

# A Statistical Analysis of Patient Mental Health in Japan during the COVID-19 Pandemic

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# Data Overview

- **Study Type:** Longitudinal survey
- **Population:** Equal-sized age groups (20-69 years old), sex groups (male and female) and employment status (full-time worker; no regular employment; and unemployed, including homemaker, retired, and jobless)
- Lived in Japanese prefectures under special precautions that were related to the COVID-19 pandemic: Tokyo, Saitama, Chiba, Kanagawa, Osaka, Hyogo, Fukuoka, Hokkaido, Ibaraki, Ishikawa, Gifu, Aichi, and Kyoto.
- **Repeated measures:** Three surveys were conducted: July 2020, September 2020 and January 2021
- **Response variable of interest:** Patient Health Questionnaire-9 (PHQ-9), a diagnostic assessment for mental health (score from 0-27)
- **Covariates:** Demographic information, economic impact of the COVID-19 pandemic, anger, and coping strategy scale.
- **Dataset size:** 1468 patients, 17 covariates

# Variable Descriptions

## Demographic variables:

- **Age, sex, Residential Areas** (0 = out of mild lockdown, 1 = in mild lockdown)
- **Having an underlying disease** (0 = Yes, 1 = No)
- **Martial Status** (1 = Single, 2 = Married), **Children** (1 = No, 2 = Yes)
- **Household-income** (1-5, 1  $\leq$  2 million JPY, 5  $\geq$  8 million JPY)
- **Employment status** (0= Full-time, 1 = No regular job, 2 = Home-maker, 3 = Not working)
- **Economically Impacted** (0 = Positive impact, 1 = No impact, 2 = Negative impact)

# Variable Descriptions

**Anger scales: State anger scale and anger control scales were used (subscales of State-Trait Anger Expression Inventory (STAXI))**

- **State anger scale:** score can range from 0 to 30, with higher scores indicating higher state anger.
- **Anger control scale:** Score can range from 0 to 21; higher scores indicate that the participant makes a greater attempt to keep calm and restrain one's behavior.

**Coping scales:**

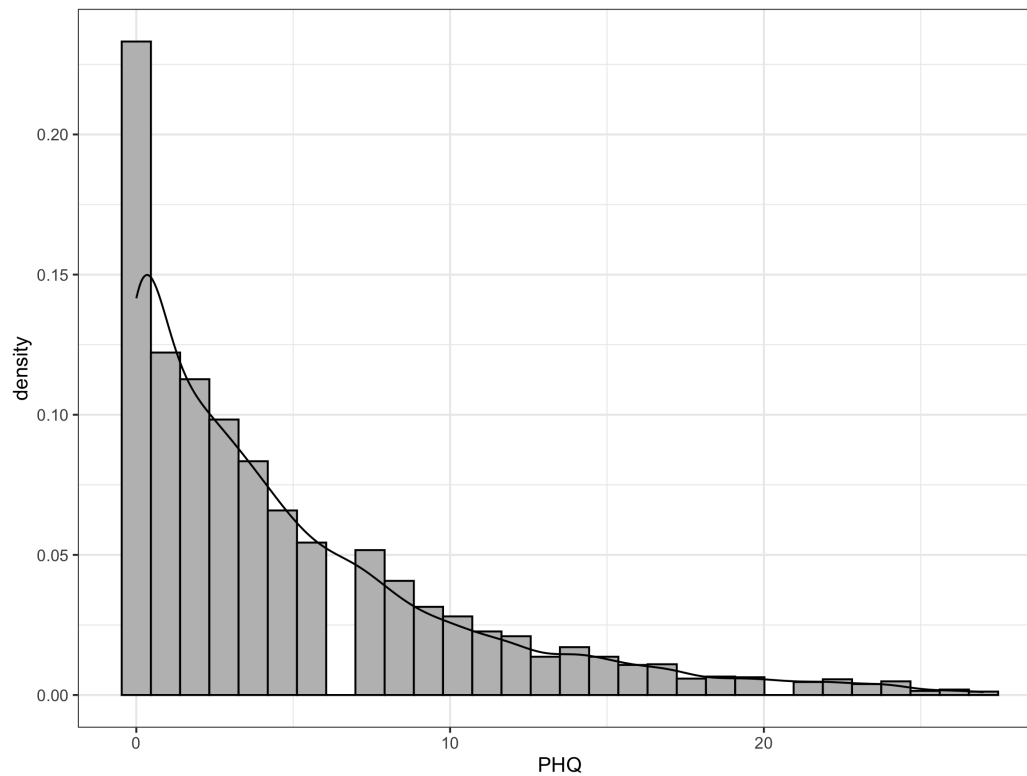
- **Brief Coping Orientation scale:** scale of different coping mechanisms with scores from 2-8 (example: Substance Use, Use of instrumental support, Religion etc.)
- Higher scores indicate higher levels of coping styles

