

Impacte del COVID-19 per estat de vacunació

Linear and Generalized Linear Models

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We are analyzing a data set that contains information about the impact of COVID-19 by vaccination status in 2021 in Catalunya. The data comes from various information systems of the Department of Health and the Catalan Health Service, as detailed here. More specifically, the data shows the impact of COVID-19 (new cases, hospitalizations, critical hospitalizations and deaths) in the entirety of Catalunya, from January 1st 2021 until now, for the date of reference of each record, by gender, by age group, according to the vaccination status of the people. Keep in mind that a person is counted as many times as the number of events that has happened to the individual in question. This means that each person may be counted up to four times in the data set as a whole. More information about the data set can be found here. Note that the data we are using was downloaded December 17th at 12:00.

The data set contains 6 columns. They are explained shortly below.

Variable	SEXE	EDAT	DATA	ESDEVENIMENT	PAUTA	RECOMPTE
Explanation	Sex	Age Group	Date	Event (Severity of illness)	Vaccination status	Count
Factor Levels	Homme, Dona	0-9, 10-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79, 80-,Not classified		Cas, Hospitalització, Critics, Defunció	No iniciada, Parcial, Completa	

Objective

The objective of the analysis is to answer the following question: *Do differences in the severity of COVID-19 infection exist between people that are unvaccinated, people that only have received one dose and people that are fully vaccinated?* More precisely, does the amount of people with a *critical* infection depend on their respective vaccination statuses?

The analysis will be performed separately for men and women. Moreover, we will only consider people that are older than 30 and only data from May 1st to December 12th. Additionally, we will only analyze differences in people that are reported with a critical event, disregarding people with new cases, people that are hospitalized (not critical) and people that have died.

Data Preparation

First we have to remove all people younger than 30 years old and cases before May 1st. The data is prepared according to the description above.

```
data <- read.csv("Impacte_del_COVID-19.csv") # Data updated 17.12.21.

clean <- function(data){
  data$DATA <- as.Date(data$DATA, format = "%d/%m/%Y")
}
```

```

#data$DATA <- parse_date_time(data$DATA, orders = "%d/%m/%Y")
data$EDAT <- as.factor(data$EDAT)
covid.data <- data %>% filter(DATA >= "2021-05-01" & DATA < "2021-12-13") %>%
  filter(EDAT %in% c("30 a 39", "40 a 49", "50 a 59", "60 a 69", "70 a 79", "80 o més"))
  # People with EDAT "No classificat" are not added
  # (these are the same people as "No classificat" in SEXE).

covid.data$PAUTA <- factor(covid.data$PAUTA)
covid.data$SEXE <- factor(covid.data$SEXE)

# Create week and month variables.
covid.data$Week <- as.factor(strftime(covid.data$DATA, format = "%W"))
covid.data$Month <- as.factor(strftime(covid.data$DATA, format = "%m"))

return(covid.data)
}
covid.data <- clean(data) %>% filter(ESDEVENIMENT == "Crítics")

```

Note also that there are 637 registries in the data set that are not classified into groups in SEXE and EDAT. These rows are disregarded in the analysis.

Exploratory Data Analysis

```

covid.data.women <- covid.data %>% filter(SEXE == "Dona")
covid.data.men <- covid.data %>% filter(SEXE == "Home")

```

The data set is split into men and women. There are 1927 critical cases for men and 976 critical cases for women in the data.

Cases of Critical Infection by Age and by Gender

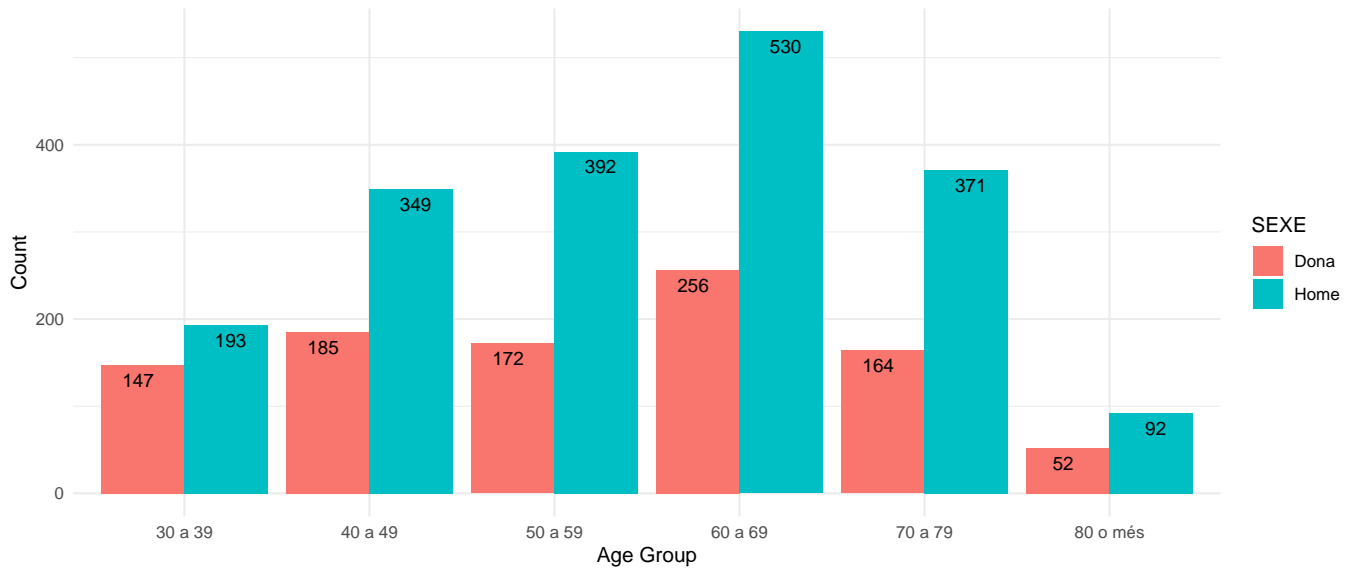
```

count.in.age.group <- function(data){
  data %>% group_by(SEXE, EDAT) %>% summarise(Count = sum(RECOMPTE), .groups = "keep")
}

all <- count.in.age.group(covid.data)
ggplot(all, aes(x = EDAT, y = Count)) +
  labs(x = "Age Group", y = "Count") +
  geom_col(aes(fill = SEXE), position = "dodge") +
  geom_text(aes(label=Count, group= SEXE), vjust = 1.6, color="black",
    size=3.5, position = position_dodge(width = 1)) +
  ggtitle("Cases of Critical COVID-19 Infection Grouped by Age") +
  theme_minimal()

```

Cases of Critical COVID-19 Infection Grouped by Age

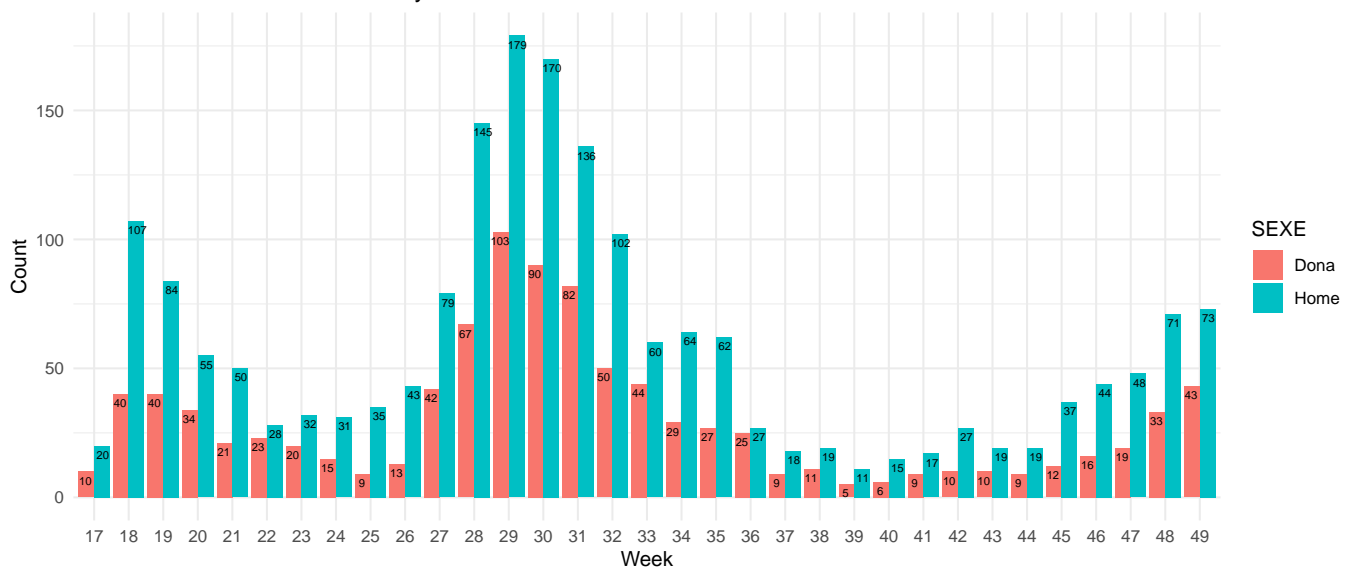


Evolution of Critical Infections in Time by Gender

```
count.each.week <- function(data){
  data %>% group_by(SEXE, Week) %>% summarise(Count = sum(RECOMPTE), .groups = "keep")
}

week.data <- count.each.week(covid.data)
ggplot(data = week.data, aes(x = as.factor(Week), y = Count)) +
  labs(x = "Week", y = "Count") +
  geom_col(aes(fill = SEXE), position = "dodge") +
  geom_text(aes(label=Count, group= SEXE), vjust = 1.6, color="black",
    size=2, position = position_dodge(width = 1)) +
  ggtitle("Evolution of Critical Infections by Week") +
  theme_minimal()
```

