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Assignment 1 –

Hierarchical Regression Model

Introduction

This assignment, to calculate a hierarchical regression model, was based on a sample with N=160 participants who were asked to answer question about how they perceived their pain after a removal of their wisdom teeth. Shortly before the operation, the participants were asked about sex, age, weight as well as psychological variables such anxiety measured through a STAI questionnaire, their proneness to pain catastrophizing and their mindfulness habits– a tendency to turn attention to present-moment experiences in an open non-judgemental way. The cortisol levels were taken 5 minutes before the operations through a blood and salivary sample. This means that heightened cortisol levels should be found in (probably all) patients but especially patients prone to anxiety. The assignment seeks to answer if including the psychological variables and creating a mode complex model will produce a significantly better model for predicting postoperative pain in comparison to a simpler model which is just taking sex and age into account.

Result

The first glance at the data gained through the command describe (data_sample_1) showed no missings. The command sum(is.na.data.frame(data_sample_1)) confirmed the same. Going through the min and max scores however revealed several weaknesses: 1 person was removed due to age and two others due to impossible scores (below the lowest limit) on the mindfulness questionnaire which ranges from 1 to 6. The cortisol scales were not extensively described in the assignment. However, there are no negative values, and the arithmetic mean of 5 would imply an elevated cortisol level which is to be expected before surgery. Comparing the two means of cortisol saliva (4.98) and serum(5) also indicate no problem since 4.98 and 5 are basically the same. The commands: hist(data_sample_1$cortisol_serum), hist(data_sample_1$cortisol_saliva) give a rough visual comparison of the two distributions. There was no obvious problem as the two distributions showed nice and uniform bell curves. The second step was to have a closer look at the variables and test their normality using the shapiro wilks test (shapiro.test(data_sample_2$pain)) as well as creating boxplots (data_sample_2$pain). This revealed some outliers which resulted in the removal of two more participants due to unbelievable STAI and pain catastrophizing scores. Removing any person in a dataset is a matter of delicacy. If the scores seem normal in an outlier, the rule of thumb is to let the participant stay in the data set. It is true that outliers will distort the data, however, any regression or other calculation is just a function of the sample. Therefore, it is important to keep that sample as real as possible.

The first simple model consisting of pain ~ age, sex was analyzed and checked for outliers using Cook's Distance as well as normality of the residuals, homoscedasticity and multicollinearity – the assumptions of linear multiple regression. No outliers of importance were revealed, and the normality assumption of the residuals was met. The variance homogeneity also looked okay. For model 1, the multicollinearity also didn't reveal a problem. This is done using the vif(regression_m1) command. If the variables show scores over 2,5, that variable shares considerable correlation with another variable and one can be predicted by the other through a linear combination. This was no problem for model one regression_m1, sex: vif=1.01 and age: vif=0.101. However, for model 2 (regression_m2), the complex model consisting of the regression pain ~ sex, age, gender, STAItrait, pain catastrophizing, as well as cortisol saliva and cortisol serum the picture was another. Due to multicollinearity, the variable for cortisol saliva was removed (Vif=5.56). Saliva is, as is suggested by literature, to be an inferior measurement tool. When looking at the data and comparing the two, the expected higher variance of cortisol saliva as compared with the cortisol serum was also confirmed. Thus, the sample showed the same patters as the literature would suggest. A new model, regression_m2.1 was therefore made without the predictor. Also, Cook's Distance revealed one outlier close to the >1 limit and was therefore removed. All the above-mentioned steps were repeated for the new regression model without any issues being detected. Tables with the coefficient can be found in figure one and two presented at the end of the assignment.

Based on the calculations above. it is easy to see that just as expected, model 2.1 is a significant improvement over model 1 with an F= 18.2(6,147), p<0.01, Adj R^2=0.40., AIC 476.77.

Model 2.1 is able to explain 40.3% of the variance, compared to just 14.4 % for model 1 which has an F=13.84(2,151), p<0.01, Adj. R^2=0.14 and AIC 531.11. The Akaike information criterion (AIC) scores reported above measure the *relative* model quality (AIC considers goodness of fit versus model complexity). Lower scores are better.