# Questions of Interest

1. How do changes in patient mental health over time during the COVID-19 pandemic differ between the three different age-groups (young adults (20-39), middle-aged adults (40-64) and older adults (65-79)?
2. How do general demographic characteristics (sex, financial stability, relationship status) play a role in influencing the patient mental health score?
3. Which coping mechanisms seem to be associated with an increase in patient mental health (quantified by a low PHQ score)?

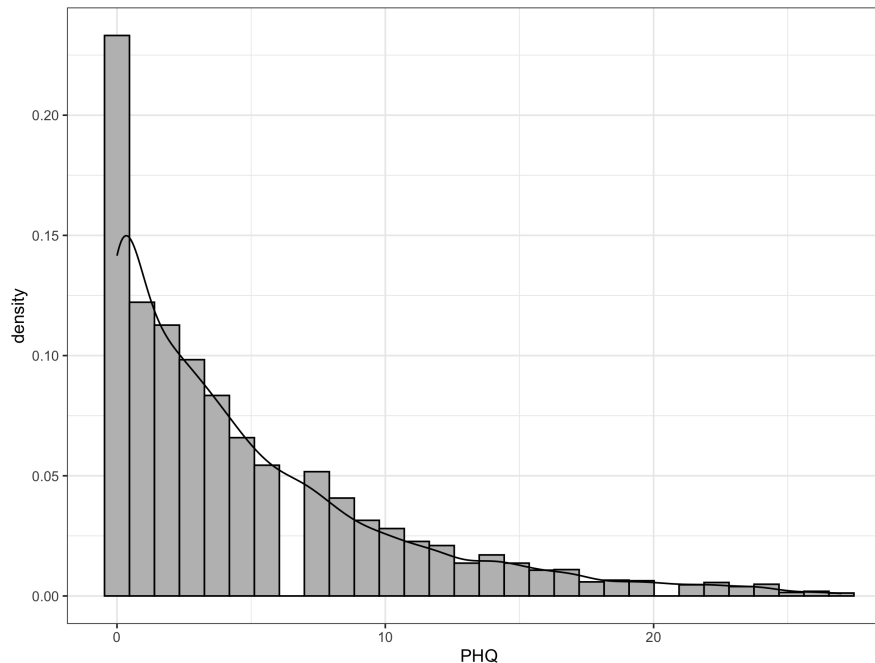
# Model: Distribution of response variable (PHQ scores)

- Positive scores: bounded at 0 and 27
- Relatively high proportion of zero scores



# Model: Zero-inflation in PHQ score

- Zero-inflated models: "structural zeroes" and "sampling zeroes"
- "Structural zeroes:" Patient may just have been feeling healthy mentally
- "Sampling zeroes:" Patient may select zero on purpose: maybe feeling stigma to declare that they are depressed/questions may not be fine-grained to their symptoms but they may still be depressed: **not "true" zeroes**



# Model: Distribution of response variable (PHQ scores)

- Possible scores are all values in  $[0, 27]$
- Can think of each of the 27 possibilities of scores as 27 trials. A patient could thus theoretically have a chance to score a success (1) in each "trial". This is akin to an aggregated Binomial sampling distribution
- Use a zero-inflated binomial distribution: respects bounds nature of data

Over the last 2 weeks, how often have you been bothered by any of the following problems?	Not at all	Several days	More than half the days	Nearly every day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself – or that you are a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3



# Model Specification: Mixed Effects Zero-inflated Binomial (ZIB) Linear Model

Let  $\text{PHQ}_{ij}$  denote the PHQ scores of interest for  $i, i = 1, \dots, N$  for subjects  $j = 1, \dots, J$ .