Evolution of Critical Infections by Week

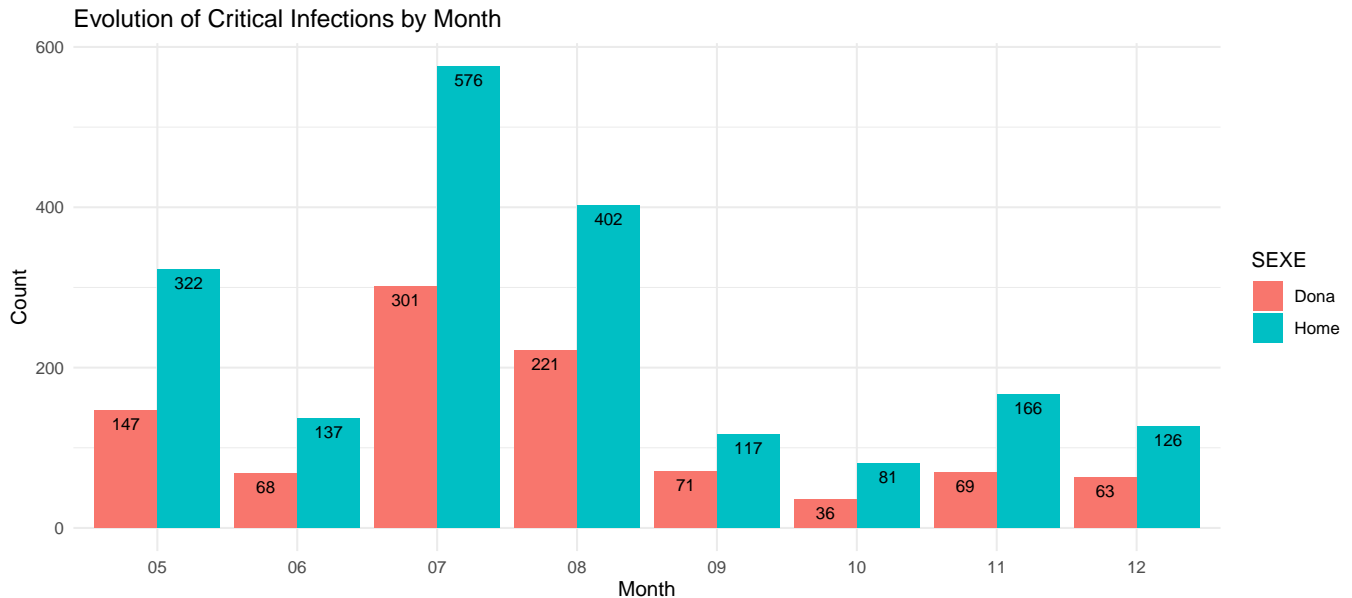


```
count.each.month <- function(data){
  data %>% group_by(SEXE, Month) %>% summarise(Count = sum(RECOMPTE), .groups = "keep")
}
```

```

month.data <- count.each.month(covid.data)
ggplot(data = month.data, aes(x = as.factor(Month), y = Count)) +
  labs(x = "Month", y = "Count") +
  geom_col(aes(fill = SEXE), position = "dodge") +
  geom_text(aes(label=Count, group= SEXE), vjust = 1.6, color="black",
            size=3, position = position_dodge(width = 0.9)) +
  ggtitle("Evolution of Critical Infections by Month") +
  theme_minimal()

```



Cases of Critical Infection by Vaccination Status and Age for each Gender

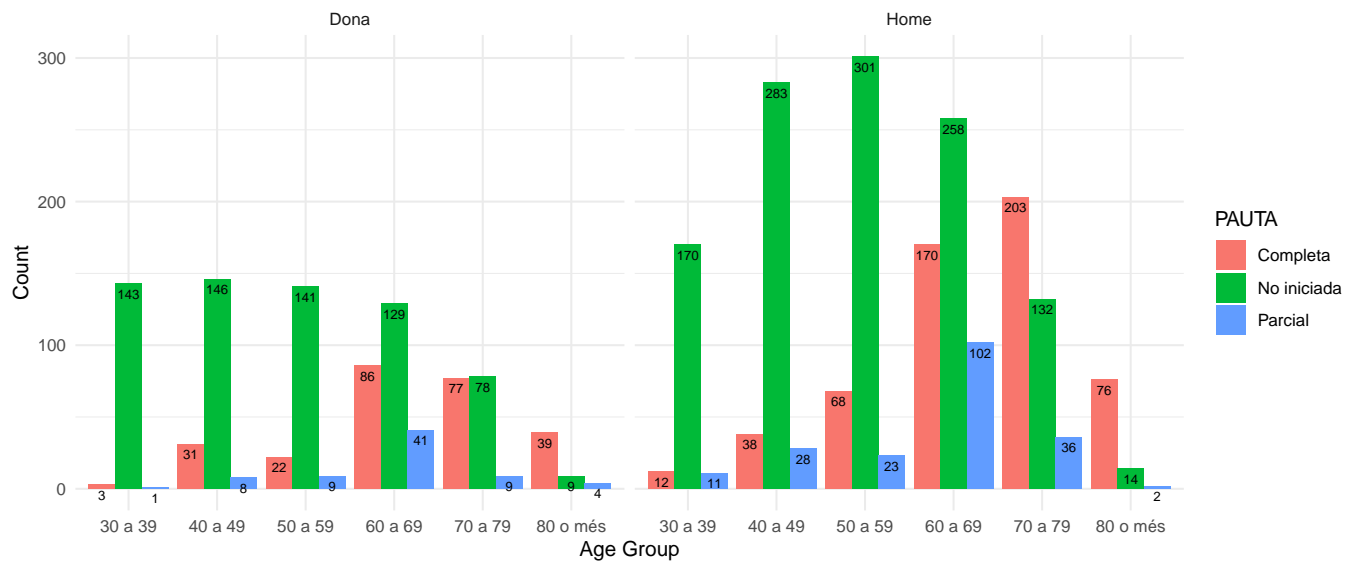
```

group.by.vacc.age.gender <- function(data){
  data %>% group_by(SEXE, EDAT, PAUTA) %>% summarise(Count = sum(RECOMPTE), .groups = "keep")
}
d5 <- group.by.vacc.age.gender(covid.data)

ggplot(d5, aes(x = EDAT, y = Count)) +
  labs(x = "Age Group", y = "Count") +
  geom_col(aes(fill = PAUTA), position = "dodge") +
  geom_text(aes(label=Count, group= PAUTA), vjust = 1.6, color="black",
            size=2.5, position = position_dodge(width = 0.9)) +
  ggtitle("Critical Infections per Age Group based on Vaccination Status") +
  facet_wrap(~ SEXE) +
  theme_minimal()

```

Critical Infections per Age Group based on Vaccination Status



```
group.by.vacc.age <- function(data){
  data %>% group_by(EDAT, PAUTA) %>% summarise(Count = sum(RECOMPTE), .groups = "keep")
}
d4 <- group.by.vacc.age(covid.data.women)
knitr::kable(d4, caption = "Women with Critical Infection as
Function of Vaccination Status and Age")
```

Table 2: Women with Critical Infection as Function of Vaccination Status and Age

EDAT	PAUTA	Count
30 a 39	Completa	3
30 a 39	No iniciada	143
30 a 39	Parcial	1
40 a 49	Completa	31
40 a 49	No iniciada	146
40 a 49	Parcial	8
50 a 59	Completa	22
50 a 59	No iniciada	141
50 a 59	Parcial	9
60 a 69	Completa	86
60 a 69	No iniciada	129
60 a 69	Parcial	41
70 a 79	Completa	77
70 a 79	No iniciada	78
70 a 79	Parcial	9
80 o més	Completa	39
80 o més	No iniciada	9
80 o més	Parcial	4

```
d3 <- group.by.vacc.age(covid.data.men)
knitr::kable(d3, caption = "Men with Critical Infection as
Function of Vaccination Status and Age")
```