The regression equation model for model 2.1. is based on the following:

*pain=Ix=0(male)+b1*Ix=1(female)+b2*age+b3*Stai_trait+b4*pain_cat+b5*cortisol_serum +b6*mindfulness*

When adding numbers we get:

*Y = 4.00 + 0.32*X1 +(-0.08)*X2 +(0.06)*X3+0.06*X4+0.62*X5 +(-0.25)*X6*

Discussion.

The standardized coefficients β gives us as clue as to which variables are relevant predictors of postoperative pain relative to each other, as is also indicated by their *p*-values. By looking at theses it can be concluded that a lot of that additional explanatory power comes from including cortisol serum. STAItrait however shows no added value, and mindfulness as well as pain_cat show only small contributions to the overall improvement. Also, it can be concluded that age is significantly relevant, just as prior research has indicated.

Assignment 2 –

Adding Weight as Predictor

and

Backward Regression Comparison

Introduction

The new model, which was based upon the models in assignment one, added the predictor of weight but still excluded the predictor of cortisol saliva. Upon this model, a backward regression was calculated. This backward model was then compared to model two from the first assignment, here known as the theoretical model. As a final step, the trained theoretical model and the backward model predictive power was tested and compared with each other.

Result

The dataset which was used in the first assignment was also a part of this assignment. However, weight was added as a predictor and the regression called regression_m3 was subsequently tested with no oddities. Then the backward model was created called backward_regression_m. Subsequently, all the assumptions for the linear regression, i.e. normal distribution of residuals, linearity, homoscedasticity, and non-multicollinearity were retested for model three and the backward model and were all met.

The model diagnostics were then performed in the same way as in assignment 1 on the new dataset. This resulted in the removal of 6 participants in total.

Based on the calculations above, it becomes plain that all three final models perform very similarly.

The backward regression model has F= 26.79(4,149), p<0.01, Adj R^2=0.40., AIC 476.82. This model is thus able explain 39.53%. Regression model 3 in comparison had F=15.49(7,146), p<0.01, Adj. R^2=0.40 and can explain 39.87 % of the total variance. The AIC was higher: 478.82. It is then hardly surprising that the ANOVA comparison between the two also show no significant difference F=1.7 (2, 147) , *p*=.179).

Both models have very similar AIC scores and a difference of >2 can be interpreted as meaningful. However, this margin is just barely reached with a 2.02 difference in AIC score. It is therefore difficult to decide if it really is meaningful or not. As we can see on the measurements, the difference is not significant. If in doubt which to choose, one should always go with the simplest model (Steyer,2002), i.e. the backward regression model.

The theoretical model which has F=18.08(6,147), p<0.01, Adj. R^2=0.40, is able to explain 40.12% of the variance and has an AIC of 476,80.

Based on the calculations, it becomes plain that the two models perform very similarly.

The trained backward regression model has an F= 14(4,149), p<0.01, Adj R^2=.26, AIC 507.97. This model is thus able explain 25,81% compared to the theoretical model which has a F=18.08(6,147), p<0.01, Adj. R^2=0.40 and is able to explain 40.12% of the variance.

The equation is as follows: *Y = 3.69+ (-.07)*age +.06*pain_cat +.61*cortisol_serum+(-.16)**mindfulness

All the predictors for the different models as well as their coefficients can be found in the R-script as well as in Figures two to four.

Discussion

Deciding which model is better is a real challenge. The ANOVA's show no significant difference in predictive power compared to each other. However, the rule of thumb is to always go with the simpler model and as judged by most comparisons and AIC scores, this is the backward model. However, as nothing ever is easy, it is important to state that the backward model uses a method which automatically selects the predictors and this causes a serious risk of overfitting.

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Assignment 3 –

Repeated measures with linear

and

quadratic mixed effect models

Introduction

Following the stud in assignment one and two, this final assignment looked at the aforementioned predictors on pain and the correlations between them during several days. Here, only twenty adults were contacted 5 hours post-surgery and then again during the following three consecutive days. Similarly, to assignments one and two, these participants were asked to rate their pain, but this time on a scale of one to four, alongside the established assessment procedure described in assignment one.

