changes the most in insomnia.
3. Tertiary Analysis (Mechanisms): Use Multivariate Latent Growth Models to see how people change. Does change in your proposed process variables (DBAS, AAQ) correlate with change in insomnia? This is best done within each treatment group to test your theories about how CBT and ACT work

0. Data exploration

Trajectories of change:

```
Warning: Removed 34 rows containing missing values or values outside the scale range
(`geom_point()`).
```

```
Warning: Removed 34 rows containing missing values or values outside the scale range
(`geom_line()`).
```



1. Treatment Efficacy

First, to adapt the model for unequally spaced time points, I need to create a continuous numeric time variable that reflects the actual time elapsed since baseline.

Test the models with increasing complexity: random intercept, linear and quadratic.

```
Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
  method [lmerModLmerTest]
Formula: igi_escore ~ poly(time, 2) * randomizacao + (1 | record_id)
```

```
   Data: mydata2

     AIC      BIC   logLik deviance df.resid
  3523.8   3572.4  -1750.9   3501.8      606

Scaled residuals:
     Min       1Q   Median       3Q      Max
-2.41177 -0.61544 -0.00753  0.60145  2.44992

Random effects:
 Groups    Name        Variance Std.Dev.
 record_id (Intercept) 12.12    3.482
 Residual              10.11    3.180
Number of obs: 617, groups:  record_id, 227

Fixed effects:
                                Estimate Std. Error       df t value Pr(>|t|)
(Intercept)                      13.8730     0.4622 228.5014  30.017  < 2e-16
poly(time, 2)1                  -66.8793     5.6736 407.5324 -11.788  < 2e-16
poly(time, 2)2                   72.3159     5.8078 408.6717  12.451  < 2e-16
randomizacaocbt                  -1.3407     0.6582 233.0119  -2.037   0.0428
randomizacaowl                    3.5285     0.6509 223.8770   5.421 1.53e-07
poly(time, 2)1:randomizacaocbt  -11.8049     8.2049 410.8230  -1.439   0.1510
poly(time, 2)2:randomizacaocbt   20.5624     8.3562 412.2648   2.461   0.0143
poly(time, 2)1:randomizacaowl    38.7805     7.8974 404.4804   4.911 1.32e-06
poly(time, 2)2:randomizacaowl   -39.7190     8.0725 404.1971  -4.920 1.26e-06

(Intercept)                     ***
poly(time, 2)1                  ***
poly(time, 2)2                  ***
randomizacaocbt                 *
randomizacaowl                  ***
poly(time, 2)1:randomizacaocbt
poly(time, 2)2:randomizacaocbt  *
poly(time, 2)1:randomizacaowl   ***
poly(time, 2)2:randomizacaowl   ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
                  (Intr) pl(,2)1 pl(,2)2 rndmzcc rndmzcw ply(tm,2)1:rndmzcc
poly(tm,2)1        0.023
poly(tm,2)2       -0.051  0.006
```

```
randomzccbt         -0.702 -0.016   0.036
randomizcwl         -0.710 -0.016   0.036   0.499
ply(tm,2)1:rndmzcc  -0.016 -0.691  -0.004   0.037   0.011
ply(tm,2)2:rndmzcc   0.035 -0.004  -0.695  -0.064  -0.025   0.013
ply(tm,2)1:rndmzcw  -0.017 -0.718  -0.005   0.012   0.010   0.497
ply(tm,2)2:rndmzcw   0.037 -0.005  -0.719  -0.026  -0.034   0.003
                    ply(tm,2)2:rndmzcc ply(tm,2)1:rndmzcw
poly(tm,2)1
poly(tm,2)2
randomzccbt
randomizcwl
ply(tm,2)1:rndmzcc
ply(tm,2)2:rndmzcc
ply(tm,2)1:rndmzcw   0.003
ply(tm,2)2:rndmzcw   0.500               0.001
```

Both CBT and ACT were effective at reducing insomnia symptoms compared to the waitlist. Furthermore, while CBT and ACT had similar initial rates of improvement, they differed significantly in the shape of their recovery trajectories over the long term.