Table 3: Men with Critical Infection as Function of Vaccination Status and Age

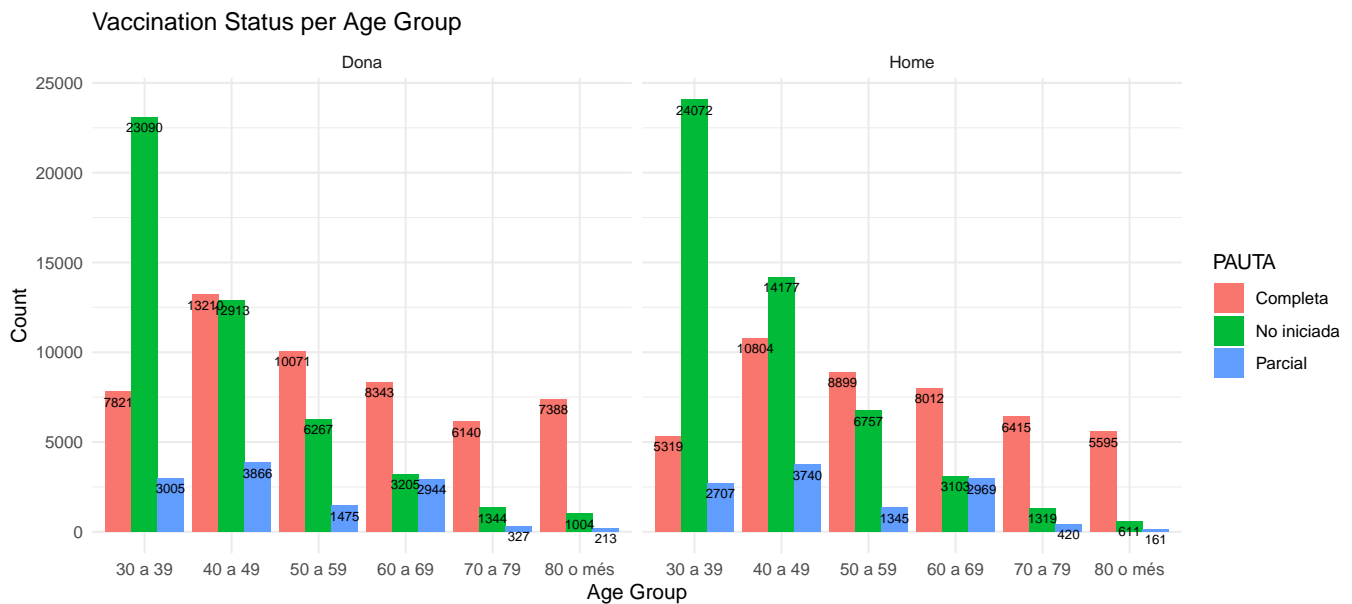
EDAT	PAUTA	Count
30 a 39	Completa	12
30 a 39	No iniciada	170
30 a 39	Parcial	11
40 a 49	Completa	38
40 a 49	No iniciada	283
40 a 49	Parcial	28
50 a 59	Completa	68
50 a 59	No iniciada	301
50 a 59	Parcial	23
60 a 69	Completa	170
60 a 69	No iniciada	258
60 a 69	Parcial	102
70 a 79	Completa	203
70 a 79	No iniciada	132
70 a 79	Parcial	36
80 o més	Completa	76
80 o més	No iniciada	14
80 o més	Parcial	2

Vaccination Status per Age Group

When considering the critical cases by vaccination status and age for each gender, it is good to keep the vaccination status per age group in the population in mind. This data is shown below, where all four different classifications of severity of infection are kept in the data set.

```
count.vacc.status.in.age.group <- function(data){
  data %>% group_by(SEXE, EDAT, PAUTA) %>% summarise(Count = sum(RECOMPTE), .groups = "keep")
}

vacc.status.per.age <- count.vacc.status.in.age.group(clean(data))
ggplot(vacc.status.per.age, aes(x = EDAT, y = Count)) +
  labs(x = "Age Group", y = "Count") +
  geom_col(aes(fill = PAUTA), position = "dodge") +
  geom_text(aes(label=Count, group= PAUTA), vjust = 1.6, color="black",
            size=2.5, position = position_dodge(width = 0.9)) +
  ggtitle("Vaccination Status per Age Group") +
  facet_wrap(~ SEXE) +
  theme_minimal()
```



Model Fit

Linear Model

We wish to examine how the vaccination status affects the number of critical patients in this period. Since we observe that the number of critical patients vary very much from month to month, we choose to group aggregate the number of patients each month, and include it as a categorical covariate in our model.

```
covid.data.aggr <- aggregate(RECOMPTE ~ EDAT + SEXE + PAUTA + Month,
                             covid.data, FUN = sum)
covid.data.aggr$Month <- as.factor(covid.data.aggr$Month)
head(covid.data.aggr)
```

```
##      EDAT SEXE   PAUTA Month RECOMPTE
## 1  30 a 39 Dona Completa    05        1
## 2  50 a 59 Dona Completa    05        1
## 3  60 a 69 Dona Completa    05        1
## 4  70 a 79 Dona Completa    05        1
## 5  80 o més Dona Completa    05        3
## 6  30 a 39 Home Completa    05        1
```

```
dim(covid.data.aggr)
```

```
## [1] 221  5
```

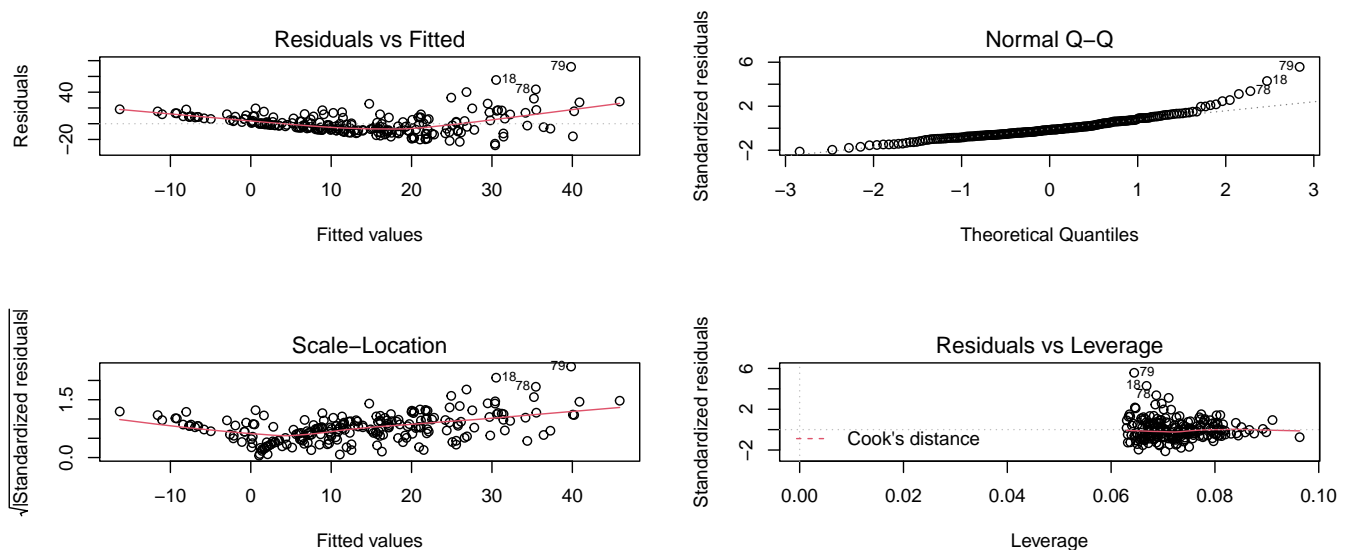
First we try a simple linear model with all covariates included. As the adjusted R-squared is low, and the residuals does not fit the normal assumption, we reject this model.

```
model3 <- lm(RECOMPTE ~ EDAT + SEXE + PAUTA + Month, data = covid.data.aggr)
summary(model3)
```

```
##
## Call:
## lm(formula = RECOMPTE ~ EDAT + SEXE + PAUTA + Month, data = covid.data.aggr)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -27.405  -7.925  -1.933   6.400  72.158
##
```

```
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)      6.996      3.835   1.824 0.069541 .
## EDAT40 a 49       4.384      3.410   1.286 0.200031
## EDAT50 a 59       5.431      3.379   1.607 0.109507
## EDAT60 a 69      10.434      3.322   3.140 0.001937 **
## EDAT70 a 79       4.608      3.332   1.383 0.168151
## EDAT80 o més     -5.053      3.529  -1.432 0.153718
## SEXEHome         8.624      1.811   4.762 3.63e-06 ***
## PAUTANo iniciada  9.465      2.044   4.631 6.45e-06 ***
## PAUTAParcial     -8.874      2.535  -3.501 0.000568 ***
## Month06          -9.372      3.463  -2.706 0.007376 **
## Month07          10.373      3.358   3.089 0.002288 **
## Month08           4.706      3.534   1.331 0.184526
## Month09          -11.145      3.567  -3.124 0.002042 **
## Month10          -13.528      3.656  -3.700 0.000277 ***
## Month11          -9.971      3.714  -2.685 0.007850 **
## Month12          -11.317      3.768  -3.003 0.003003 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 13.39 on 205 degrees of freedom
## Multiple R-squared:  0.4554, Adjusted R-squared:  0.4155
## F-statistic: 11.43 on 15 and 205 DF, p-value: < 2.2e-16

par(mfrow = c(2,2))
plot(model13, ask = F)
```



Since we have aggregated the number of critical patients by month, we can interpret this data collection as a counting process which starts each months. This is a poisson process, which we can fit as a general linear model from the poisson family. The model is fitted without interaction, and includes all covariates. The residuals still look bad, and the model has a dispersion parameter above seven.