Results[1]

This new data was analyzed as well as prepared in an almost identical fashion as in assignment one and two. No missings were found, nor were there any other eyebrow-raising number found.

The mixed effects models which use the predictors mentioned in assignment two, (age, sex, weight, STAI, pain catastrophizing, mindfulness and cortisol serum) in order to predict pain can be seen in Figure…

The conditional AIC method (cAIC) gives the same value for both the intercept and random. This tells us either that something strange is going on, or both models perform equally well. The subsequent ANOVA however, found the latter model to be significantly different ($p < .001$). This can be confirmed, albeit a bit difficultly, if one looks at the visual comparison of figures nine and ten. As a last step, "days since surgery" was added. This was done as a quadratic term, resulting in a quadratic model with random intercept. The cAIC resulted in a lower value of 198.59 as compared to the earlier mixed models. The model can be seen in figure 11.

Discussion

The plots indicates the quadratic model with random intercept to have the comparatively best fit, in this, the cAIC scores also agree. The fit however, might only be an effect of the increased complexity, compared to the other models.

[1] This part, assignment 3 was done in a hasty last day and therefore contains some errors. After debating whether it should be included at all, I decided in the last minute to let it at least be a small part.

Figures: many more can be found in the R-Script

Figure 1: Regression model 2.1

```
Residuals:
     Min       1Q   Median       3Q      Max
-3.07412 -0.80697  0.02272  0.77872  2.73347

Coefficients:
               Estimate Std. Error t value Pr(>|t|)
(Intercept)     4.19787    1.39805   3.003  0.00315 **
sex_I          -0.31301    0.18117  -1.728  0.08615 .
age            -0.06942    0.01927  -3.603  0.00043 ***
STAI_trait     -0.01647    0.02673  -0.616  0.53880
pain_cat        0.05892    0.02533   2.326  0.02138 *
cortisol_serum  0.64959    0.12248   5.304 4.09e-07 ***
mindfulness    -0.24209    0.11111  -2.179  0.03094 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 2: Regression model 3

```
Residuals:
     Min       1Q   Median       3Q      Max
-3.13905 -0.80808  0.00825  0.77680  2.70651

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     3.829386   1.522682   2.515  0.01299 *
sex_I          -0.311103   0.181581  -1.713  0.08878 .
age            -0.066283   0.019963  -3.320  0.00114 **
STAI_trait     -0.022470   0.028496  -0.789  0.43166
pain_cat        0.059760   0.025419   2.351  0.02006 *
cortisol_serum  0.663905   0.124905   5.315 3.91e-07 ***
mindfulness    -0.247520   0.111691  -2.216  0.02823 *
weight          0.005713   0.009248   0.618  0.53767
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 3- Trained regression model

```
Residuals:
    Min      1Q  Median      3Q     Max
-3.2022 -0.8325  0.0601  0.6792  2.6259

Coefficients:
               Estimate Std. Error t value Pr(>|t|)
(Intercept)     3.69462    1.37528   2.686  0.00804 **
age            -0.07140    0.01773  -4.027 8.96e-05 ***
pain_cat        0.05641    0.02326   2.425  0.01652 *
cortisol_serum  0.60522    0.10942   5.531 1.39e-07 ***
mindfulness    -0.22448    0.11123  -2.018  0.04536 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 4 Backward model

```
Residuals:
    Min      1Q  Median      3Q     Max 
-3.2022 -0.8325  0.0601  0.6792  2.6259 

