The Effects of a Stress-Relieving Program in Hospital Nurses: A Three-Level Analysis

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November 27, 2023

Outline

Data Introduction

- The dataset is from the Multilevel analysis: Techniques and applications (Hox, J. J., Moerbeek, M., & Schoot, R, 2018), which contains data from a cross-sectional hypothetical study on stress experienced by nurses in hospitals.

- In each of 25 hospitals, four wards were selected and randomly assigned to an experimental or control condition, where the intervention included a training program to cope with job-related stress. After the intervention was implemented, a random sample of 10 nurses from each ward completed a survey to test job-related stress level.

Variables in the dataset

- *hospital*: ID number for a hospital $(1, \ldots, 25)$, a total of 25 hospitals
- *ward*: ward numbering within a hospital $(1, 2, 3, 4)$, a total of 4 wards from each hospital
- *nurse*: ID number for a nurse $(1, \ldots, 1000)$, a total of 1000 nurses (not used in programming)
- *age*: nurse's age in years gender: nurse's gender $(0 = \text{male}, 1 = \text{female})$
- *experience*: nurse's years of experience working stress: outcome variable, a scale from 1 to 7
- *wardtype*: type of hospital ward ('general care', 'special care')
- *hospize*: hospital size ('small', 'medium', 'large')
- *expcon*: intervention indicator variable ('control', 'experiment')

Variables overview

hospital <dbl>	ward <dbl>	wardid <dbl>	nurse <dbl>	age <dbl>	gender <dbl>	experience <dbl>	stress <dbl>	wardtype <chr>	hospsize <chr>
1	1	11	1	36	0	11	7	general care	large
1	1	11	2	45	0	20	7	general care	large
1	1	11	3	32	0	7	7	general care	large
1	1	11	4	57	1	25	6	general care	large
1	1	11	5	46	1	22	6	general care	large
1	1	11	6	60	1	22	6	general care	large

expcon <chr>	hospsize.n <dbl>	wardtype.n <dbl>	expcon.n <dbl>	cgender <chr>	age.C <dbl>	experience.C <dbl>	Chospsize <dbl>	Cexpcon <dbl>
experiment	2	0	1	Male	-7.005	-6.057	1	0.5
experiment	2	0	1	Male	1.995	2.943	1	0.5
experiment	2	0	1	Male	-11.005	-10.057	1	0.5
experiment	2	0	1	Female	13.995	7.943	1	0.5
experiment	2	0	1	Female	2.995	4.943	1	0.5
experiment	2	0	1	Female	16.995	4.943	1	0.5

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Descriptive statistics, aggregate over entire sample
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Statistic     N     Mean   St. Dev.   Min     Max
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hospital     1,000  13.016  6.947       1      25
ward         1,000   2.493  1.119       1       4
wardid       1,000 132.653 69.476      11     254
nurse        1,000 500.500 288.819      1   1,000
age          1,000  43.005 12.042      23      64
gender       1,000   0.735  0.442       0       1
experience   1,000  17.057  6.042       1      38
stress       1,000   4.977  0.980       1       7
hospsize.n   1,000   0.776  0.689       0       2
wardtype.n   1,000   0.501  0.500       0       1
expcon.n     1,000   0.504  0.500       0       1
age.C        1,000  -0.000 12.042  -20.005  20.995
experience.C 1,000   0.000  6.042  -16.057  20.943
Chospsize    1,000  -0.224  0.689      -1       1
Cexpcon      1,000   0.004  0.500  -0.500   0.500
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▮ : observation index
▮ : outcome
▮ : covariates

Observed Stress versus Nurse's Age by Intervention Group
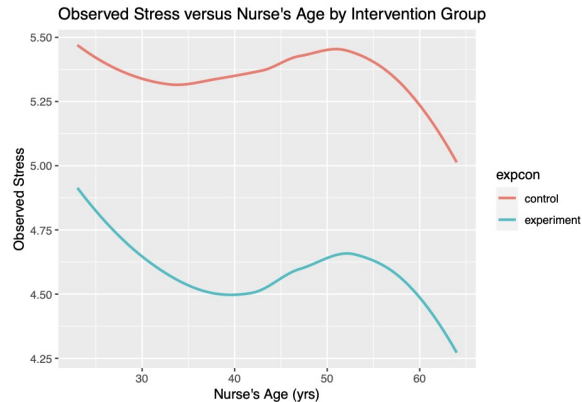
- It can be viewed as approximately linear, considering that the lower number of nurses in older age groups may be an artifact of the data.