1. The ACT Group's Trajectory (The Reference Group)

- (Intercept) = 13.87 ($p < .001$): The estimated average insomnia score for the ACT group at baseline (time = 0) is 13.87.
- poly(time, 2)1 = -66.88 ($p < .001$): This represents the linear time trend for the ACT group. The significant negative value indicates a steep, linear decline in insomnia symptoms over time.
- poly(time, 2)2 = 72.32 ($p < .001$): This represents the quadratic (curvature) time trend for the ACT group. A significant positive quadratic term combined with a negative linear term is the classic signature of a curve that levels off. So, for the ACT group, the initial steep decline in insomnia slowed down over the follow-up period, just as you observed visually.

2. Baseline Differences Between Groups

- randomizacaocbt = -1.34 ($p = .043$): The CBT group's average baseline insomnia score was 1.34 points lower than the ACT group's, and this difference is statistically significant.
- randomizacaowl = 3.53 ($p < .001$): The Waitlist group's average baseline insomnia score was 3.53 points higher than the ACT group's.

3. Differences in Change Over Time (The Interactions) This is the most important part for answering your primary question.

- poly(time, 2)1:randomizacaocbt = -11.80 (p = .151): This tests if the linear slope differs between the CBT and ACT groups. Since it's not significant, there is no evidence that their initial rates of decline were different.
- poly(time, 2)2:randomizacaocbt = 20.56 (p = .014): This tests if the quadratic trend (curvature) differs between the CBT and ACT groups. This effect is significant. The positive value means the CBT group had an even stronger positive curvature than the ACT group, suggesting their recovery trajectory leveled off more pronouncedly.
- poly(time, 2)1:randomizacaowl = 38.78 (p < .001): This tests if the linear slope differs between the Waitlist and ACT groups. The large, positive, and significant coefficient means the Waitlist group's slope was significantly less steep (i.e., they improved much less) than the ACT group's slope. This confirms ACT was effective.
- poly(time, 2)2:randomizacaowl = -39.72 (p < .001): This tests if the curvature differs between the Waitlist and ACT groups. The significant negative value indicates that the Waitlist group's trajectory did not have the same "leveling off" shape as the ACT group's.

What the Results Mean Together

The ACT Group (Our Reference): Remember, the ACT group itself has a significant negative linear term (-66.88) and a significant positive quadratic term (72.32). This means the ACT trajectory is also a curve—it shows a steep initial improvement that then slows down and begins to level off.

The CBT Group (The Comparison): Linear Interaction (p = .151): The initial "steepness" of the decline was statistically the same as ACT. Quadratic Interaction (p = .014): The quadratic term for CBT was significantly more positive (by 20.56) than for ACT.

So, what does a "more positive" quadratic term mean in this context? It means the upward bend of the curve is more pronounced. When you have a steep decline followed by an upward bend, a stronger bend means the leveling off happens earlier or more sharply. Evaluating Your Hypothesis

"…does it mean that for CBT, the change tends to happen only at t2 and stall at the same level, while for ACT, it progresses until the measurement taken at t3?"

Your description of CBT is excellent: Your intuition that the change for CBT is rapid and then "stalls" is a very good way to describe a more pronounced curve. The data suggests most of the therapeutic gains happened between baseline and 6 weeks, followed by a period of maintenance.

Your description of ACT needs a slight correction: Your model suggests that ACT also slows down and levels off. The difference is that its "leveling off" is less pronounced than CBT's. It doesn't necessarily mean it progresses linearly all the way to t3; rather, its curve is just gentler.