Coefficients:
               Estimate Std. Error t value Pr(>|t|)    
(Intercept)     3.69462    1.37528   2.686  0.00804 ** 
age            -0.07140    0.01773  -4.027 8.96e-05 ***
pain_cat        0.05641    0.02326   2.425  0.01652 *  
cortisol_serum  0.60522    0.10942   5.531 1.39e-07 ***
mindfulness    -0.22448    0.11123  -2.018  0.04536 *  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.113 on 149 degrees of freedom
Multiple R-squared:  0.4111,	Adjusted R-squared:  0.3953 
F-statistic:    26 on 4 and 149 DF,  p-value: 2.339e-16
```

Figure 4

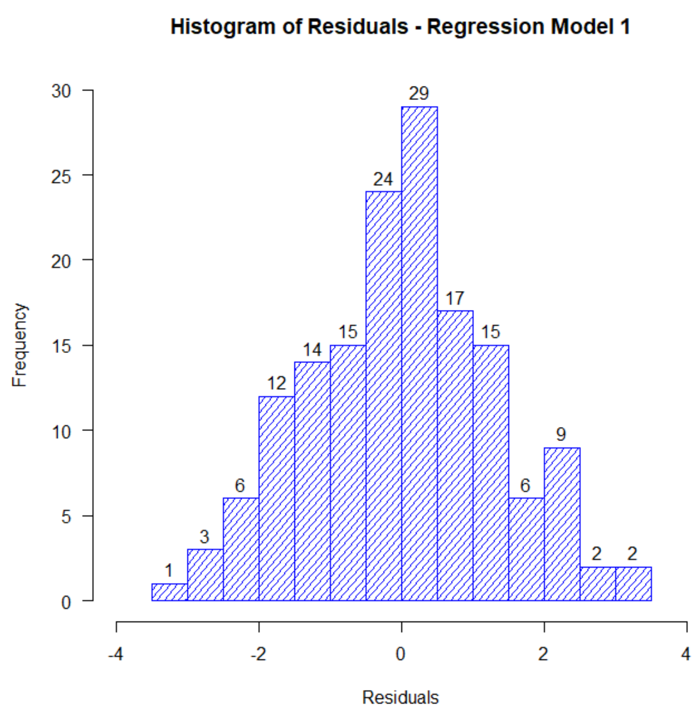
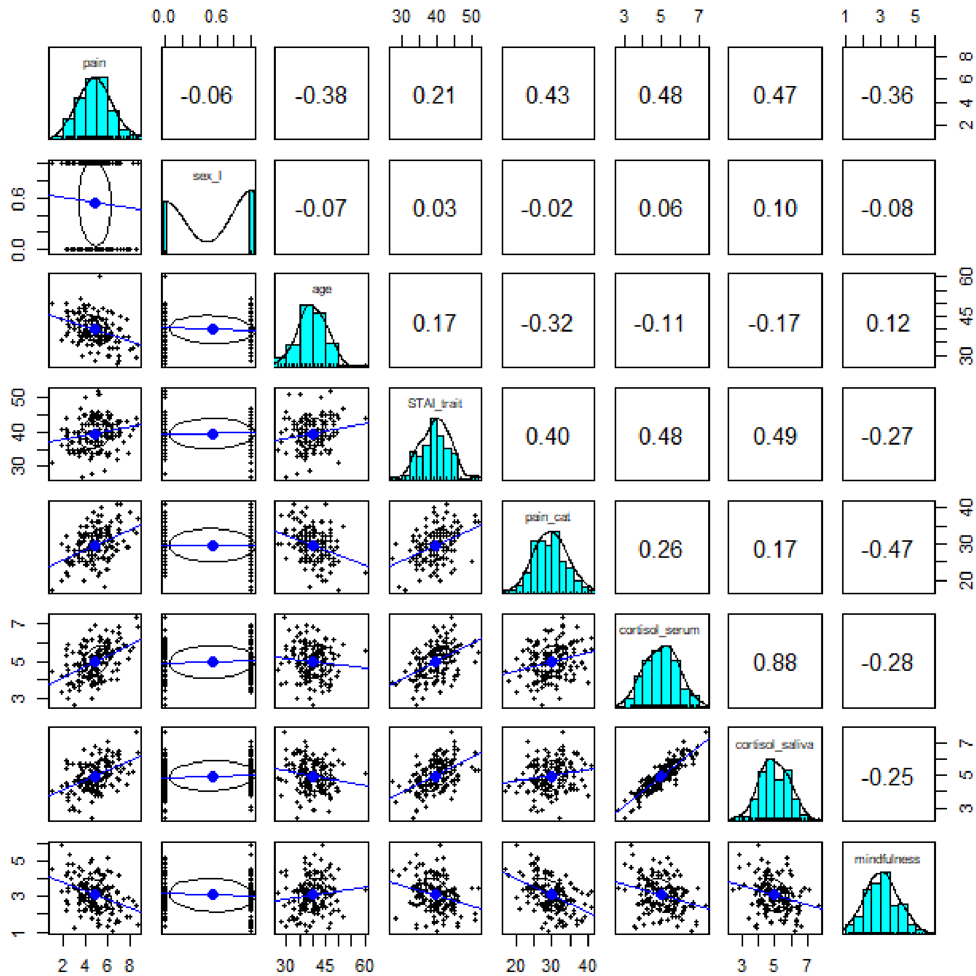


Figure 6:


pain
sex_I
age
STAI_trait
pain_cat
cortisol_serum
cortisol_saliva
mindfulness
-0.06
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-0.08
0.17
-0.32
-0.11
-0.17