- Given that both lines are simply parallel to each other, there is no moderating effect of intervention on this association.

Distribution of Observed Stress by Gender and Intervention Group
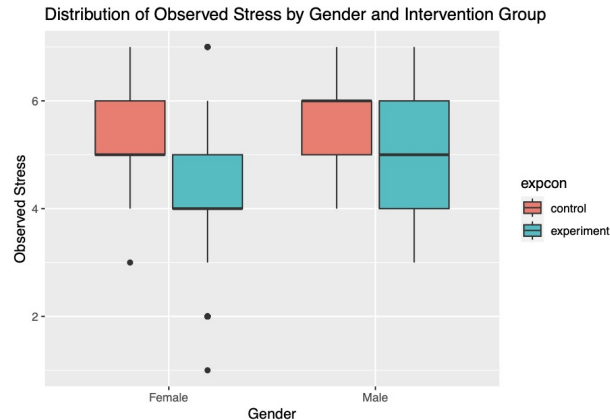
- Among males, there is a large overlaps in stress, and it is unclear whether there is an intervention effect among females.
- The plot does not suggest a moderating effect of intervention on the association between stress and gender.

Observed Stress versus Nurse's Work Experience by Intervention Group
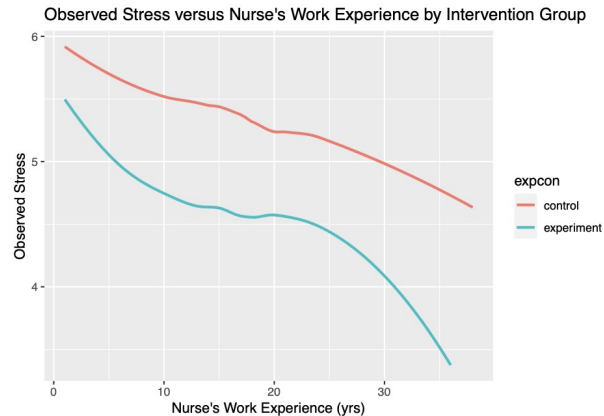
- There appears to be a liner relationship between observed stress and nurse's experience in years.

- Given that the two trajectories behave in parallel, this does not suggest a moderating effect of intervention on this association.

Distribution of Observed Stress by Hospital Ward Type and Intervention Group
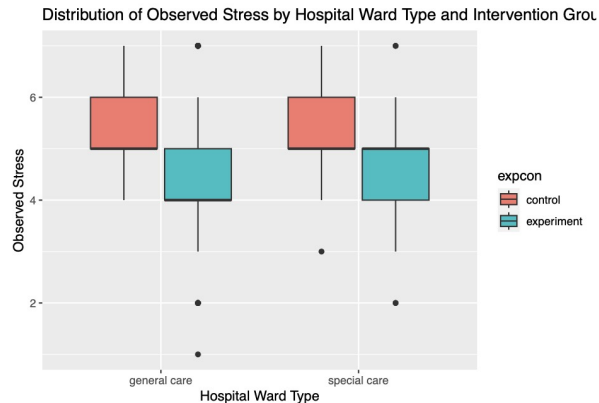
- Since the intervention effect size seems to be the same within each ward type, therefore, there does not seem to be a moderating effect.

Distribution of Observed Stress by Hospital Size and Intervention Group
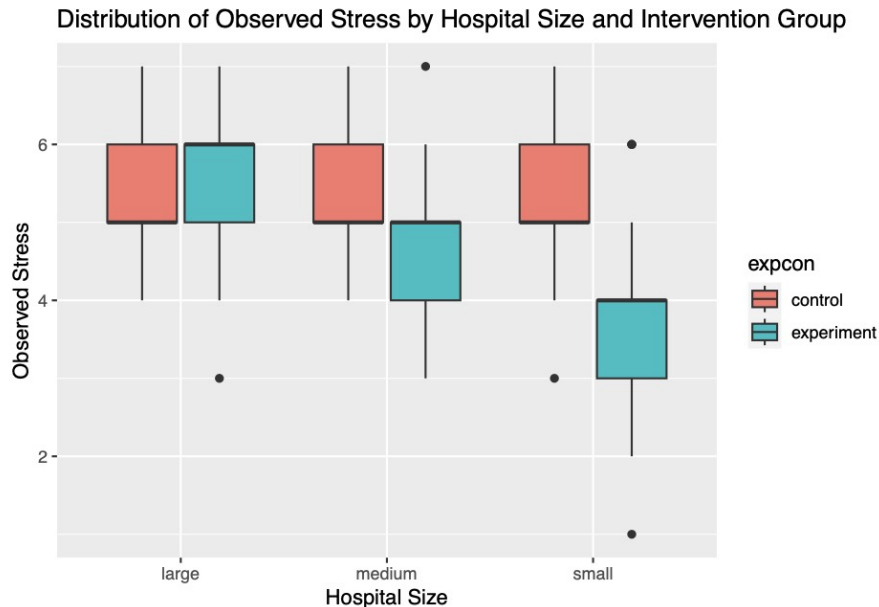
- It seems that there is a linear decline in stress across the hospital size;
- Because the effect size of intervention is different between the hospital sizes, there is a potential moderating effect.