[Likelihood]

$$\text{PHQ}_{ij} = \begin{cases} 0, & \text{with probability } zi \\ \mathcal{B}(27, \pi_{ij}), & \text{with probability } (1 - zi) \end{cases}$$

$$\text{logit}(\pi_{ij}) = \alpha_{j[i]} + \beta_{\{k=1,\dots,18\}} \{\text{Demographic and Scale variables}\}_{ij}$$

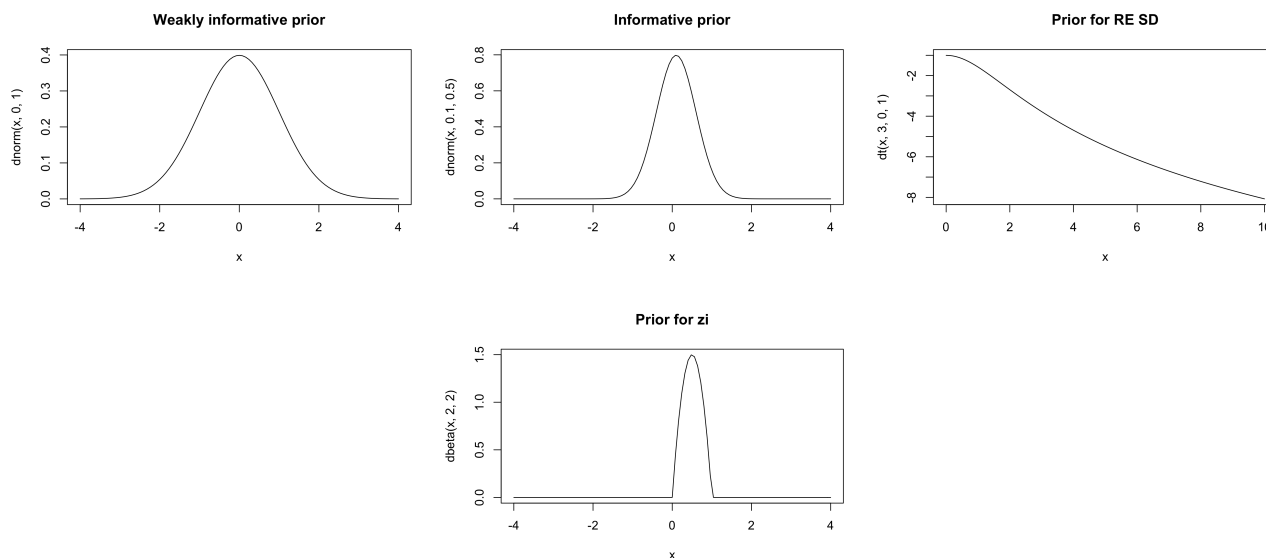
[Individual-level random effects]

