

Silent and spoken intervals in naming: Data check

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```
library(psych)
library(reshape2)
library(mice)
library(lattice)
```

1 Introduction

In this document we present analyses addressing data quality considerations for the silent and spoken intervals in discrete and serial naming tasks and associated reading tasks. An important concern addressed here is the distribution of each type of data and the selection of transformation that best approaches normality while retaining a common scale across metrics to the largest extent possible.

The analyses and computations reported below produce the main data file used subsequently for all analyses reported in the manuscript as well as supplementary ones.

2 Demographic and reading data

We first consider demographics (sex, age, and grade) and reading scores because these were collected manually and thus stored separately. There were two reading accuracy tasks (words and pseudowords), where the score is the number of correct items, and two reading fluency tasks (words and pseudowords), where the score is the number of items read correctly within one minute.

The reading accuracy scores are severely skewed due to a ceiling effect (expected for these ages and the relative transparency of the Greek orthography), therefore nonlinear transformations are applied to reduce the skewness for further analyses.

```
read.table("demographics_reading.txt",stringsAsFactors=TRUE) -> dsdw
dsdw$logwacc <- 4-log(82-dsdw$wrdacc)
dsdw$sqpwacc <- 5-sqrt(39-dsdw$pwracc)
str(dsdw)
```

```
## 'data.frame': 298 obs. of 11 variables:
## $ sID : Factor w/ 298 levels "S1101","S1102",...: 1 2 3 4 5 6 7 8 9 10 ...
## $ sex : Factor w/ 2 levels "F","M": 2 2 2 NA 1 1 1 1 2 1 ...
## $ grade : Factor w/ 3 levels "G1","G3","G5": 1 1 1 1 1 1 1 1 1 1 ...
## $ graden : int 1 1 1 1 1 1 1 1 1 1 ...
## $ agemonths: int NA 87 84 NA 83 88 81 81 81 81 ...
## $ wrdacc : int 74 72 78 NA 60 61 76 62 73 77 ...
## $ pwracc : int 19 20 22 NA 20 19 29 20 24 22 ...
## $ wflut : int 24 34 36 NA 31 22 40 20 33 29 ...
## $ pwflu : int 14 22 24 NA 19 17 21 15 19 16 ...
## $ logwacc : num 1.921 1.697 2.614 NA 0.909 ...
## $ sqpwacc : num 0.528 0.641 0.877 NA 0.641 ...
```

```
summary(dsdw)
```

	sID	sex	grade	graden	agemonths	wrdacc	pwracc
##	S1101 : 1	F :161	G1: 99	Min. :1.000	Min. : 77.00	Min. :46.00	Min. :14.00
##	S1102 : 1	M :127	G3:102	1st Qu.:1.000	1st Qu.: 86.25	1st Qu.:72.00	1st Qu.:22.00
##	S1103 : 1	NA's: 10	G5: 97	Median :3.000	Median :108.00	Median :77.00	Median :29.00
##	S1104 : 1			Mean :2.987	Mean :107.73	Mean :74.25	Mean :28.43
##	S1105 : 1			3rd Qu.:5.000	3rd Qu.:127.00	3rd Qu.:79.00	3rd Qu.:36.00
##	S1106 : 1			Max. :5.000	Max. :136.00	Max. :80.00	Max. :38.00
##	(Other):292				NA's :40	NA's :5	NA's :5
##	wflut	pwflu	logwacc	sqpwacc			
##	Min. :11.00	Min. : 6.00	Min. :0.4165	Min. :0.0000			
##	1st Qu.:34.00	1st Qu.:20.00	1st Qu.:1.6974	1st Qu.:0.8769			
##	Median :55.00	Median :28.00	Median :2.3906	Median :1.8377			
##	Mean :52.72	Mean :27.85	Mean :2.2546	Mean :1.9952			
##	3rd Qu.:68.00	3rd Qu.:35.00	3rd Qu.:2.9014	3rd Qu.:3.2679			
##	Max. :95.00	Max. :54.00	Max. :3.3069	Max. :4.0000			
##	NA's :6	NA's :6	NA's :5	NA's :5			

2.1 Basic descriptives per grade