Model1: Three-level model using only a random intercept at each appropriate level of hierarchy

Level 1 (nurse): $Y_{ijk} = \gamma_{0jk} + \gamma_{1jk}\,\mathrm{Sex}_{ijk} + \gamma_{2jk}\,\mathrm{Cexp}_{ijk} + \gamma_{3jk}\,\mathrm{Cage}_{ijk} + \epsilon_{ijk}$

Level 2 (ward): $\gamma_{0jk} = \gamma_{00k} + b_{0jk} + \gamma_{01k}\mathrm{Nwardtype}_{jk} + \gamma_{02k}\mathrm{Cexpcon}_{ik}$

Level 3 (hospital): $\gamma_{00k} = \beta_{000} + b_{0k} + \beta_{001}\mathrm{Chospsize}_k;$

$\gamma_{02k} = \beta_{020} + \beta_{021}\mathrm{Chospsize}_k; \gamma_{01k} = \beta_{010}; \gamma_{1jk} = \beta_{100}; \gamma_{2jk} = \beta_{200}; \gamma_{3jk} = \beta_{300}$

Combined Model: $Y_{ijk} = \beta_{000} + b_{0k} + b_{0jk} + \beta_{001}\mathrm{Chospsize}_k + \beta_{010}\mathrm{Nwardtype}_{ik}$
$+ (\beta_{020} + \beta_{021}\mathrm{Chospsize}_k)\,\mathrm{Cexpcon}_{jk} + \beta_{100}\mathrm{Sex}_{ijk} + \beta_{200}\,\mathrm{Cexp}_{ijk} + \beta_{300}\,\mathrm{Cage}_{ijk} + \epsilon_{ijk}$

Conditional ICCs:
- The ICC within the same ward and the same hospital is 58.42%.
- The ICC from the same hospital regardless of ward type is 26.20%.

Model2: Three-level model adding a random slope for centered intervention indicator variable due to hospital

Level 1 (nurse): $Y_{ijk} = \gamma_{0jk} + \gamma_{1jk}\text{Sex}_{ijk} + \gamma_{2jk}\text{Cexp}_{ijk} + \gamma_{3jk}\text{Cage}_{ijk} + \epsilon_{ijk}$

Level 2 (ward): $\gamma_{0jk} = \gamma_{00k} + b_{0jk} + \gamma_{01k}\text{Nwardtype}_{ik} + \gamma_{02k} \text{ Cexpcon }_{ik}$

Level 3 (hospital): $\gamma_{00k} = \beta_{000} + b_{0k} + \beta_{001}\text{Chospsize}_k;$

$\gamma_{02k} = \beta_{020} + \beta_{021}\text{Chospsize}_k + b_{02k}; \gamma_{01k} = \beta_{010}; \gamma_{1jk} = \beta_{100}; \gamma_{2jk} = \beta_{200}; \gamma_{3jk} = \beta_{300}$

Combined Model: $Y_{ijk} = \beta_{000} + b_{0k} + b_{0jk} + \beta_{001}\text{Chospsize}_k + \beta_{010}\text{Nwardtype}_{jk} +$
$(\beta_{020} + \beta_{021}\text{Chospsize}_k + b_{02k})\text{Cexpcon}_{jk} + \beta_{100}\text{Sex}_{ijk} + \beta_{200}\text{Cexp}_{ijk} + \beta_{300}\text{Cage}_{ijk} + \epsilon_{ijk}$

Conditional ICCs:

- The ICC within the same ward, the same hospital, and same condition is 68.86%.
- The ICC within the same ward and the same hospital is 39.74%.
- The ICC within the same hospital is 23.81%.