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0.26
0.17
-0.47
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-0.28
-0.25

Figure 7:

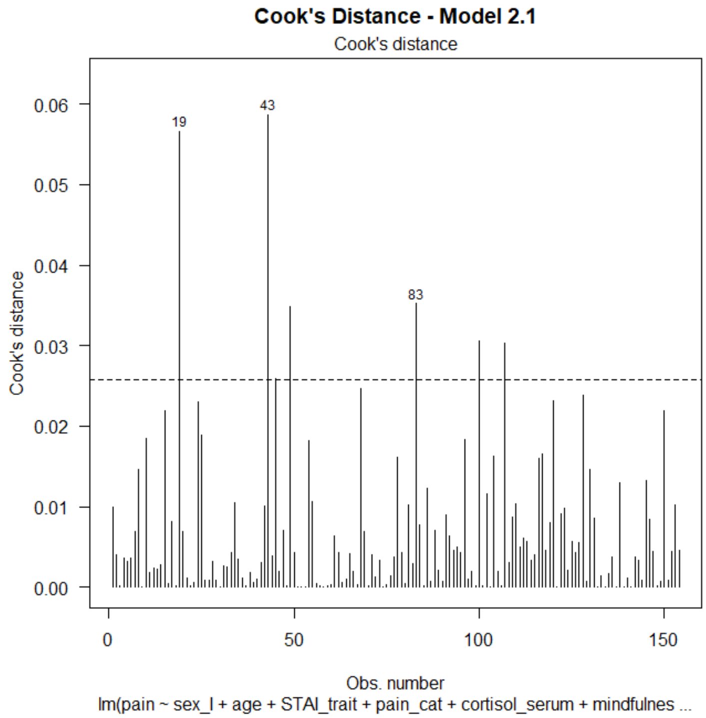


Figure 8

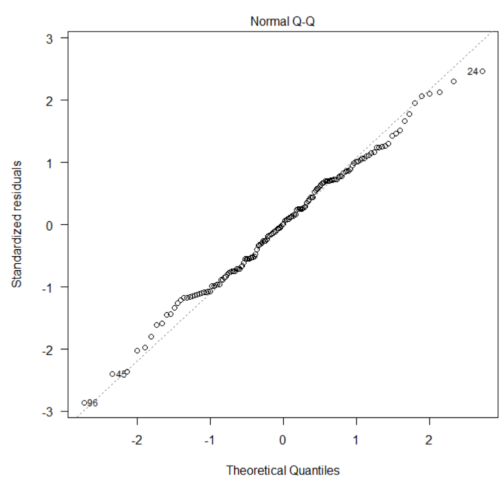


Figure 9

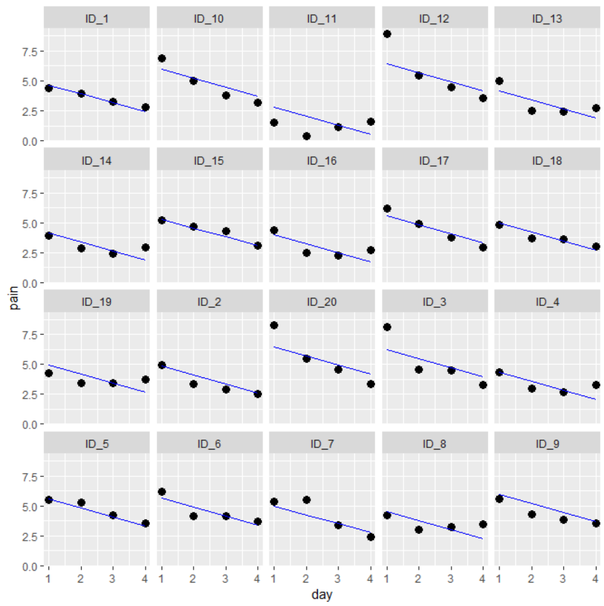


Figure 10

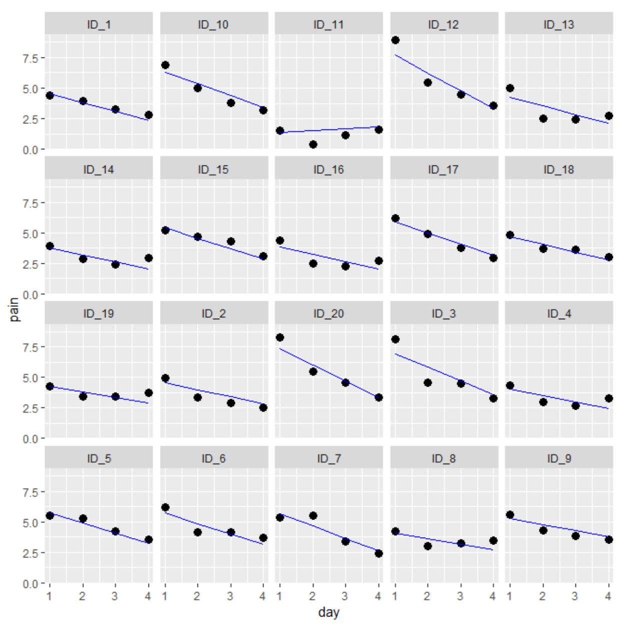
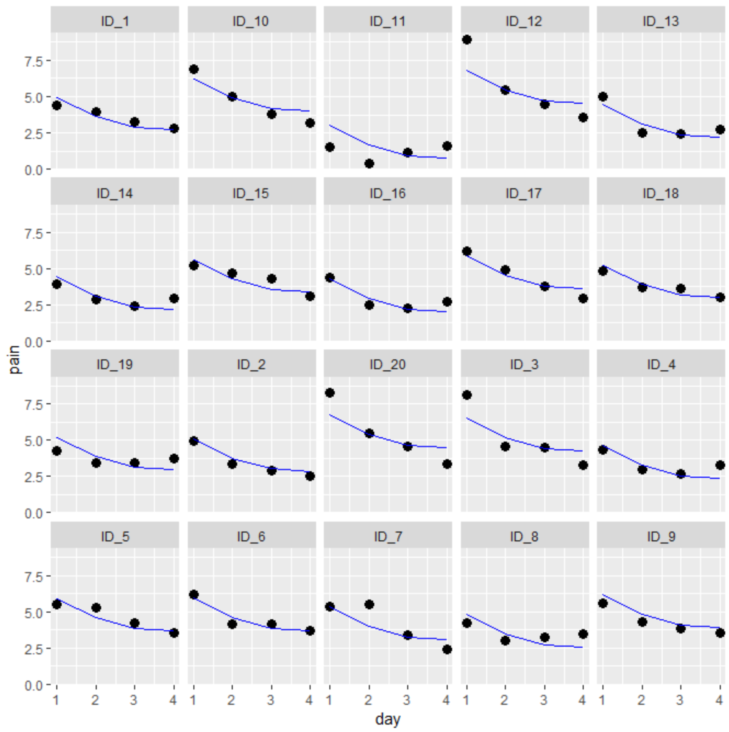


Figure 11: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