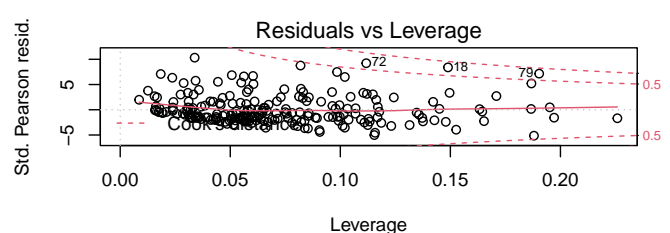
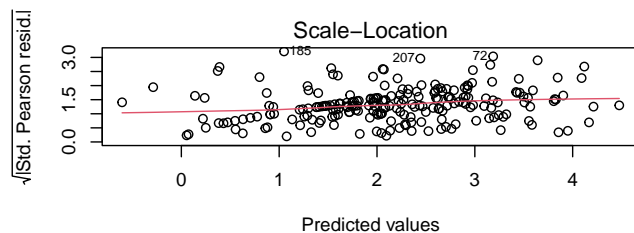
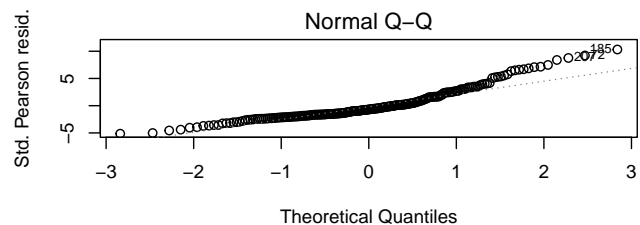
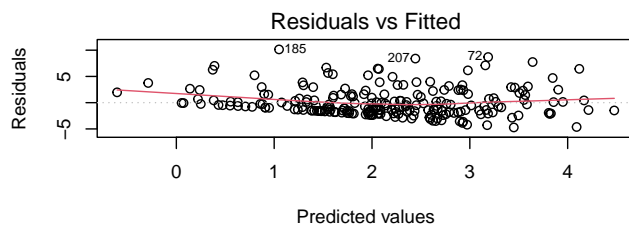
```
model15 <- glm(RECOMPTE ~ EDAT + SEXE + PAUTA + Month, data = covid.data.aggr,
               family = poisson(link = "log"))
summary(model15)
```

```
##
## Call:
## glm(formula = RECOMPTE ~ EDAT + SEXE + PAUTA + Month, family = poisson(link = "log"),
```



```
## data = covid.data.aggr)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -5.8785  -1.9662  -0.7042   1.2364   7.1265
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)    1.99219    0.08075  24.670 < 2e-16 ***
## EDAT40 a 49     0.27202    0.06958   3.909 9.25e-05 ***
## EDAT50 a 59     0.32011    0.06884   4.650 3.32e-06 ***
## EDAT60 a 69     0.62929    0.06523   9.647 < 2e-16 ***
## EDAT70 a 79     0.24453    0.06954   3.516 0.000438 ***
## EDAT80 o més   -0.91594    0.09961  -9.195 < 2e-16 ***
## SEXEHome       0.65979    0.03933  16.774 < 2e-16 ***
## PAUTANo iniciada 0.66973    0.04215  15.889 < 2e-16 ***
## PAUTAParcial    -0.82644    0.07029 -11.757 < 2e-16 ***
## Month06        -0.85545    0.08379 -10.209 < 2e-16 ***
## Month07         0.52527    0.05729   9.169 < 2e-16 ***
## Month08         0.26199    0.06126   4.276 1.90e-05 ***
## Month09        -0.93686    0.08640 -10.843 < 2e-16 ***
## Month10        -1.36409    0.10349 -13.181 < 2e-16 ***
## Month11        -0.68628    0.08013  -8.565 < 2e-16 ***
## Month12        -0.83792    0.08650  -9.686 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
##      Null deviance: 3746.1  on 220  degrees of freedom
## Residual deviance: 1400.5  on 205  degrees of freedom
## AIC: 2248.7
##
## Number of Fisher Scoring iterations: 5
```

```
par(mfrow = c(2,2))
plot(model5, ask = F)
```



```
# Checking for overdispersion
PS <- sum(residuals(model5, type="pearson")^2)
```

```
phi <- PS / model5$df.res
phi
```

```
## [1] 7.684779
```

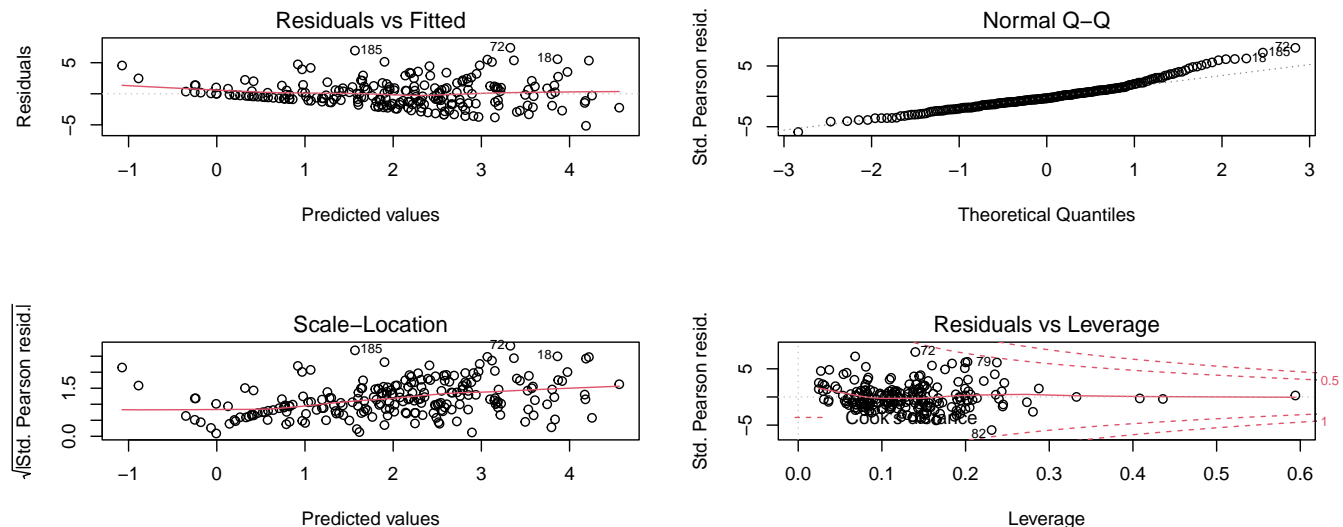
Next we include an interaction between the vaccination status and month. This has sense because the vaccination status should increase as a time goes, and more people is vaccinated.

```
model6 <- glm(RECOMPTE ~ EDAT + SEXE + PAUTA + Month + PAUTA:Month, data = covid.data.aggr,
              family = poisson(link = "log"))
summary(model6)
```

```
##
## Call:
## glm(formula = RECOMPTE ~ EDAT + SEXE + PAUTA + Month + PAUTA:Month,
##      family = poisson(link = "log"), data = covid.data.aggr)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -5.9298  -1.4289  -0.2761   0.9461   6.2597
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)    -0.06542    0.27267  -0.240  0.810389
## EDAT40 a 49      0.24289    0.06986   3.477  0.000508 ***
## EDAT50 a 59      0.27829    0.06928   4.017  5.89e-05 ***
## EDAT60 a 69      0.58723    0.06559   8.952  < 2e-16 ***
## EDAT70 a 79      0.21008    0.07001   3.001  0.002693 **
## EDAT80 o més    -1.00809    0.10001  -10.080  < 2e-16 ***
## SEXEHome        0.64748    0.03937  16.444  < 2e-16 ***
## PAUTANo iniciada 3.00268    0.27219  11.031  < 2e-16 ***
## PAUTAParcial     1.61943    0.29278   5.531  3.18e-08 ***
## Month06          0.18656    0.35242   0.529  0.596550
## Month07          2.32816    0.27729   8.396  < 2e-16 ***
## Month08          2.57699    0.27615   9.332  < 2e-16 ***
## Month09          1.49058    0.29135   5.116  3.12e-07 ***
## Month10          1.39339    0.29221   4.769  1.86e-06 ***
## Month11          1.99276    0.28113   7.088  1.36e-12 ***
## Month12          1.81194    0.28377   6.385  1.71e-10 ***
## PAUTANo iniciada:Month06 -1.16329    0.36587  -3.180  0.001475 **
## PAUTAParcial:Month06  -0.73956    0.40127  -1.843  0.065322 .
## PAUTANo iniciada:Month07 -1.93668    0.28505  -6.794  1.09e-11 ***
## PAUTAParcial:Month07  -2.04851    0.31517  -6.500  8.04e-11 ***
## PAUTANo iniciada:Month08 -2.56920    0.28539  -9.003  < 2e-16 ***
## PAUTAParcial:Month08  -3.58618    0.37203  -9.639  < 2e-16 ***
## PAUTANo iniciada:Month09 -2.76918    0.31148  -8.890  < 2e-16 ***
## PAUTAParcial:Month09  -3.50456    0.47335  -7.404  1.32e-13 ***
## PAUTANo iniciada:Month10 -3.57151    0.33440 -10.680  < 2e-16 ***
## PAUTAParcial:Month10  -3.54097    0.65818  -5.380  7.45e-08 ***
## PAUTANo iniciada:Month11 -3.33020    0.30290 -10.995  < 2e-16 ***
## PAUTAParcial:Month11  -4.20512    0.65332  -6.437  1.22e-10 ***
## PAUTANo iniciada:Month12 -3.32022    0.30999 -10.711  < 2e-16 ***
## PAUTAParcial:Month12  -4.60066    1.04655  -4.396  1.10e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
```

```
##
## Null deviance: 3746.1 on 220 degrees of freedom
## Residual deviance: 954.5 on 191 degrees of freedom
## AIC: 1830.6
##
## Number of Fisher Scoring iterations: 5
```

```
par(mfrow = c(2,2))
plot(model6, ask = F)
```



```
# Checking for overdispersion
PS <- sum(residuals(model6, type="pearson")^2)
phi <- PS / model6$df.res
phi
```

```
## [1] 5.075594
```