Model Comparison

- To compare the two models, the only difference between them is in the covariance matrix – therefore, we need to conduct a LRT using REML: The hypotheses are:

$$H_0 : \sigma^2_{b_{02k}} = 0$$

$$H_1 : \sigma^2_{b_{02k}} \neq 0$$

- The likelihood ratio test (LRT), implemented via REML, with df=2, G2=8.406 and p=0.0149 (smaller than 0.10), indicates that the addition of the **random effect of intervention across different hospitals** is significantly improving the fit of the model to the data.

- Hence, we choose Model2 as our final model.

Fixed effects of the final model

	Value	Std.Error	DF	t-value	p-value
(Intercept)	5.399858	0.10327271	897	52.28737	0.0000
age.C	0.022300	0.00219598	897	10.15512	0.0000
gender	-0.454716	0.03489625	897	-13.03050	0.0000
experience.C	-0.061804	0.00446073	897	-13.85515	0.0000
wardtype.n	0.053069	0.07304260	72	0.72655	0.4699
Chospsize	0.458206	0.12922692	23	3.54575	0.0017
Cexpcon	-0.498967	0.12074955	72	-4.13225	0.0001
Chospsize:Cexpcon	0.998592	0.16741718	72	5.96469	0.0000

As hospital size increased from small to medium to large, the significant reduction
in mean stress level due to intervention was significantly diminished/diluted:
There are

- a significant reduction in mean stress level due to intervention at **small
  hospitals** (an estimated reduction of
  $\beta_{Cexpon} - \beta_{Chospsize:Cexpcon}$=-0.499-0.998=**-1.5**);
- a significant reduction in mean stress level due to intervention in
  medium-sized hospitals (an estimated reduction of β_{Cexpon}=**-0.499**
  points);
- a non-significant increase in large-sized hospitals (an estimated increase of
  $\beta_{Cexpon}+\beta_{Chospsize:Cexpcon}$=-0.499+.998=**0.499**), meaning that
  intervention did not seem to significantly impact mean stress level among
  nurses in **large hospitals**.

Random effects of the final model

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Random Effects:
  Level: hospital
                                lower       est.      upper
sd((Intercept))             0.2771991 0.3893819 0.5469652
sd(Cexpcon)                 0.2554489 0.4223545 0.6983133
cor((Intercept),Cexpcon)   -0.2634529 0.3238953 0.7360486
  Level: ward
                     lower      est.      upper
sd((Intercept)) 0.2605456 0.3297284 0.4172812