$$\alpha_j \sim \mathcal{N}(\mu_{\alpha_j}, \sigma^2_{\alpha_j})$$

$zi$  modelled as parameter independent of covariates

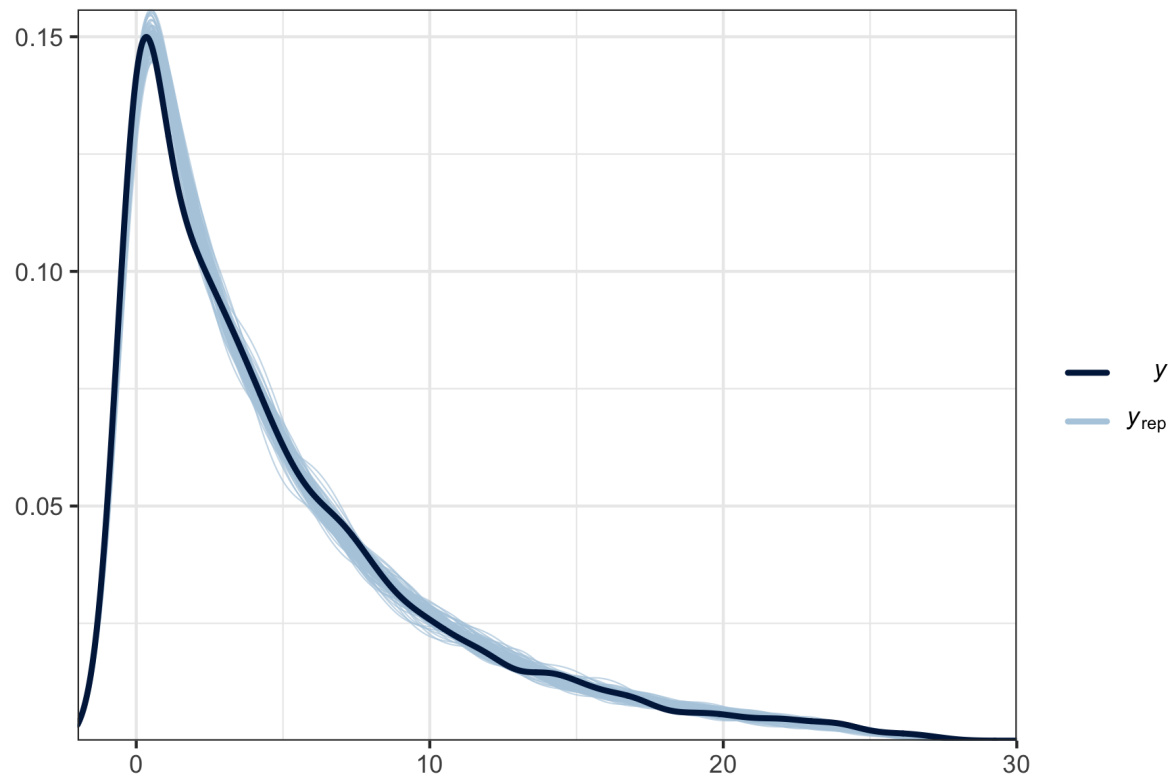
# Bayesian Mixed Effects Model: Priors

- Model fit with `{brms}` package in R: Uses Hamiltonian Monte Carlo no-U turn sampler (HMC-NUTS)
- Different priors for  $\beta_k$ 's: some of which include  $\mathcal{N}(0, 1)$ ,  $\mathcal{N}(0.1, 0.5)$  and  $\mathcal{N}(-0.1, 0.5)$
- $\sigma_{\alpha_j} \sim \text{Student-t}(3, 0, 1)$  (standard deviation of random effects)
- $z_i \sim \text{Beta}(2, 2)$  (mixing proportion/proportion of "sampling zeroes")



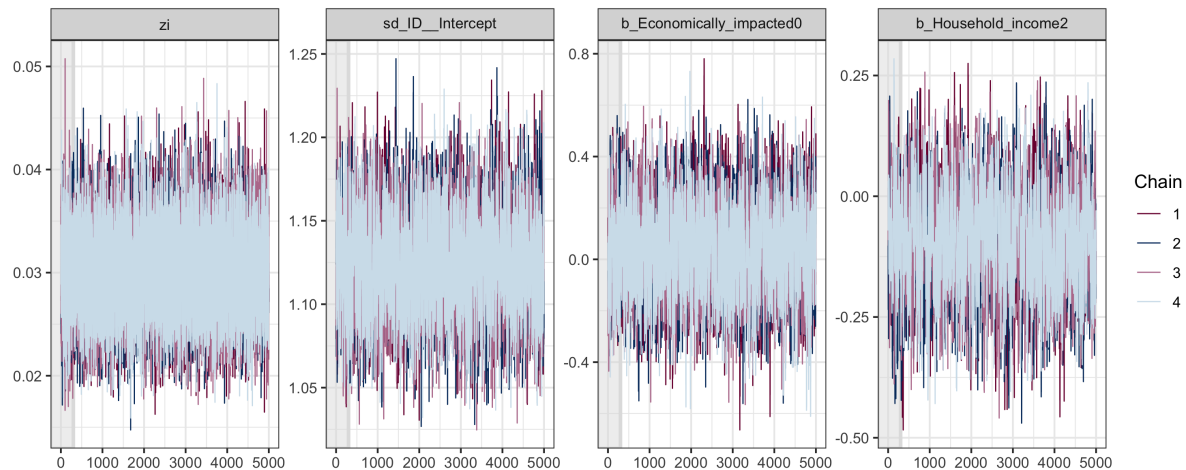
# Posterior Predictive Check

- Draw 100 simulated datasets under the fitted model and plot against observed data distribution
- Good check to see if model makes "sense" - gives valid predictions



