SAKA003 Quantitative Methods: Multivariate Analysis
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Lab Report 5 – Mixed Models 2

Introduction

So far, we have attempted to explain the variation of perioperative pain among individuals statically: measuring it only at one point in time after the operation. This report addresses change in pain over time by analyzing data collected from 20 individuals – who underwent wisdom tooth surgery – for four consecutive days after the surgery with three different mixed models.

Data Exploration and Preparation

Table 1 presents the descriptive statistics for the variables used in the models (complete output of the exploration of the dataset can be found in "Lab_5 – Descriptives_and_Models" in the GitHub repository link). There seems to be no missing values or coding errors. Further, the exploration for influential observations or outliers shows that participant 11 is relatively farther apart from the other observations in the boxplots graph, and participant 8 presents a flat line (pain level of 3 for all four days). However, there seems to be no reason to exclude any of these observations from the analysis.

In order to correctly perform the required analysis data needs to be restructured form wide to long format (this and all the other analysis run are included in "Lab_5 – Syntax")

Data Analysis

In a first stage two random effects models were compared. The first includes only random effects for the intercept, while the second includes also random slope effects for time. As shown in Table 5 AIC is more than 9 points lower for the second model (random slope for time), therefore we have gained prediction efficiency by including the random slope effects for time. The better fit can be also observed in "Lab_5 – Prediction_lines_1" (observed, random intercept, and random slope). Estimates and confidence intervals for both models are presented in tables 2 and 3 respectively.

In a second stage, a quadratic term for time is included into the model to test for a non-linear relation between pain and time. In order to avoid multicollinearity, a centered variable for time had to be created. AIC in Table 5 shows a significant improvement (almost 20 points); thus, this model is a better fit for our data. The prediction lines for this model are provided in "Lab_5 – Prediction_lines_2" (observed, and random slope with time squared). Estimates and confidence intervals for this model are presented in Table 4.

Results for model diagnostics are shown in "Lab_5 – Model_Diagnostics". First it is possible to see that residuals are normally distributed since both skewness and kurtosis are within -1 and 1. This is confirmed when looking at the histogram and Q-Q plot. Second, checking for linearity by plotting residuals against the predicted values and each predictor, any non-linear relationship is observed; thus, the assumption is considered met. Third, the plot of residuals vs predicted values indicates no heteroscedasticity. Fourth, the highest correlation between the predictors is -0.599 between cortisol and mindfulness, a value not to be considered problematic; therefore, multicollinearity is not an issue. Fifth, constant variance of residuals across clusters is checked by regressing the square if residuals against all (but one) ID dummies. F=1.257 and p-value=0.246, therefore the assumption is met. Sixth, both random effects (intercept and slope) look normally distributed since skewedness and kurtosis are within -1 and 1, and Q-Q plots follow the diagonal line. The correlation between random effects is 0.414 which indicates that unstructured covariance type was the right kind to use.

In summary, of all three models, the last one, including a quadratic term of time and random slope effects for time, is the one that best fits the data, confirmed by AIC values and pain vs time plots. The model also meets all the assumptions.

Discussion

Based on the models tested, it appears that pain does not change linearly during the postoperative days. Rather, it decreases rapidly during the first days and more slowly after. This could be clearly observed in Figure 1 that presents the mean of observed pain and the prediction over time. On average both the predictions of the random intercept and random slope without time squared models are almost identical, whereas the prediction of the random slope with time squared fits much closely the observed data. Consequently, a model including a time and time squared is a better fit and should be used in order to predict pain in an actual clinical context. The accuracy gained could have sizable impacts on painkillers stocks management and/or the availability of other palliative treatments.

Finally, comparing the regression results with our previous static research, cortisol level, which used to be the greatest predictor has now changed sign and become statistically not significant. Mindfulness is still significant and with a negative relation, while pain catastrophizing and gender are now statistically significant, with a positive and negative relationship respectively. Gender becomes significant only when the quadratic term of time is added, which could be explained by looking at Figure 2, where it is clear that females and males (on average) experience quite different paths of pain evolution over time (more linear for males, quadratic for females), while the starting and ending points are almost the same.