```
desclist <- describeBy(dsdw,dsdw$grade)
for (grd in levels(dsdw$grade)) {
```

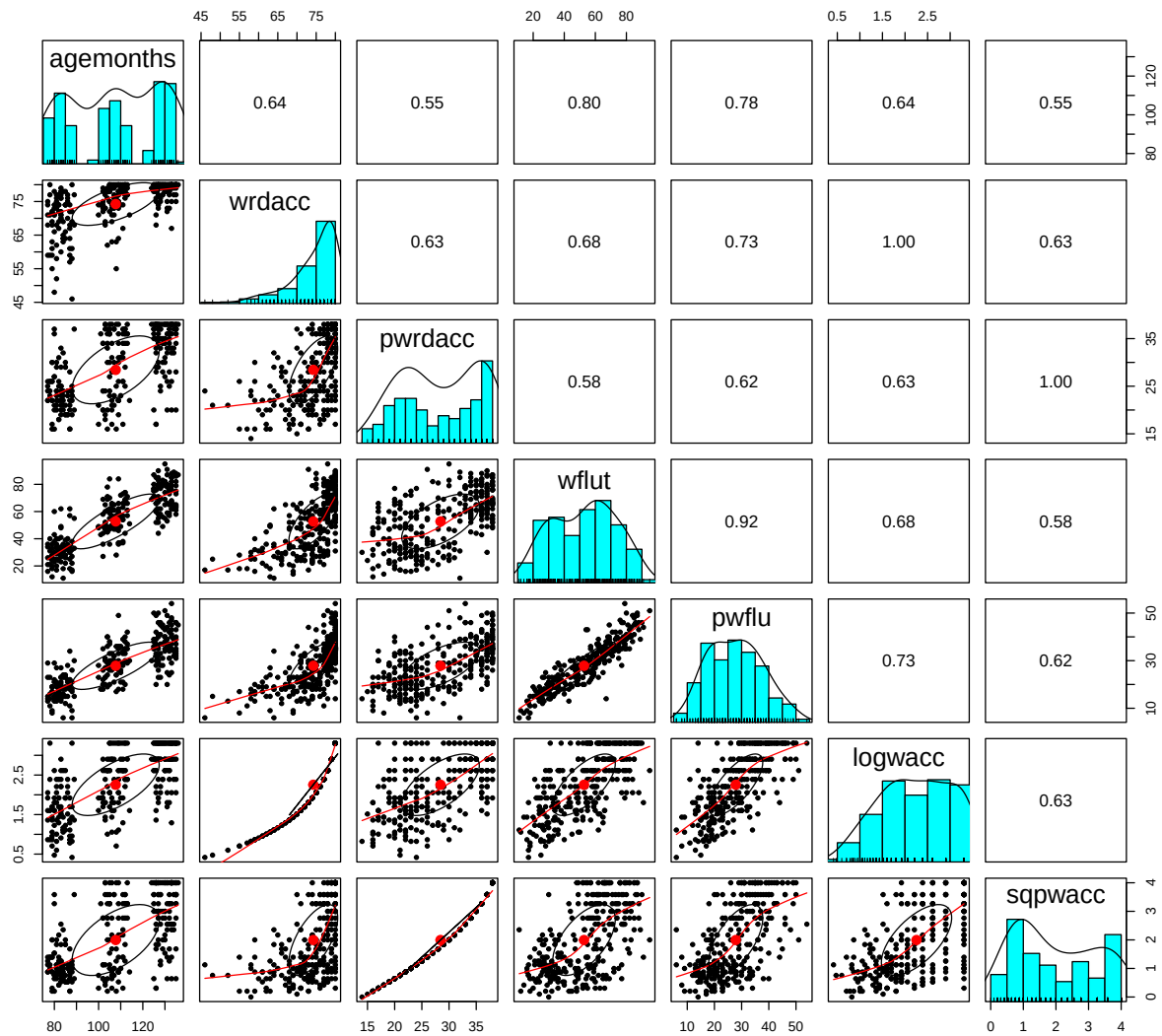
```
print(paste("Descriptives for grade",grd))
print(desclist[[grd]][,-c(1,6,7,10,13)])
}
```