The model improves, but the residuals still shows clear patterns, and the model is overdispersed. Now we include an interaction between vaccination status and age group. This has sense since the older age group likely was vaccinated earlier than the younger age group.

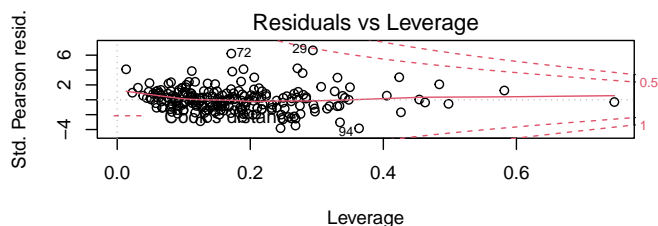
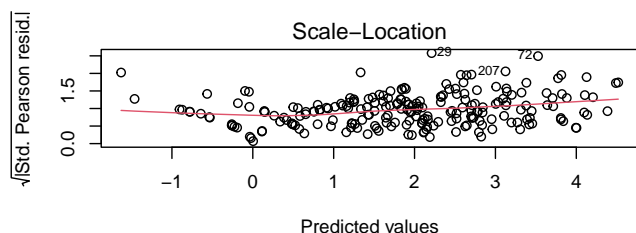
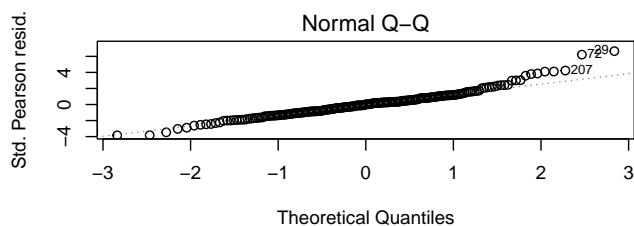
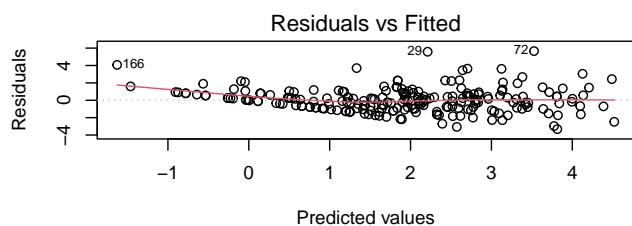
```
model7 <- glm(RECOMPTE ~ EDAT + SEXE + PAUTA + Month + PAUTA:Month + EDAT:PAUTA, data = covid.data.aggr,
              family = poisson(link = "log"))
summary(model7)
```

```
##
## Call:
## glm(formula = RECOMPTE ~ EDAT + SEXE + PAUTA + Month + PAUTA:Month +
##      EDAT:PAUTA, family = poisson(link = "log"), data = covid.data.aggr)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -3.8305  -0.9572   0.0000   0.6922   4.9875
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)   -1.461571   0.366753  -3.985 6.74e-05 ***
## EDAT40 a 49     0.925016   0.286089   3.233 0.001224 **
## EDAT50 a 59     1.201044   0.280038   4.289 1.80e-05 ***
## EDAT60 a 69     2.214167   0.266924   8.295 < 2e-16 ***
## EDAT70 a 79     2.287555   0.266153   8.595 < 2e-16 ***
## EDAT80 o més    1.413922   0.275749   5.128 2.94e-07 ***
```

```

## SEXEHome          0.679437    0.039378   17.254 < 2e-16 ***
## PAUTANo iniciada  4.596782    0.372534   12.339 < 2e-16 ***
## PAUTAParcial      2.350647    0.489088    4.806 1.54e-06 ***
## Month06           0.005237    0.352897    0.015 0.988160
## Month07           2.209180    0.277733    7.954 1.80e-15 ***
## Month08           2.376726    0.276635    8.592 < 2e-16 ***
## Month09           1.339389    0.291830    4.590 4.44e-06 ***
## Month10           1.277531    0.292624    4.366 1.27e-05 ***
## Month11           1.873782    0.281564    6.655 2.83e-11 ***
## Month12           1.692963    0.284198    5.957 2.57e-09 ***
## PAUTANo iniciada:Month06 -0.995412    0.366310   -2.717 0.006580 **
## PAUTAParcial:Month06 -0.547188    0.401796   -1.362 0.173244
## PAUTANo iniciada:Month07 -1.817701    0.285483   -6.367 1.93e-10 ***
## PAUTAParcial:Month07 -1.848283    0.317081   -5.829 5.57e-09 ***
## PAUTANo iniciada:Month08 -2.368943    0.285858   -8.287 < 2e-16 ***
## PAUTAParcial:Month08 -3.460160    0.375512   -9.215 < 2e-16 ***
## PAUTANo iniciada:Month09 -2.631431    0.311917   -8.436 < 2e-16 ***
## PAUTAParcial:Month09 -3.408012    0.474021   -7.190 6.50e-13 ***
## PAUTANo iniciada:Month10 -3.481329    0.334735  -10.400 < 2e-16 ***
## PAUTAParcial:Month10 -3.484864    0.659551   -5.284 1.27e-07 ***
## PAUTANo iniciada:Month11 -3.224665    0.303287  -10.632 < 2e-16 ***
## PAUTAParcial:Month11 -4.344508    0.654287   -6.640 3.14e-11 ***
## PAUTANo iniciada:Month12 -3.174093    0.310531  -10.221 < 2e-16 ***
## PAUTAParcial:Month12 -4.965018    1.047933   -4.738 2.16e-06 ***
## EDAT40 a 49:PAUTANo iniciada -0.642183    0.295628   -2.172 0.029836 *
## EDAT50 a 59:PAUTANo iniciada -0.888359    0.289659   -3.067 0.002163 **
## EDAT60 a 69:PAUTANo iniciada -2.034367    0.277582   -7.329 2.32e-13 ***
## EDAT70 a 79:PAUTANo iniciada -2.719072    0.280746   -9.685 < 2e-16 ***
## EDAT80 o més:PAUTANo iniciada -3.973817    0.350421  -11.340 < 2e-16 ***
## EDAT40 a 49:PAUTAParcial -0.249233    0.441089   -0.565 0.572046
## EDAT50 a 59:PAUTAParcial -0.894509    0.444376   -2.013 0.044119 *
## EDAT60 a 69:PAUTAParcial -0.510626    0.407023   -1.255 0.209647
## EDAT70 a 79:PAUTAParcial -1.644763    0.426127   -3.860 0.000113 ***
## EDAT80 o més:PAUTAParcial -2.325473    0.579507   -4.013 6.00e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
## Null deviance: 3746.09 on 220 degrees of freedom
## Residual deviance: 398.57 on 181 degrees of freedom
## AIC: 1294.7
##
## Number of Fisher Scoring iterations: 5
par(mfrow = c(2,2))
plot(model7, ask = F)

```



Checking for overdispersion

```
PS <- sum(residuals(model7, type="pearson")^2)
```

```
PS
```

```
## [1] 415.0215
```

```
phi <- PS / model7$df.res
```

```
phi
```

```
## [1] 2.292937
```

```
anova(model7)
```

```
## Analysis of Deviance Table
```

```
##
```

```
## Model: poisson, link: log
```

```
##
```

```
## Response: RECOMPTE
```

```
##
```

```
## Terms added sequentially (first to last)
```

```
##
```

```
##
```