Appendix

Table 1. Descriptive Statistics

	N	Min	Max	Mean	Std. Deviation
Pain level	80	2.00	8.00	4.29	1.398
Age	80	30.00	46.00	37.60	4.425
STAI	80	32.00	47.00	39.65	4.296
Pain cat.	80	26.00	45.00	32.20	4.496
Cortisol (serum)	80	3.98	7.57	5.51	0.831
Mindfulness	80	1.00	4.18	2.73	0.782
Gender	80	0.00	1.00	0.50	0.503
Valid N (listwise)	80				

Table 2. Mixed Model with Random Intercept

	Estimate	Std. Error	95% CI lb for Est.	95% CI ub for Est.
Constant	4.92	3.09	-1.76	11.59
Age	-0.01	0.04	-0.10	0.07
STAI	-0.01	0.04	-0.09	0.07
Pain cat.	0.05	0.04	-0.03	0.13
Cortisol (serum)	0.32	0.25	-0.23	0.86
Mindfulness	-0.43	0.25	-0.96	0.10
Time	-0.77	0.08	-0.93	-0.60
Gender	-0.13	0.34	-0.86	0.60

Table 3. Mixed Model with Random Slope for Time

	Estimate	Std. Error	95% CI lb for Est.	95% CI ub for Est.
Constant	5.38	2.45	0.05	10.71
Age	0.01	0.03	-0.06	0.08
STAI	0.02	0.03	-0.05	0.08
Pain cat.	0.07	0.03	0.01	0.13
Cortisol (serum)	-0.17	0.20	-0.60	0.27
Mindfulness	-0.47	0.19	-0.89	-0.05
Time	-0.77	0.11	-0.99	-0.54
Gender	-0.53	0.26	-1.11	0.04

Table 4. Mixed Model with Time Squared and Random Slope for Time

	Estimate	Std. Error	95% CI lb for Est.	95% CI ub for Est.
Constant	3.18	2.37	-1.95	8.30
Age	0.01	0.03	-0.05	0.08
STAI	0.02	0.03	-0.04	0.08
Pain cat.	0.08	0.03	0.02	0.14
Cortisol (serum)	-0.27	0.19	-0.69	0.15
Mindfulness	-0.48	0.19	-0.89	-0.07
Gender	-0.62	0.26	-1.18	-0.06
Time centered	-0.77	0.11	-0.99	-0.54
Time cent. Square	0.31	0.06	0.20	0.43

Table 5. AIC and CAIC for All Models

Model	AIC	CAIC
Random Intercept	233.615	240.169
Random Slope for Time	224.238	237.345
Random Slope for Time (w/ Time Sq)	204.916	217.967