  Within-group standard error:
     lower      est.      upper
 0.4444111 0.4654225 0.4874272
```

- Estimated correlation between b_{0k} and b_{02k} is 0.34, which means the larger the deviation of a hospital's mean for nurses' stress from the overall mean of stress averaged across all hospitals, the larger the deviation for that hospital's intervention effect from the overall intervention effect size averaged across all hospitals.
- Similar to M1, the majority of heterogeneity in stress (response variable) is explained by the correlation among responses from the same ward within a hospital, but it is now composed of an additional source of heterogeneity due to the varying effect sizes of intervention across different hospitals.
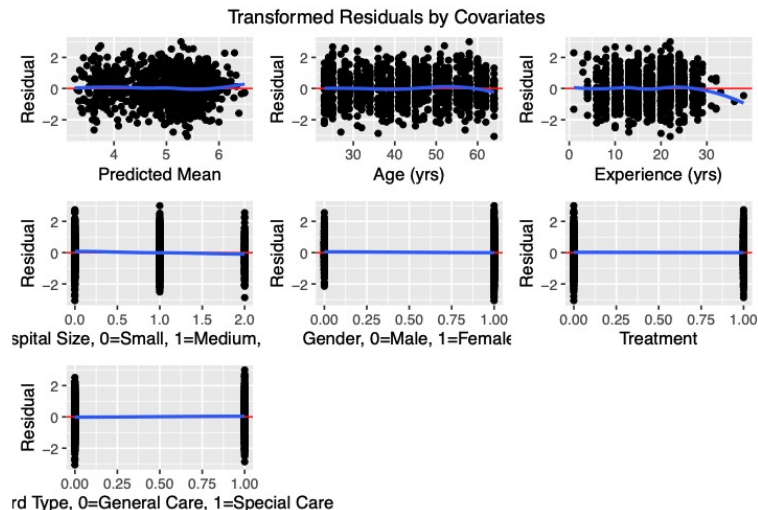
Histogram and Q-Qplot for the transformed residuals
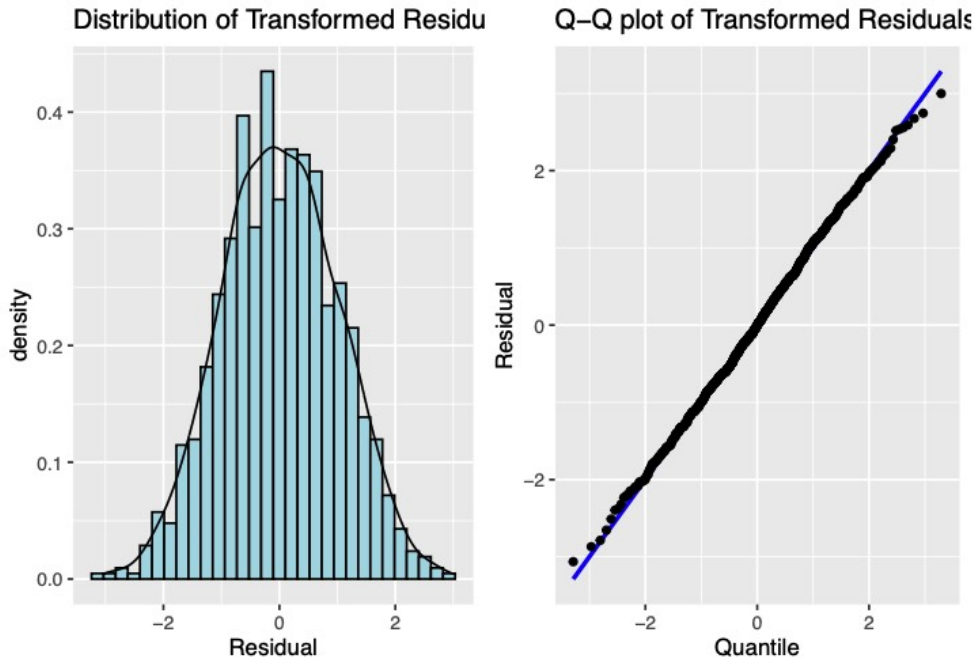
The histogram of residuals looks pretty normal, and the Q-Q plot indicates no significant departures from the Normality.
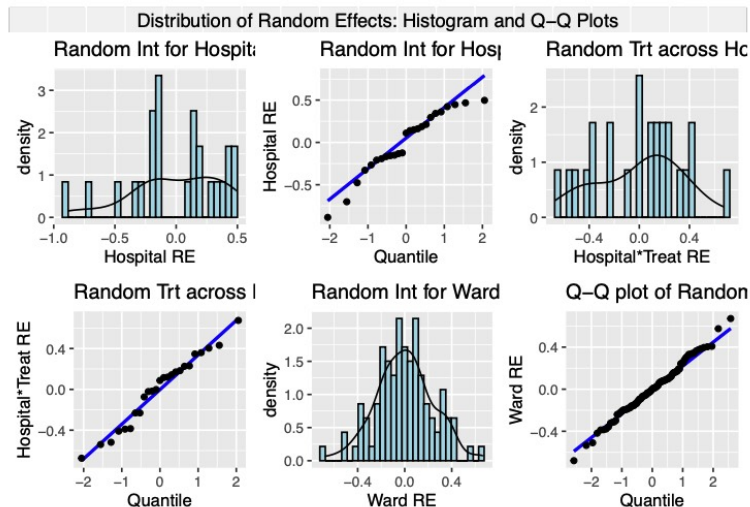
Marginal transformed residuals

Transformed Residuals by Covariates

The residuals are approximately 0 on average and their variability is approximately half above and half below the average of 0.

Histograms and Q-Q plots of the random effects BLUPS

Despite the small number of hospitals and in the study, the residuals appear to follow a normal distribution.

Discussion

- **Conclusion**: This intervention lowered stress among nurses working in small hospitals and to a smaller degree in medium sized hospitals. The intervention did not exhibit an effect in large hospitals.
- Strength:
  - This analysis was able to incorporated all three levels of clustering while additionally controlling for many covariates, both categorical (nurse gender and ward type) and continuous (nurse age and experience in years).
  - Heterogeneity was accounted for in terms of the intervention's effect at various hospitals. This would NOT be possible via any ANOVA type analysis.

Additional works

- **Two levels or three levels?**: Use LRT via REML to compare the null models with and without the nesting of wards in hospitals; We choose three levels;

- **Use centered variables or not?** We choose centered;

- **What fixed effects are significant to be included?** We choose fixed effects in the final model;

- **What cross-level interactions are significant to be included?** We choose *Chospsize × Cexpcon*;

- **What random slope should be included?** This is the slice I show today.