	Df	Deviance	Resid. Df	Resid. Dev
## NULL			220	3746.1
## EDAT	5	322.16	215	3423.9
## SEXE	1	263.07	214	3160.9
## PAUTA	2	634.90	212	2526.0
## Month	7	1125.42	205	1400.5
## PAUTA:Month	14	446.04	191	954.5
## EDAT:PAUTA	10	555.94	181	398.6

```
qchisq(0.95, model7$df.res, lower.tail=TRUE)
```

```
## [1] 213.3906
```

Now the model shows clear improvement, and the dispersion parameter is reduced to right above two.

```
model8 <- glm(RECOMPTE ~ SEXE + EDAT*PAUTA*Month,
```

```
data = covid.data.aggr,
```

```
family = poisson(link = "log"))
```

```
summary(model8)
```

```
##
```

```
## Call:
## glm(formula = RECOMPTE ~ SEXE + EDAT * PAUTA * Month, family = poisson(link = "log"),
##     data = covid.data.aggr)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -2.0144  -0.4083   0.0000   0.3728   2.4252
##
## Coefficients: (20 not defined because of singularities)
##
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)    -3.974e-01  7.076e-01  -0.562  0.574346
## SEXEHome        6.811e-01  3.965e-02  17.177 < 2e-16
## EDAT40 a 49      4.095e-01  1.000e+00   0.409  0.682194
## EDAT50 a 59     -5.806e-15  1.000e+00   0.000  1.000000
## EDAT60 a 69      3.974e-01  1.225e+00   0.324  0.745616
## EDAT70 a 79      6.931e-01  8.660e-01   0.800  0.423492
## EDAT80 o més     1.496e+00  9.133e-01   1.638  0.101390
## PAUTANo iniciada 2.862e+00  7.270e-01   3.937  8.26e-05
## PAUTAParcial     3.927e+00  1.778e+00   2.209  0.027174
## Month06        -2.836e-01  1.225e+00  -0.232  0.816866
## Month07         8.150e-01  9.130e-01   0.893  0.372038
## Month08         8.805e-01  1.014e+00   0.869  0.385038
## Month09         8.150e-01  9.130e-01   0.893  0.372038
## Month10         6.931e-01  8.660e-01   0.800  0.423492
## Month11        -2.836e-01  1.225e+00  -0.232  0.816866
## Month12        -2.836e-01  1.225e+00  -0.232  0.816866
## EDAT40 a 49:PAUTANo iniciada 4.660e-01  1.020e+00   0.457  0.647837
## EDAT50 a 59:PAUTANo iniciada 1.172e+00  1.019e+00   1.151  0.249853
## EDAT60 a 69:PAUTANo iniciada 3.780e-01  1.242e+00   0.304  0.760880
## EDAT70 a 79:PAUTANo iniciada 4.196e-02  8.901e-01   0.047  0.962397
## EDAT80 o més:PAUTANo iniciada -3.953e+00  1.094e+00  -3.615  0.000301
## EDAT40 a 49:PAUTAParcial    -3.939e+00  2.159e+00  -1.824  0.068136
## EDAT50 a 59:PAUTAParcial    -3.927e+00  2.040e+00  -1.925  0.054198
## EDAT60 a 69:PAUTAParcial    -1.462e+00  1.460e+00  -1.001  0.316646
## EDAT70 a 79:PAUTAParcial    -1.879e+00  1.855e+00  -1.013  0.311177
## EDAT80 o més:PAUTAParcial   -5.423e+00  2.159e+00  -2.512  0.012002
## EDAT40 a 49:Month06        2.796e-01  1.528e+00   0.183  0.854788
## EDAT50 a 59:Month06        6.811e-01  1.733e+00   0.393  0.694236
## EDAT60 a 69:Month06        5.794e-01  1.658e+00   0.349  0.726823
## EDAT70 a 79:Month06        6.891e-01  1.385e+00   0.498  0.618676
## EDAT80 o més:Month06      -5.193e-01  1.443e+00  -0.360  0.719045
## EDAT40 a 49:Month07        7.214e-01  1.186e+00   0.609  0.542834
## EDAT50 a 59:Month07        1.824e+00  1.170e+00   1.559  0.119029
## EDAT60 a 69:Month07        2.046e+00  1.361e+00   1.503  0.132861
## EDAT70 a 79:Month07        1.926e+00  1.049e+00   1.837  0.066277
## EDAT80 o més:Month07        2.917e-01  1.097e+00   0.266  0.790368
## EDAT40 a 49:Month08        1.275e+00  1.252e+00   1.019  0.308434
## EDAT50 a 59:Month08        1.604e+00  1.253e+00   1.281  0.200275
## EDAT60 a 69:Month08        2.360e+00  1.428e+00   1.652  0.098519
## EDAT70 a 79:Month08        2.037e+00  1.136e+00   1.793  0.072977
## EDAT80 o més:Month08      -3.617e-01  7.917e-01  -0.457  0.647813
## EDAT40 a 49:Month09      -3.082e-01  1.239e+00  -0.249  0.803495
## EDAT50 a 59:Month09        5.108e-01  1.238e+00   0.413  0.679952
## EDAT60 a 69:Month09        9.277e-01  1.376e+00   0.674  0.500082
## EDAT70 a 79:Month09        1.233e+00  1.056e+00   1.167  0.243203
## EDAT80 o més:Month09      -3.651e-01  1.113e+00  -0.328  0.742834
```

## EDAT40 a 49:Month10	6.109e-15	1.225e+00	0.000	1.000000
## EDAT50 a 59:Month10	8.109e-01	1.167e+00	0.695	0.487003
## EDAT60 a 69:Month10	9.889e-01	1.347e+00	0.734	0.462724
## EDAT70 a 79:Month10	1.179e+00	1.019e+00	1.157	0.247427
## EDAT80 o mês:Month10	-3.174e-01	1.077e+00	-0.295	0.768325
## EDAT40 a 49:Month11	1.260e+00	1.458e+00	0.865	0.387312
## EDAT50 a 59:Month11	2.075e+00	1.443e+00	1.438	0.150486
## EDAT60 a 69:Month11	2.907e+00	1.589e+00	1.829	0.067347
## EDAT70 a 79:Month11	2.611e+00	1.332e+00	1.960	0.050001
## EDAT80 o mês:Month11	1.496e+00	1.366e+00	1.095	0.273669
## EDAT40 a 49:Month12	1.127e+00	1.464e+00	0.770	0.441484
## EDAT50 a 59:Month12	1.788e+00	1.453e+00	1.230	0.218570
## EDAT60 a 69:Month12	3.085e+00	1.588e+00	1.943	0.052008
## EDAT70 a 79:Month12	2.481e+00	1.333e+00	1.861	0.062807
## EDAT80 o mês:Month12	2.917e-01	1.394e+00	0.209	0.834322
## PAUTANo iniciada:Month06	-1.361e-02	1.252e+00	-0.011	0.991325
## PAUTAParcial:Month06	1.208e+00	1.191e+00	1.015	0.310117
## PAUTANo iniciada:Month07	6.133e-01	9.322e-01	0.658	0.510592
## PAUTAParcial:Month07	-3.132e+00	1.896e+00	-1.652	0.098480
## PAUTANo iniciada:Month08	-2.312e-01	9.920e-01	-0.233	0.815725
## PAUTAParcial:Month08	-4.398e+00	1.065e+00	-4.131	3.61e-05
## PAUTANo iniciada:Month09	-1.480e+00	9.579e-01	-1.545	0.122361
## PAUTAParcial:Month09	-4.383e+00	8.049e-01	-5.446	5.16e-08
## PAUTANo iniciada:Month10	-3.150e+00	1.054e+00	-2.987	0.002816
## PAUTAParcial:Month10	-4.896e+00	1.149e+00	-4.260	2.04e-05
## PAUTANo iniciada:Month11	-7.868e-01	1.270e+00	-0.620	0.535465
## PAUTAParcial:Month11	-5.352e+00	1.143e+00	-4.682	2.85e-06
## PAUTANo iniciada:Month12	-3.894e-01	1.303e+00	-0.299	0.765005
## PAUTAParcial:Month12	-5.947e+00	1.431e+00	-4.154	3.26e-05
## EDAT40 a 49:PAUTANo iniciada:Month06	-6.290e-01	1.561e+00	-0.403	0.686938
## EDAT50 a 59:PAUTANo iniciada:Month06	-1.374e+00	1.761e+00	-0.780	0.435416
## EDAT60 a 69:PAUTANo iniciada:Month06	-1.568e+00	1.696e+00	-0.924	0.355245
## EDAT70 a 79:PAUTANo iniciada:Month06	-2.736e+00	1.463e+00	-1.870	0.061431
## EDAT80 o mês:PAUTANo iniciada:Month06	8.205e-01	1.727e+00	0.475	0.634761
## EDAT40 a 49:PAUTAParcial:Month06	-1.885e+00	2.063e+00	-0.914	0.360784
## EDAT50 a 59:PAUTAParcial:Month06	1.860e-01	1.872e+00	0.099	0.920848
## EDAT60 a 69:PAUTAParcial:Month06	-1.968e+00	1.656e+00	-1.189	0.234442
## EDAT70 a 79:PAUTAParcial:Month06	-3.256e+00	1.426e+00	-2.284	0.022393
## EDAT80 o mês:PAUTAParcial:Month06	NA	NA	NA	NA
## EDAT40 a 49:PAUTANo iniciada:Month07	-1.505e+00	1.208e+00	-1.246	0.212680
## EDAT50 a 59:PAUTANo iniciada:Month07	-3.261e+00	1.193e+00	-2.734	0.006249
## EDAT60 a 69:PAUTANo iniciada:Month07	-3.151e+00	1.382e+00	-2.279	0.022650
## EDAT70 a 79:PAUTANo iniciada:Month07	-3.981e+00	1.084e+00	-3.674	0.000239
## EDAT80 o mês:PAUTANo iniciada:Month07	-1.027e+00	1.319e+00	-0.779	0.436237
## EDAT40 a 49:PAUTAParcial:Month07	3.763e+00	2.282e+00	1.649	0.099113
## EDAT50 a 59:PAUTAParcial:Month07	2.508e+00	2.167e+00	1.157	0.247131
## EDAT60 a 69:PAUTAParcial:Month07	9.356e-01	1.612e+00	0.580	0.561610
## EDAT70 a 79:PAUTAParcial:Month07	-1.944e+00	2.056e+00	-0.946	0.344260
## EDAT80 o mês:PAUTAParcial:Month07	2.423e+00	2.476e+00	0.979	0.327796
## EDAT40 a 49:PAUTANo iniciada:Month08	-2.024e+00	1.244e+00	-1.627	0.103775
## EDAT50 a 59:PAUTANo iniciada:Month08	-2.406e+00	1.243e+00	-1.936	0.052857
## EDAT60 a 69:PAUTANo iniciada:Month08	-2.796e+00	1.421e+00	-1.967	0.049136
## EDAT70 a 79:PAUTANo iniciada:Month08	-3.085e+00	1.132e+00	-2.725	0.006426
## EDAT80 o mês:PAUTANo iniciada:Month08	NA	NA	NA	NA
## EDAT40 a 49:PAUTAParcial:Month08	3.097e+00	1.679e+00	1.845	0.065025
## EDAT50 a 59:PAUTAParcial:Month08	2.310e+00	1.782e+00	1.297	0.194762