```
## [1] "Descriptives for grade G1"
##           n mean   sd median   min   max   skew kurtosis
## sID*      99 50.00 28.72   50.0   1.00 99.00   0.00   -1.24
## sex*      97  1.45  0.50    1.0   1.00  2.00   0.18   -1.99
## grade*    99  1.00  0.00    1.0   1.00  1.00   NaN     NaN
## graden    99  1.00  0.00    1.0   1.00  1.00   NaN     NaN
## agemonths 81 82.74  3.39   83.0  77.00 89.00   0.07   -1.09
## wrdacc     97 69.36  7.09   71.0 46.00 80.00  -0.92    0.60
## pwracc     97 23.60  4.74   23.0 15.00 37.00   0.65    0.24
## wflut      97 30.71 10.25   30.0 11.00 62.00   0.91    1.27
## pwflu      97 18.14  5.18   18.0  6.00 34.00   0.23    0.43
## logwacc    97  1.63  0.60    1.6  0.42  3.31   0.42   -0.14
## sqpwacc    97  1.14  0.69    1.0  0.10  3.59   1.34    2.31
## [1] "Descriptives for grade G3"
##           n mean   sd median   min   max   skew kurtosis
## sID*     102 150.50 29.59 150.50 100.0 201.00   0.00   -1.24
## sex*      95  1.44  0.50    1.0   1.0   2.00   0.23   -1.97
## grade*   102  2.00  0.00    2.0   2.0   2.00   NaN     NaN
## graden   102  3.00  0.00    3.0   3.0   3.00   NaN     NaN
## agemonths 84 107.18  3.58 107.00 100.0 114.00  -0.02   -1.08
## wrdacc    99  75.19  4.91  77.00  55.0  80.00  -1.72    3.38
## pwracc    99  28.47  7.37  30.00  14.0  38.00  -0.20   -1.43
## wflut     98  55.79 11.57  55.50  27.0  84.00  -0.12   -0.08
## pwflu     98  28.74  6.67  29.00  14.0  49.00   0.17   -0.04
## logwacc   99   2.30  0.66   2.39   0.7   3.31  -0.18   -0.67
## sqpwacc   99   2.01  1.25   2.00   0.0   4.00   0.15   -1.43
## [1] "Descriptives for grade G5"
##           n mean   sd median   min   max   skew kurtosis
## sID*      97 250.00 28.15 250.0 202.00 298.00   0.00   -1.24
## sex*      96  1.43  0.50    1.0   1.00  2.00   0.29   -1.94
## grade*    97  3.00  0.00    3.0   3.00  3.00   NaN     NaN
## graden    97  5.00  0.00    5.0   5.00  5.00   NaN     NaN
## agemonths 93 130.00  3.33 130.0 124.00 136.00   0.05   -1.32
## wrdacc     97  78.19  2.69  79.0  67.00  80.00  -2.00    4.02
## pwracc     97  33.23  5.51  35.0  17.00  38.00  -1.29    0.76
## wflut      97  71.62 11.36  73.0  42.00  95.00  -0.30   -0.61
## pwflu      97  36.64  7.30  36.0  20.00  54.00  -0.01   -0.43
## logwacc    97   2.83  0.55   2.9  1.29  3.31  -0.97   -0.09
## sqpwacc    97   2.84  1.07   3.0  0.31  4.00  -0.69   -0.59
```

2.2 Intercorrelations (across grades)

In this and all following panel sets, nonparametric correlation coefficients (Spearman's ρ) are displayed, which are rank-based and thus not vulnerable to nonlinearities.

```
pairs.panels(dsdw[,5:11],cex.cor=0.5,method="spearman")
```



2.3 Bivariate distributions of reading scores (color-coded by grade)

```
par(mfrow=c(2,2))
par(oma=c(0,2,2,0))
par(mai=c(0.25,0.2,0.1,0.1))
par(mgp=c(2,0.5,0))
par(tcl= -0.3)

plot(pwracc~wrdacc,dsw,type="n",main="",xlab="",ylab="",xlim=c(45,80),ylim=c(13,40))
points(pwracc~jitter(wrdacc),dsw,subset=grade=="G1",cex=1.25,col="#008000",lwd=3)
points(pwracc~jitter(wrdacc),dsw,subset=grade=="G3",cex=1.25,col="#FF6000",lwd=3)
points(pwracc~jitter(wrdacc),dsw,subset=grade=="G5",cex=1.25,col="#0000FF",lwd=3)
mtext("Word accuracy",3,line=1,cex=1.25)
mtext("Pseudoword accuracy",2,line=2,cex=1.25)