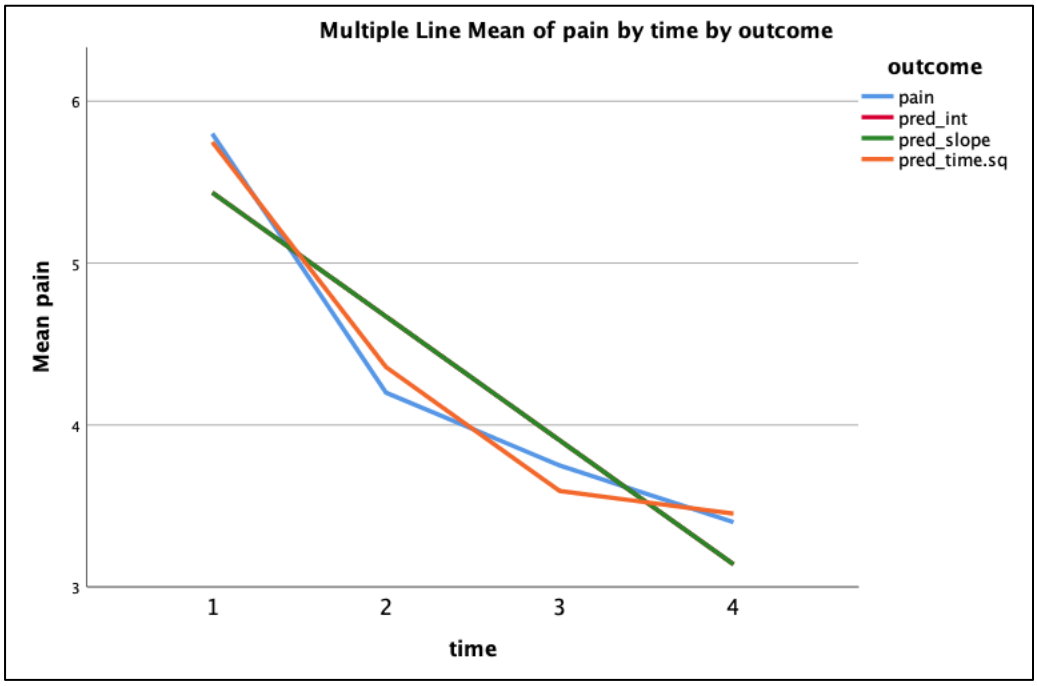

Figure 1. Pain vs Time (observed and predictions)

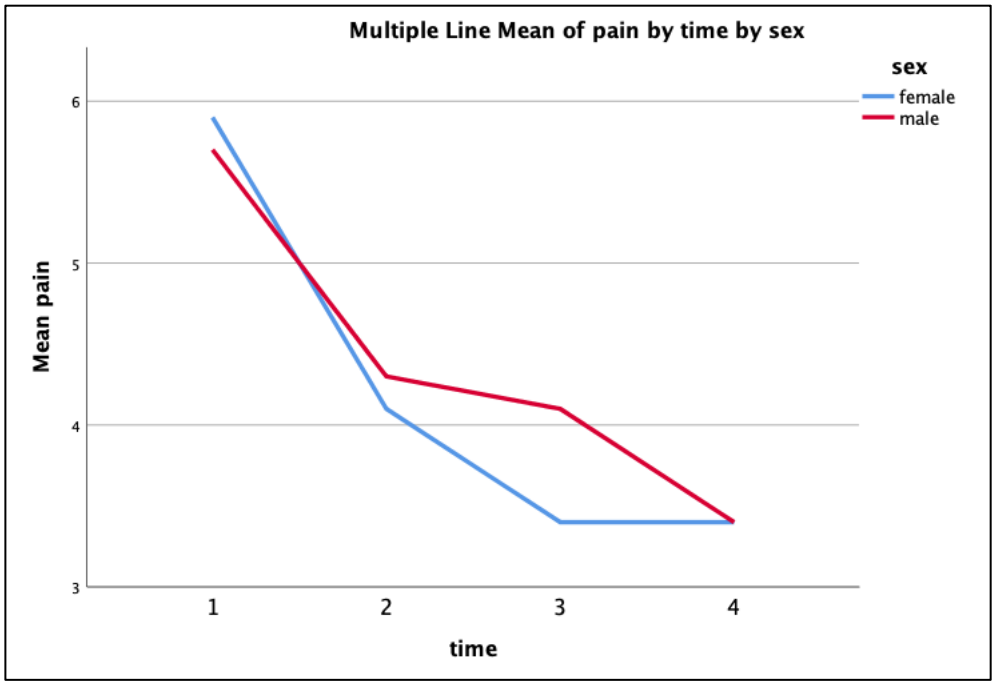

Figure 2. Pain vs Time (male and female)

Links

Syntax, outputs, and datasets:
https://github.com/avonborries/SAKA003-VT20/tree/master/Lab%205