##	EDAT60	a	69:PAUTAParcial:Month08	NA	NA	NA	NA
##	EDAT70	a	79:PAUTAParcial:Month08	NA	NA	NA	NA
##	EDAT80	o	més:PAUTAParcial:Month08	NA	NA	NA	NA
##	EDAT40	a	49:PAUTANo iniciada:Month09	-3.666e-01	1.294e+00	-0.283	0.777006
##	EDAT50	a	59:PAUTANo iniciada:Month09	-1.395e+00	1.292e+00	-1.080	0.280018
##	EDAT60	a	69:PAUTANo iniciada:Month09	-1.226e+00	1.423e+00	-0.862	0.388783
##	EDAT70	a	79:PAUTANo iniciada:Month09	-2.460e+00	1.142e+00	-2.154	0.031232
##	EDAT80	o	més:PAUTANo iniciada:Month09	3.410e-01	1.630e+00	0.209	0.834261
##	EDAT40	a	49:PAUTAParcial:Month09	NA	NA	NA	NA
##	EDAT50	a	59:PAUTAParcial:Month09	3.057e+00	1.532e+00	1.995	0.046023
##	EDAT60	a	69:PAUTAParcial:Month09	1.837e-01	1.438e+00	0.128	0.898386
##	EDAT70	a	79:PAUTAParcial:Month09	NA	NA	NA	NA
##	EDAT80	o	més:PAUTAParcial:Month09	NA	NA	NA	NA
##	EDAT40	a	49:PAUTANo iniciada:Month10	5.909e-01	1.397e+00	0.423	0.672259
##	EDAT50	a	59:PAUTANo iniciada:Month10	-1.002e+00	1.363e+00	-0.735	0.462081
##	EDAT60	a	69:PAUTANo iniciada:Month10	-7.834e-01	1.521e+00	-0.515	0.606490
##	EDAT70	a	79:PAUTANo iniciada:Month10	-9.329e-01	1.241e+00	-0.752	0.452045
##	EDAT80	o	més:PAUTANo iniciada:Month10	3.459e+00	1.536e+00	2.253	0.024285
##	EDAT40	a	49:PAUTAParcial:Month10	4.203e+00	2.018e+00	2.083	0.037234
##	EDAT50	a	59:PAUTAParcial:Month10	NA	NA	NA	NA
##	EDAT60	a	69:PAUTAParcial:Month10	7.495e-01	1.848e+00	0.406	0.685101
##	EDAT70	a	79:PAUTAParcial:Month10	NA	NA	NA	NA
##	EDAT80	o	més:PAUTAParcial:Month10	NA	NA	NA	NA
##	EDAT40	a	49:PAUTANo iniciada:Month11	-1.913e+00	1.522e+00	-1.257	0.208820
##	EDAT50	a	59:PAUTANo iniciada:Month11	-2.554e+00	1.499e+00	-1.704	0.088306
##	EDAT60	a	69:PAUTANo iniciada:Month11	-2.701e+00	1.637e+00	-1.650	0.098995
##	EDAT70	a	79:PAUTANo iniciada:Month11	-3.266e+00	1.406e+00	-2.323	0.020193
##	EDAT80	o	més:PAUTANo iniciada:Month11	-1.570e-02	1.626e+00	-0.010	0.992298
##	EDAT40	a	49:PAUTAParcial:Month11	NA	NA	NA	NA
##	EDAT50	a	59:PAUTAParcial:Month11	NA	NA	NA	NA
##	EDAT60	a	69:PAUTAParcial:Month11	2.761e-01	1.691e+00	0.163	0.870334
##	EDAT70	a	79:PAUTAParcial:Month11	NA	NA	NA	NA
##	EDAT80	o	més:PAUTAParcial:Month11	NA	NA	NA	NA
##	EDAT40	a	49:PAUTANo iniciada:Month12	-2.177e+00	1.555e+00	-1.399	0.161706
##	EDAT50	a	59:PAUTANo iniciada:Month12	-2.751e+00	1.537e+00	-1.790	0.073464
##	EDAT60	a	69:PAUTANo iniciada:Month12	-3.652e+00	1.666e+00	-2.192	0.028361
##	EDAT70	a	79:PAUTANo iniciada:Month12	-3.796e+00	1.445e+00	-2.627	0.008623
##	EDAT80	o	més:PAUTANo iniciada:Month12	-2.413e-02	1.724e+00	-0.014	0.988835
##	EDAT40	a	49:PAUTAParcial:Month12	NA	NA	NA	NA
##	EDAT50	a	59:PAUTAParcial:Month12	NA	NA	NA	NA
##	EDAT60	a	69:PAUTAParcial:Month12	NA	NA	NA	NA
##	EDAT70	a	79:PAUTAParcial:Month12	NA	NA	NA	NA
##	EDAT80	o	més:PAUTAParcial:Month12	NA	NA	NA	NA
##							
##	(Intercept)						
##	SEXHome	***					
##	EDAT40	a	49				
##	EDAT50	a	59				
##	EDAT60	a	69				
##	EDAT70	a	79				
##	EDAT80	o	més				
##	PAUTANo iniciada	***					
##	PAUTAParcial	*					
##	Month06						
##	Month07						
##	Month08						


```

## Month09
## Month10
## Month11
## Month12
## EDAT40 a 49:PAUTANo iniciada
## EDAT50 a 59:PAUTANo iniciada
## EDAT60 a 69:PAUTANo iniciada
## EDAT70 a 79:PAUTANo iniciada
## EDAT80 o mês:PAUTANo iniciada      ***
## EDAT40 a 49:PAUTAParcial          .
## EDAT50 a 59:PAUTAParcial          .
## EDAT60 a 69:PAUTAParcial
## EDAT70 a 79:PAUTAParcial
## EDAT80 o mês:PAUTAParcial          *
## EDAT40 a 49:Month06
## EDAT50 a 59:Month06
## EDAT60 a 69:Month06
## EDAT70 a 79:Month06
## EDAT80 o mês:Month06
## EDAT40 a 49:Month07
## EDAT50 a 59:Month07
## EDAT60 a 69:Month07
## EDAT70 a 79:Month07                .
## EDAT80 o mês:Month07
## EDAT40 a 49:Month08
## EDAT50 a 59:Month08
## EDAT60 a 69:Month08                .
## EDAT70 a 79:Month08                .
## EDAT80 o mês:Month08
## EDAT40 a 49:Month09
## EDAT50 a 59:Month09
## EDAT60 a 69:Month09
## EDAT70 a 79:Month09
## EDAT80 o mês:Month09
## EDAT40 a 49:Month10
## EDAT50 a 59:Month10
## EDAT60 a 69:Month10
## EDAT70 a 79:Month10
## EDAT80 o mês:Month10
## EDAT40 a 49:Month11
## EDAT50 a 59:Month11
## EDAT60 a 69:Month11                .
## EDAT70 a 79:Month11                .
## EDAT80 o mês:Month11
## EDAT40 a 49:Month12
## EDAT50 a 59:Month12
## EDAT60 a 69:Month12                .
## EDAT70 a 79:Month12                .
## EDAT80 o mês:Month12
## PAUTANo iniciada:Month06
## PAUTAParcial:Month06
## PAUTANo iniciada:Month07
## PAUTAParcial:Month07                .
## PAUTANo iniciada:Month08
## PAUTAParcial:Month08                ***
## PAUTANo iniciada:Month09