plot(pwracc~wflut,dsw,type="n",main="",xlab="",ylab="",xlim=c(10,96),ylim=c(13,40))
points(pwracc~wflut,dsw,subset=grade=="G1",cex=1.25,col="#008000",lwd=3)
```

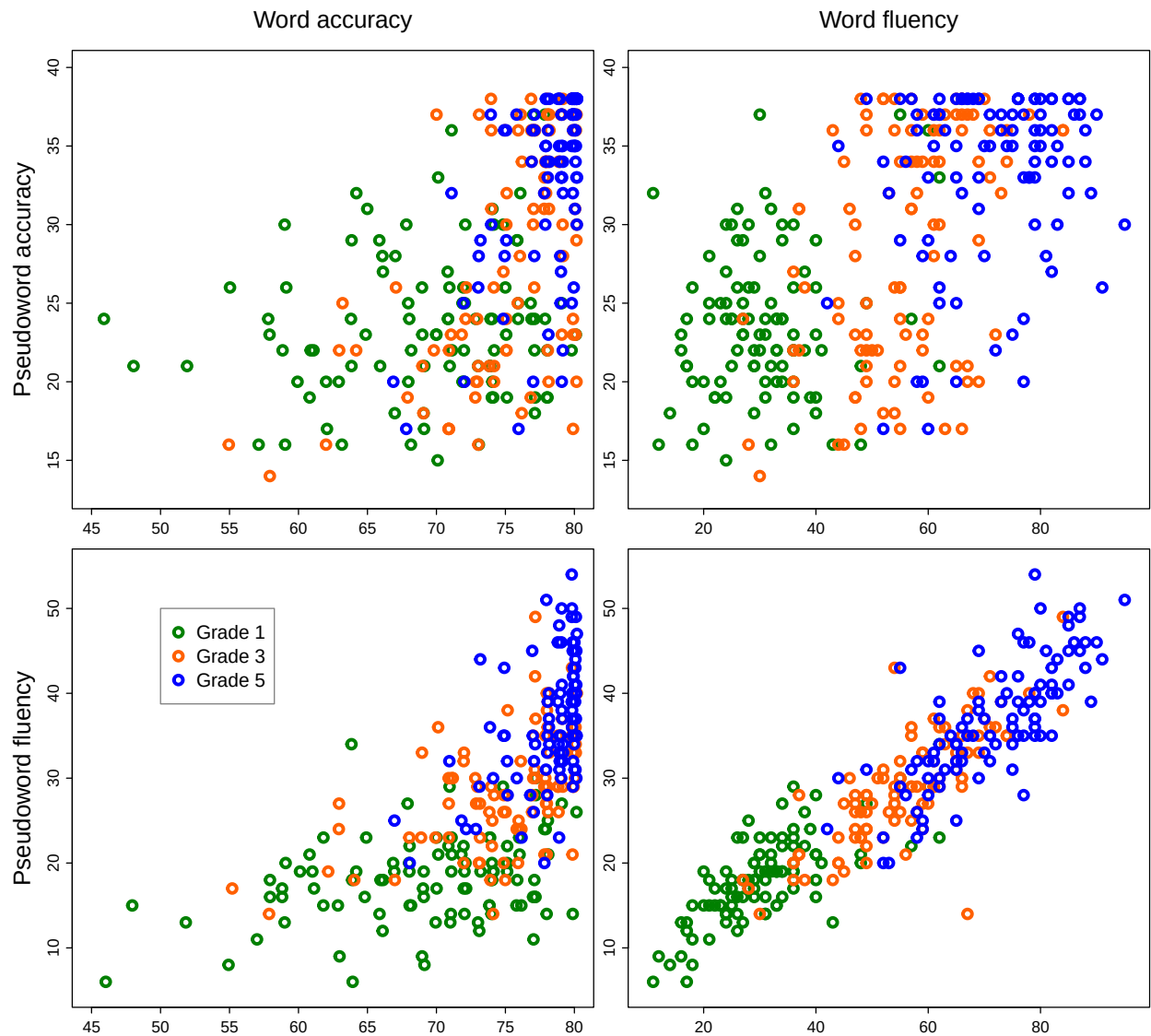
```

points(pwrdacc~wflut,dsdw,subset=grade=="G3",cex=1.25,col="#FF6000",lwd=3)
points(pwrdacc~wflut,dsdw,subset=grade=="G5",cex=1.25,col="#0000FF",lwd=3)
mtext("Word fluency",3,line=1,cex=1.25)