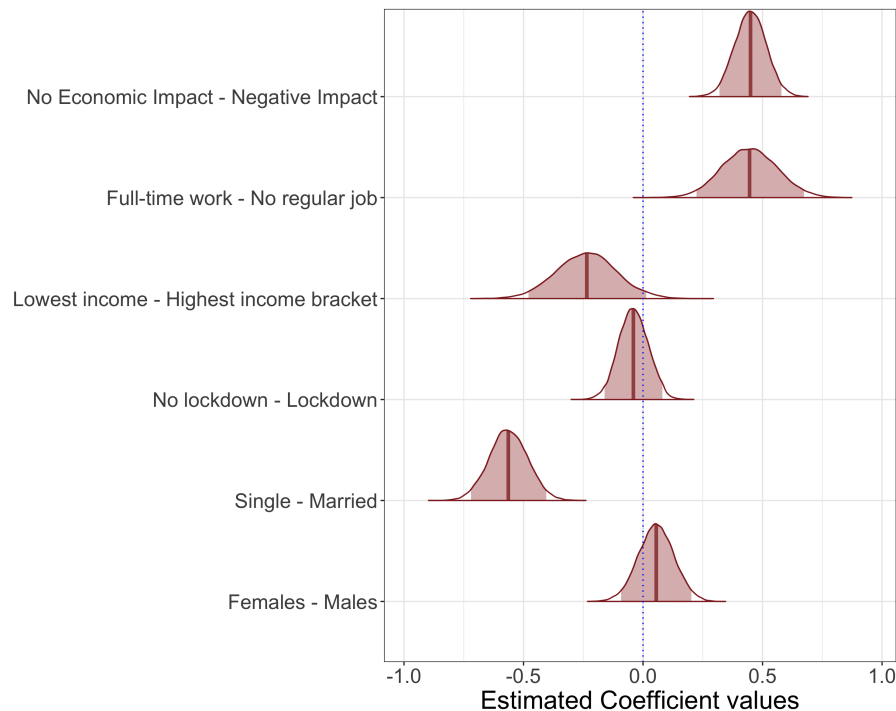
# Convergence checks

- Ratio of effective sample size  $n_{eff}/N$  well above 0.1 for all covariates
- Don't see any obvious issues in traceplots