```

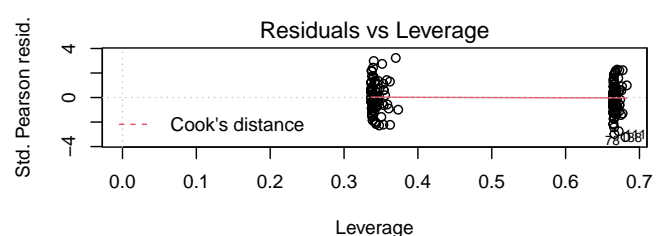
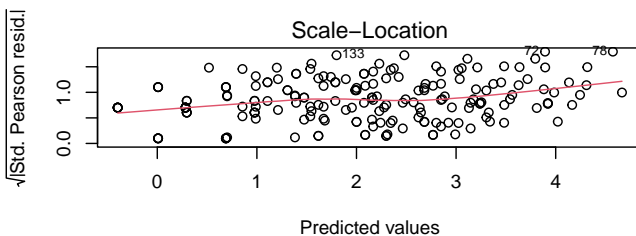
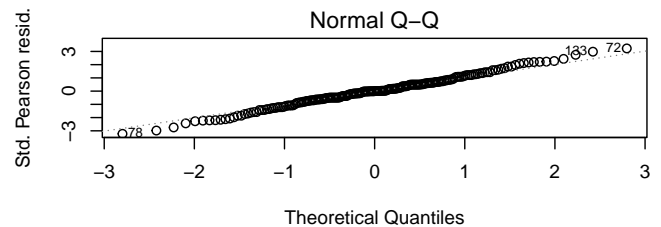
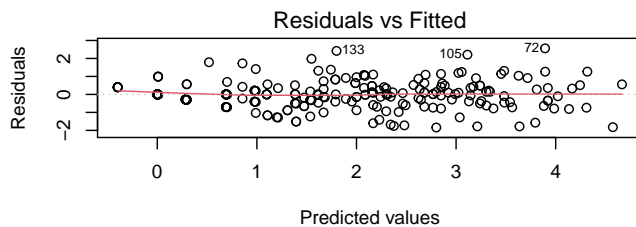
```

## PAUTAParcial:Month09          ***
## PAUTANo iniciada:Month10      **
## PAUTAParcial:Month10          ***
## PAUTANo iniciada:Month11
## PAUTAParcial:Month11          ***
## PAUTANo iniciada:Month12
## PAUTAParcial:Month12          ***
## EDAT40 a 49:PAUTANo iniciada:Month06
## EDAT50 a 59:PAUTANo iniciada:Month06
## EDAT60 a 69:PAUTANo iniciada:Month06
## EDAT70 a 79:PAUTANo iniciada:Month06 .
## EDAT80 o mês:PAUTANo iniciada:Month06
## EDAT40 a 49:PAUTAParcial:Month06
## EDAT50 a 59:PAUTAParcial:Month06
## EDAT60 a 69:PAUTAParcial:Month06
## EDAT70 a 79:PAUTAParcial:Month06 *
## EDAT80 o mês:PAUTAParcial:Month06
## EDAT40 a 49:PAUTANo iniciada:Month07
## EDAT50 a 59:PAUTANo iniciada:Month07 **
## EDAT60 a 69:PAUTANo iniciada:Month07 *
## EDAT70 a 79:PAUTANo iniciada:Month07 ***
## EDAT80 o mês:PAUTANo iniciada:Month07
## EDAT40 a 49:PAUTAParcial:Month07 .
## EDAT50 a 59:PAUTAParcial:Month07
## EDAT60 a 69:PAUTAParcial:Month07
## EDAT70 a 79:PAUTAParcial:Month07
## EDAT80 o mês:PAUTAParcial:Month07
## EDAT40 a 49:PAUTANo iniciada:Month08
## EDAT50 a 59:PAUTANo iniciada:Month08 .
## EDAT60 a 69:PAUTANo iniciada:Month08 *
## EDAT70 a 79:PAUTANo iniciada:Month08 **
## EDAT80 o mês:PAUTANo iniciada:Month08
## EDAT40 a 49:PAUTAParcial:Month08 .
## EDAT50 a 59:PAUTAParcial:Month08
## EDAT60 a 69:PAUTAParcial:Month08
## EDAT70 a 79:PAUTAParcial:Month08
## EDAT80 o mês:PAUTAParcial:Month08
## EDAT40 a 49:PAUTANo iniciada:Month09
## EDAT50 a 59:PAUTANo iniciada:Month09
## EDAT60 a 69:PAUTANo iniciada:Month09
## EDAT70 a 79:PAUTANo iniciada:Month09 *
## EDAT80 o mês:PAUTANo iniciada:Month09
## EDAT40 a 49:PAUTAParcial:Month09
## EDAT50 a 59:PAUTAParcial:Month09 *
## EDAT60 a 69:PAUTAParcial:Month09
## EDAT70 a 79:PAUTAParcial:Month09
## EDAT80 o mês:PAUTAParcial:Month09
## EDAT40 a 49:PAUTANo iniciada:Month10
## EDAT50 a 59:PAUTANo iniciada:Month10
## EDAT60 a 69:PAUTANo iniciada:Month10
## EDAT70 a 79:PAUTANo iniciada:Month10
## EDAT80 o mês:PAUTANo iniciada:Month10 *
## EDAT40 a 49:PAUTAParcial:Month10 *
## EDAT50 a 59:PAUTAParcial:Month10
## EDAT60 a 69:PAUTAParcial:Month10
## EDAT70 a 79:PAUTAParcial:Month10

```

```
## EDAT80 o m  s:PAUTAParcial:Month10
## EDAT40 a 49:PAUTANo iniciada:Month11
## EDAT50 a 59:PAUTANo iniciada:Month11 .
## EDAT60 a 69:PAUTANo iniciada:Month11 .
## EDAT70 a 79:PAUTANo iniciada:Month11 *
## EDAT80 o m  s:PAUTANo iniciada:Month11
## EDAT40 a 49:PAUTAParcial:Month11
## EDAT50 a 59:PAUTAParcial:Month11
## EDAT60 a 69:PAUTAParcial:Month11
## EDAT70 a 79:PAUTAParcial:Month11
## EDAT80 o m  s:PAUTAParcial:Month11
## EDAT40 a 49:PAUTANo iniciada:Month12
## EDAT50 a 59:PAUTANo iniciada:Month12 .
## EDAT60 a 69:PAUTANo iniciada:Month12 *
## EDAT70 a 79:PAUTANo iniciada:Month12 **
## EDAT80 o m  s:PAUTANo iniciada:Month12
## EDAT40 a 49:PAUTAParcial:Month12
## EDAT50 a 59:PAUTAParcial:Month12
## EDAT60 a 69:PAUTAParcial:Month12
## EDAT70 a 79:PAUTAParcial:Month12
## EDAT80 o m  s:PAUTAParcial:Month12
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
##      Null deviance: 3746.09  on 220  degrees of freedom
## Residual deviance: 133.53  on  96  degrees of freedom
## AIC: 1199.7
##
## Number of Fisher Scoring iterations: 5
```

```
par(mfrow = c(2,2))
plot(model8, ask = F)
```



```
# Checking for overdispersion
PS <- sum(residuals(model8, type="pearson")^2)
PS

## [1] 130.3739
```

```

phi <- PS / model8$df.res
phi

## [1] 1.358062

anova(model8)

## Analysis of Deviance Table
##
## Model: poisson, link: log
##
## Response: RECOMPTE
##
## Terms added sequentially (first to last)
##
##
##              Df Deviance Resid. Df Resid. Dev
## NULL              220      3746.1
## SEXE               1    260.02      219      3486.1
## EDAT               5    325.21      214      3160.9
## PAUTA              2    634.90      212      2526.0
## Month              7   1125.42      205      1400.5
## EDAT:PAUTA         10    566.71      195       833.8
## EDAT:Month         35    216.63      160       617.2
## PAUTA:Month        14    383.01      146       234.2
## EDAT:PAUTA:Month   50    100.66       96       133.5

qchisq(0.95, model8$df.res, lower.tail=TRUE)

## [1] 119.8709

```

Conclusions