plot(pwflu~wrdacc,dsdw,type="n",main="",xlab="",ylab="",xlim=c(45,80),ylim=c(5,55))
points(pwflu~jitter(wrdacc),dsdw,subset=grade=="G1",cex=1.25,col="#008000",lwd=3)
points(pwflu~jitter(wrdacc),dsdw,subset=grade=="G3",cex=1.25,col="#FF6000",lwd=3)
points(pwflu~jitter(wrdacc),dsdw,subset=grade=="G5",cex=1.25,col="#0000FF",lwd=3)
mtext("Pseudoword fluency",2,line=2,cex=1.25)
legend(50,50,c("Grade 1","Grade 3","Grade 5"),cex=1.25,col=c("#008000","#FF6000","#0000FF"),pch=1,pt.lw=3)

plot(pwflu~wflut,dsdw,type="n",main="",xlab="",ylab="",xlim=c(10,96),ylim=c(5,55))
points(pwflu~wflut,dsdw,subset=grade=="G1",cex=1.25,col="#008000",lwd=3)
points(pwflu~wflut,dsdw,subset=grade=="G3",cex=1.25,col="#FF6000",lwd=3)
points(pwflu~wflut,dsdw,subset=grade=="G5",cex=1.25,col="#0000FF",lwd=3)

```

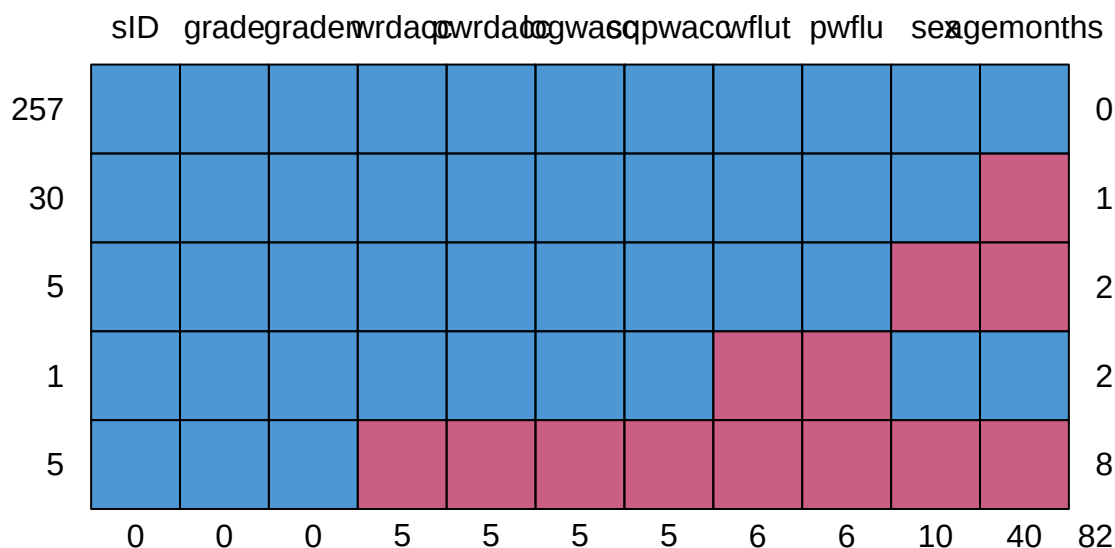


As expected, there are substantial ceiling effects in reading accuracy scores, especially for 5th grade. In contrast, fluency scores are approximately normally distributed and in a constant linear relationship across

grades.

2.4 Missing data report

```
md.pattern(dsdw)
```



```
##      sID grade graden wrdacc pwracc logwacc sqpwacc wflut pwflu sex agemoths
## 257    1     1      1      1      1      1      1      1     1     1      1  0
## 30     1     1      1      1      1      1      1      1     1     1      0  1
## 5      1     1      1      1      1      1      1      1     1     0      0  2
## 1      1     1      1      1      1      1      1      0     0     1      1  2
## 5      1     1      1      0      0      0      0      0     0     0      0  8
##      0     0      0      5      5      5      5      6     6    10     40 82
```

3 Serial data

In this section we consider data from the serial naming tasks, which have been manually processed to mark and annotate silent and spoken intervals. Variables ending in `_N` are counts of events, whereas variables ending in `_T` are (total) time durations of events (i.e., the sum of all intervals carrying the corresponding annotation) within a run. Variables ending in `E` are “adjusted” by discarding intervals not associated with correct responses (including fillers, false starts, incorrect responses, repetitions, and extraneous utterances). A more detailed description of each variable is reported in the “descriptives” document in this archive (and online).