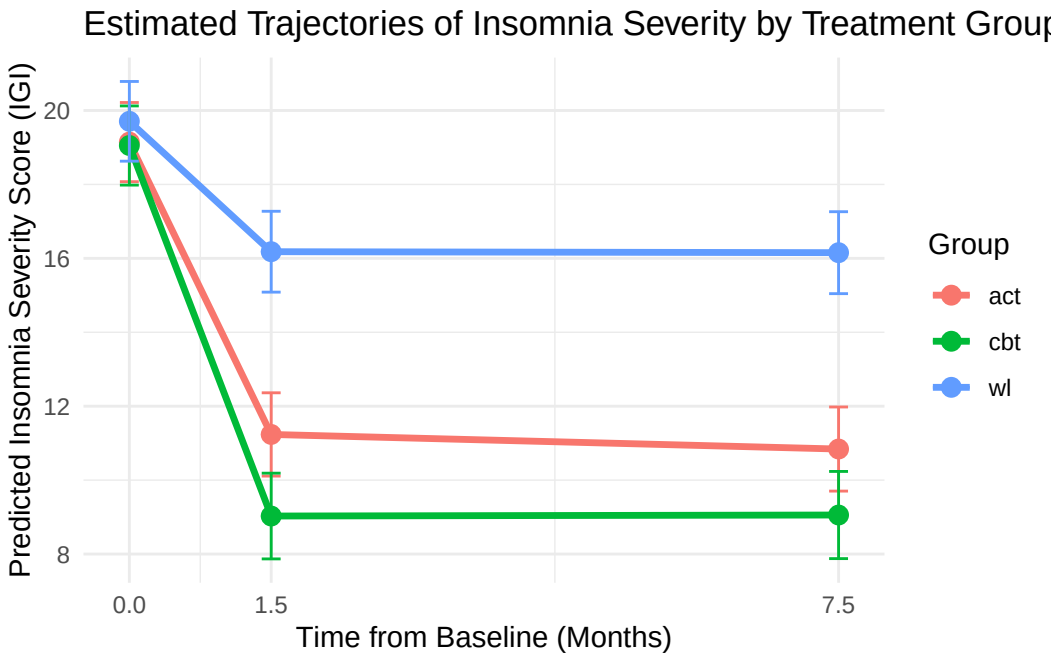
"…the 'immediate' change for ACT is comparable to CBT, but the long-term effects are more persistent for ACT"

This is the crucial question, and the coefficients alone don't give us the final answer. A "more pronounced" curve for CBT could mean two things:

Possibility A: CBT gets patients to a better state faster, and they maintain that excellent result (the curve flattens out at a very low insomnia score). Possibility B: CBT has a great initial effect, but then the progress completely stalls, while ACT's gentler, more sustained improvement eventually "catches up" or even surpasses CBT's outcome at the final time point (t3).

The model shows the trajectories have different shapes, but it doesn't tell us which group ended up with lower insomnia scores at 7.5 months.

Testing marginal means




```
time = 0.0:
 contrast  estimate    SE  df t.ratio p.value
 act - cbt   0.0921 0.770 405   0.120  0.9922
 act - wl   -0.5619 0.773 405  -0.727  0.7477
 cbt - wl   -0.6540 0.773 405  -0.846  0.6745

time = 1.5:
```

```
 contrast  estimate    SE  df t.ratio p.value
 act - cbt   2.2073 0.823 457   2.683  0.0206
 act - wl   -4.9437 0.799 432  -6.189  <.0001
 cbt - wl   -7.1510 0.811 443  -8.816  <.0001

time = 7.5:
 contrast  estimate    SE  df t.ratio p.value
 act - cbt   1.7851 0.834 469   2.141  0.0828
 act - wl   -5.3123 0.808 443  -6.573  <.0001
 cbt - wl   -7.0974 0.823 458  -8.619  <.0001

Degrees-of-freedom method: kenward-roger
P value adjustment: tukey method for comparing a family of 3 estimates
```

The difference is not statistically significant. In this case, you would conclude that you do not have sufficient evidence to say one therapy is superior to the other at Time 3. This would be the statistical support for your statement that they are "equally effective."