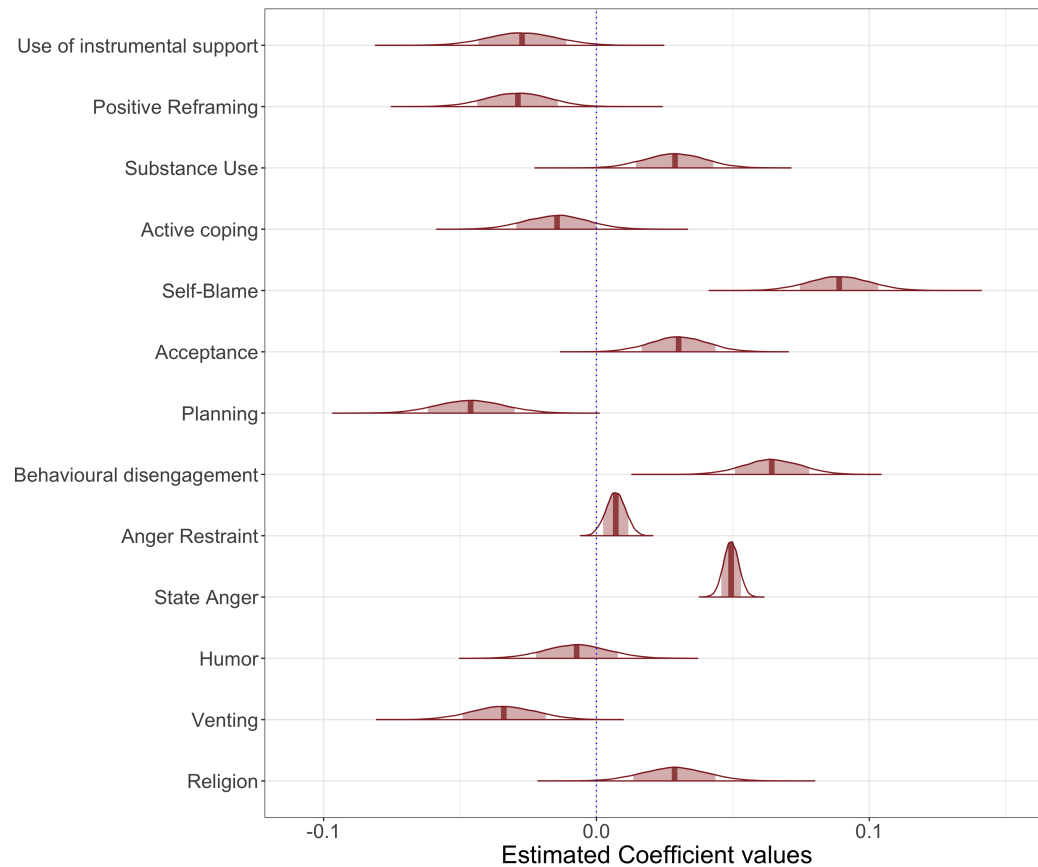
# Effects of demographic variables

- Shaded area represents area with 80 % probability mass
- Being married (v.single), and being in highest income bracket (v.lowest) associated with decrease in PHQ, Not working (v. working full-time) and negative economic impact (v.positive) associated with increase in PHQ score



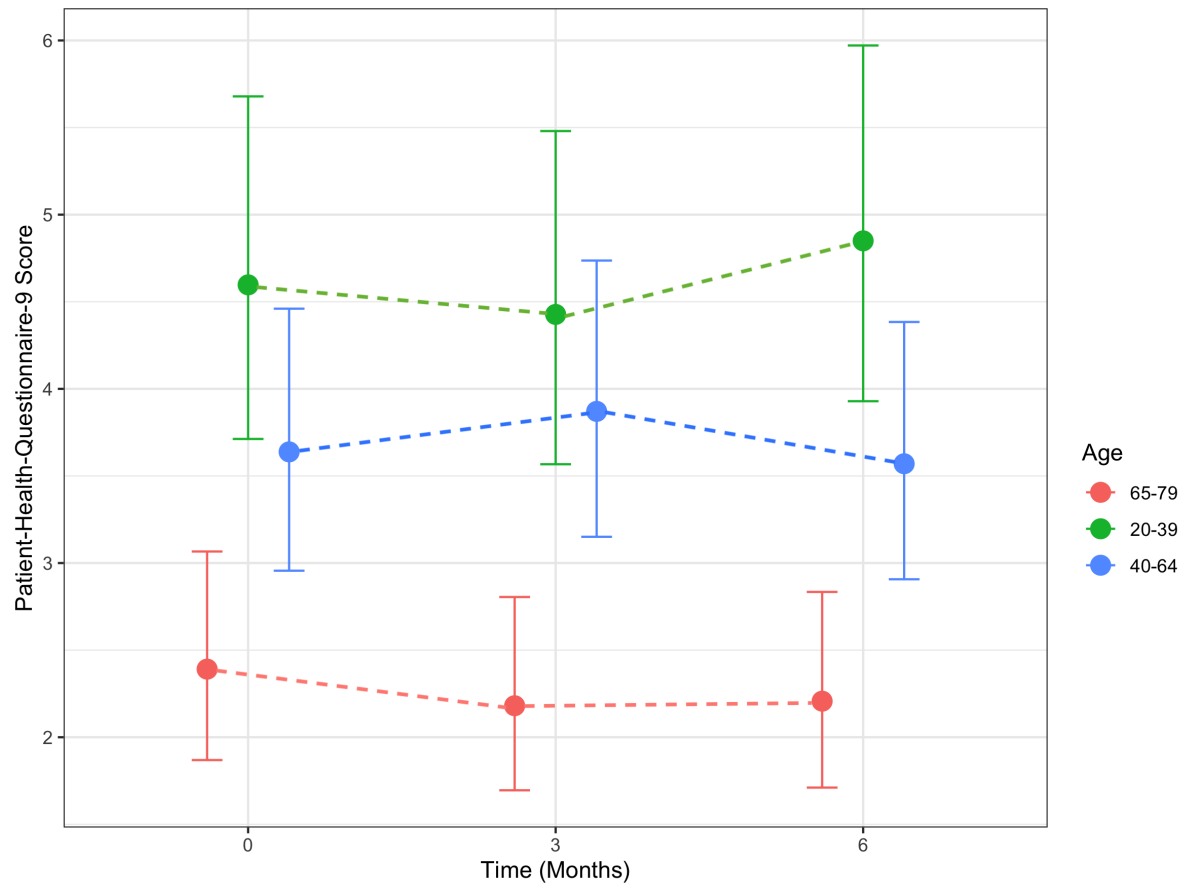
# Effects of scale variables

- Use of instrumental support, positive reframing, active-coping, planning, venting, associated with decrease in PHQ score - seem to be good coping strategies