```
read.table("serial_allfields_long.txt", stringsAsFactors=TRUE) -> serd
str(serd)
```

```
## 'data.frame':    1489 obs. of  32 variables:
## $ sID      : Factor w/ 298 levels "S1101","S1102",...: 268 269 279 1 2 3 270 271 272 273 ...
## $ graden   : int  5 5 5 1 1 1 5 5 5 5 ...
## $ grade    : Factor w/ 3 levels "G1","G3","G5": 3 3 3 1 1 1 3 3 3 3 ...
## $ task     : Factor w/ 5 levels "dice","digit",...: 2 2 2 2 2 2 2 2 2 2 ...
## $ sdtask   : Factor w/ 5 levels "s_dice","s_digit",...: 2 2 2 2 2 2 2 2 2 2 ...
## $ format   : Factor w/ 1 level "serial": 1 1 1 1 1 1 1 1 1 1 ...
## $ onslat   : num  0.601 0.864 0.52 1.691 1.473 ...
## $ tottim   : num  17.5 17.6 13.9 33.3 22.3 ...
## $ artN     : int  32 7 7 26 5 9 3 8 6 18 ...
## $ arttot   : num  10.1 13.7 11.7 22.8 18.8 ...
## $ pauN     : int  31 6 6 25 4 8 2 7 5 17 ...
## $ pautot   : num  6.81 3.04 1.65 8.77 1.95 ...
## $ artNE    : int  32 7 7 26 5 9 3 8 6 18 ...
## $ arttotE  : num  10.1 13.2 11.7 22.8 18.3 ...
## $ pauNE    : int  31 5 6 25 4 8 2 7 5 17 ...
## $ pautotE  : num  6.81 2.74 1.65 8.77 1.95 ...
## $ error_N  : int  0 0 0 0 0 0 0 0 0 0 ...
## $ error_T  : num  0 0 0 0 0 0 0 0 0 0 ...
## $ extra_N  : int  0 0 0 0 0 0 0 0 0 0 ...
## $ extra_T  : num  0 0 0 0 0 0 0 0 0 0 ...
## $ filler_N : int  0 0 0 0 1 1 0 0 0 0 ...
## $ filler_T : num  0 0 0 0 0.564 0.216 0 0 0 0 ...
## $ intrawrd_N: int  0 0 0 1 0 0 0 0 0 0 ...
## $ intrawrd_T: num  0 0 0 0.103 0 0 0 0 0 0 ...
## $ maze_N   : int  0 1 0 0 0 1 0 0 0 0 ...
## $ maze_T   : num  0 0.166 0 0 0 0.326 0 0 0 0 ...
## $ repeat_N : int  0 1 0 0 0 0 0 0 0 0 ...
## $ repeat_T : num  0 0.28 0 0 0 0 0 0 0 0 ...
## $ selfcor_N: int  0 0 0 0 0 0 0 0 0 0 ...
## $ selfcor_T: num  0 0 0 0 0 0 0 0 0 0 ...
## $ skip_N   : int  0 0 0 0 0 0 0 0 0 0 ...
## $ skip_T   : num  0 0 0 0 0 0 0 0 0 0 ...
```

```
options(width=100)
summary(serd)
```

```
##          sID          graden          grade          task          sdtask          format
## S1101   :    5   Min.    :1.000   G1:495   dice    :298   s_dice    :298   serial:1489
## S1102   :    5   1st Qu.:1.000   G3:510   digit    :298   s_digit   :298
## S1103   :    5   Median  :3.000   G5:484   numword:298   s_numword:298
## S1104   :    5   Mean     :2.985           object :297   s_object  :297
## S1105   :    5   3rd Qu.:5.000           word   :298   s_word    :298
## S1106   :    5   Max.     :5.000
## (Other):1459
##          onslat          tottim          artN          arttot          pauN          pautot
## Min.    :0.338   Min.    : 12.16   Min.    : 1.00   Min.    :10.13   Min.    : 0.00   Min.    : 0.224
## 1st Qu.:0.804   1st Qu.: 19.51   1st Qu.:10.00   1st Qu.:15.56   1st Qu.: 9.00   1st Qu.: 2.522
## Median :1.011   Median : 25.26   Median :18.00   Median :18.43   Median :17.00   Median : 5.405
## Mean    :1.123   Mean    : 29.67   Mean    :19.85   Mean    :19.62   Mean    :18.85   Mean    : 9.066
## 3rd Qu.:1.284   3rd Qu.: 34.19   3rd Qu.:28.00   3rd Qu.:22.01   3rd Qu.:27.00   3rd Qu.:11.380
## Max.    :4.683   Max.    :175.94   Max.    :69.00   Max.    :68.98   Max.    :68.00   Max.    :108.382
## NA's    :14     NA's    :4
##          artNE          arttotE          pauNE          pautotE          error_N
## Min.    : 1.0   Min.    :10.13   Min.    : 0.00   Min.    : 0.224   Min.    : 0.0000
```