# Interaction between effects of time and age

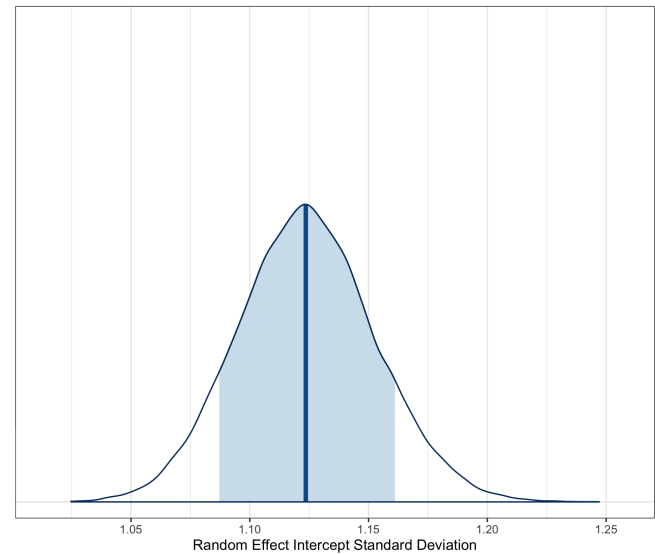
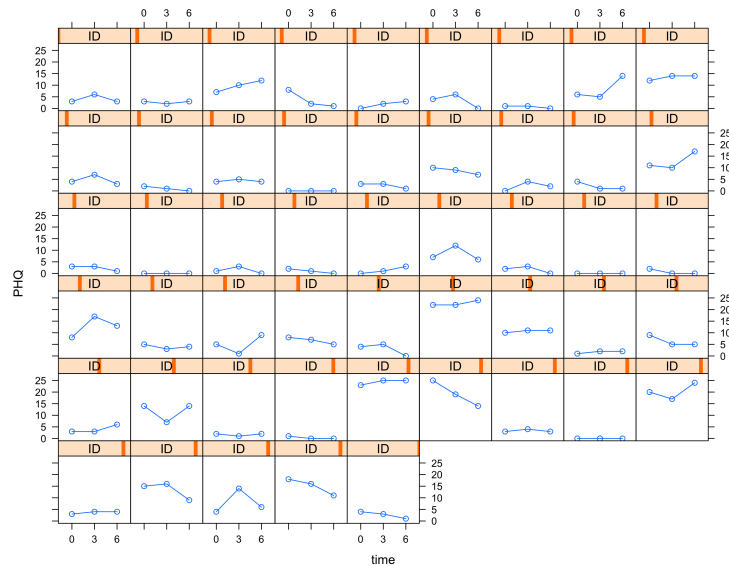
- Lowest PHQ scores in age-group 20-39 (young adults)
- For other age-groups, PHQ score seems to go down or stay constant by 6 months, increases for young adults



# Random effect intercept standard deviation

- Large amount of patient-level variation

## Posterior Distribution of Estimated Random Intercept SD





# Conclusions

1. Young adults (20-39) associated with higher PHQ-scores (higher scale of depression), progressively over time compared to other age groups
  2. Being married (v.single), and being in highest income bracket (v.lowest) associated with decreased depression scores, Not working (v. working full-time) and negative economic impact (v.positive) associated with increase. Rather than sex, lockdown status, etc. financial status seems to play a large role
  3. Use of instrumental support, positive reframing, active-coping, planning, venting, associated with decrease seem to be good coping strategies: associated with lower PHQ score
- Greater variable selection can be performed and  $z_i$  (mixing proportion) can also be modelled w.r.t covariates. Could also have looked at marginal coping mechanism effects in young adult population specifically.

# References

Fukase et al., (2022). Age-related differences in depressive symptoms and coping strategies during the COVID-19 pandemic in Japan: A longitudinal study

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