```
## 1st Qu.:10.0 1st Qu.:15.29 1st Qu.: 9.00 1st Qu.: 2.403 1st Qu.: 0.0000
## Median :17.0 Median :17.68 Median :15.00 Median : 4.917 Median : 0.0000
## Mean :18.4 Mean :18.39 Mean :17.01 Mean : 7.763 Mean : 0.6501
## 3rd Qu.:26.0 3rd Qu.:20.68 3rd Qu.:25.00 3rd Qu.:10.065 3rd Qu.: 1.0000
## Max. :57.0 Max. :43.95 Max. :56.00 Max. :69.877 Max. :13.0000
## NA's :1 NA's :3
## error_T extra_N extra_T filler_N filler_T
## Min. : 0.0000 Min. :0.00000 Min. :0.00000 Min. : 0.0000 Min. :0.0000
## 1st Qu.: 0.0000 1st Qu.:0.00000 1st Qu.:0.00000 1st Qu.: 0.0000 1st Qu.:0.0000
## Median : 0.0000 Median :0.00000 Median :0.00000 Median : 0.0000 Median :0.0000
## Mean : 0.5218 Mean :0.05977 Mean :0.02793 Mean : 0.9765 Mean :0.3251
## 3rd Qu.: 0.3790 3rd Qu.:0.00000 3rd Qu.:0.00000 3rd Qu.: 1.0000 3rd Qu.:0.3400
## Max. :30.3040 Max. :4.00000 Max. :2.48400 Max. :18.0000 Max. :7.2440
##
## intrawrd_N intrawrd_T maze_N maze_T repeat_N
## Min. : 0.0000 Min. : 0.0000 Min. : 0.0000 Min. :0.0000 Min. :0.0000
## 1st Qu.: 0.0000 1st Qu.: 0.0000 1st Qu.: 0.0000 1st Qu.:0.0000 1st Qu.:0.0000
## Median : 0.0000 Median : 0.0000 Median : 0.0000 Median :0.0000 Median :0.0000
## Mean : 0.6541 Mean : 0.1531 Mean : 0.4533 Mean :0.1725 Mean :0.3264
## 3rd Qu.: 1.0000 3rd Qu.: 0.1040 3rd Qu.: 1.0000 3rd Qu.:0.1280 3rd Qu.:0.0000
## Max. :23.0000 Max. :12.9420 Max. :14.0000 Max. :5.9840 Max. :9.0000
##
## repeat_T selfcor_N selfcor_T skip_N skip_T
## Min. :0.0000 Min. :0.0000 Min. :0.0000 Min. :0.00000 Min. :0.0000000
## 1st Qu.:0.0000 1st Qu.:0.0000 1st Qu.:0.0000 1st Qu.:0.00000 1st Qu.:0.0000000
## Median :0.0000 Median :0.0000 Median :0.0000 Median :0.00000 Median :0.0000000
## Mean :0.1724 Mean :0.2834 Mean :0.1693 Mean :0.08664 Mean :0.0001988
## 3rd Qu.:0.0000 3rd Qu.:0.0000 3rd Qu.:0.0000 3rd Qu.:0.00000 3rd Qu.:0.0000000
## Max. :5.3910 Max. :7.0000 Max. :5.5880 Max. :3.00000 Max. :0.0340000
##
```

3.1 Counts and durations of marked intervals

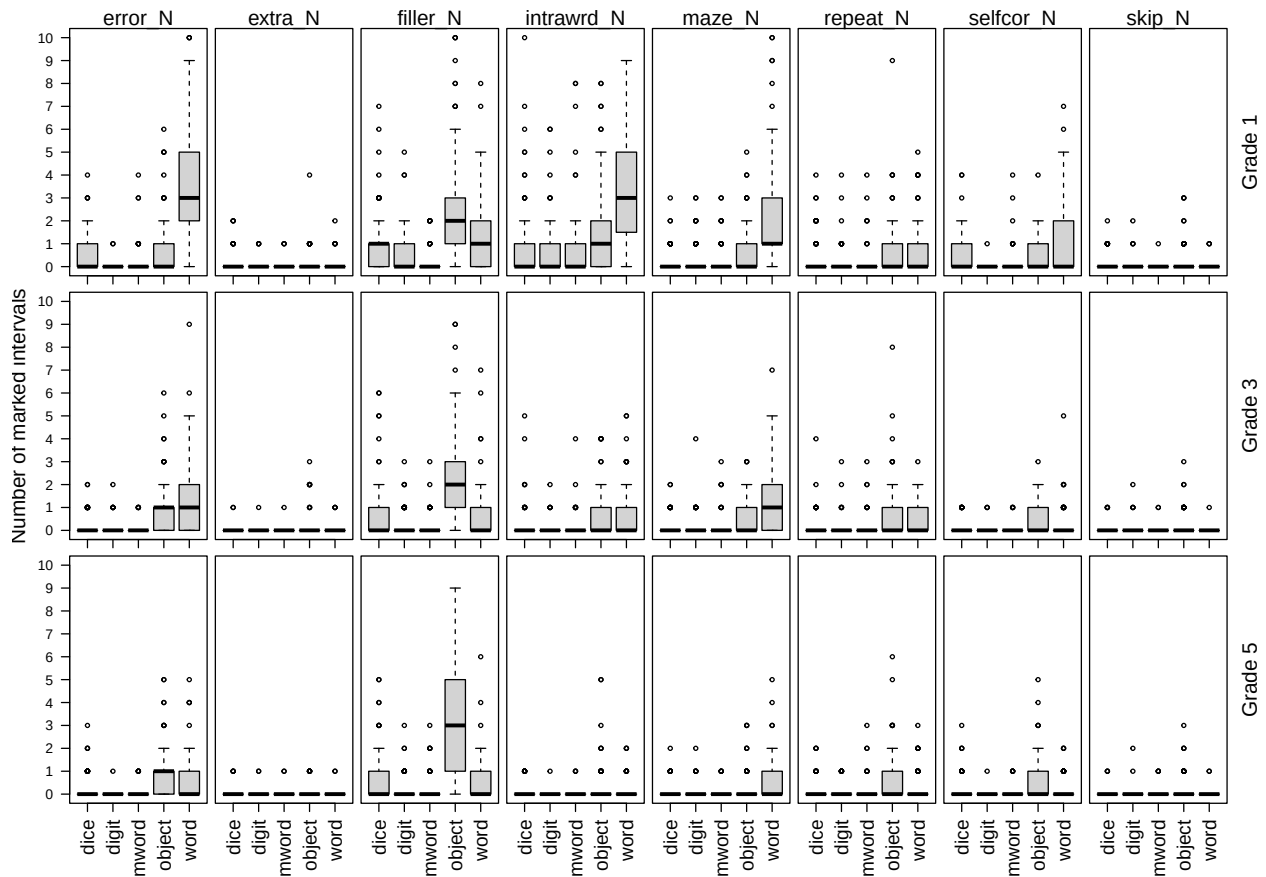
Here is a rough distribution of the number and duration of marked irregular intervals per task and grade (that is, intervals where the spoken record deviates from the normative response; see “Interval marking and processing” folder for definitions and procedures). Boxplots can only convey a limited sense of the distribution, however they make it possible to display a summary table of panels permitting direct comparisons among tasks and grades. Individual histograms for each variable are displayed in the next section.

```
tasks <- levels(serd$task)
ernumv <- names(serd)[grepl("_N$",names(serd))]
par(mfrow=c(3,length(ernumv)))
par(mar=c(0.5,0.5,0.5,0))
par(oma=c(4,3,1,2))
for (grd in levels(serd$grade)) {
  for (v in ernumv) {
    frm <- as.formula(paste(v,"task",sep="~"))
    boxplot(frm,serd,subset= grade==grd, main="", ylim=c(0,10), xlab="", ylab="", yaxt="n", xaxt="n")
    if (grd=="G5") {
      axis(1,at=1:length(tasks),labels=tasks,las=2,cex.axis=1.4)
    } else {
      axis(1,at=1:length(tasks),labels=FALSE,las=2)
    }
    if (grd=="G1") { mtext(v,3,xpd=NA)}
  }
}
```

```

    if (v==ernumv[1]) { axis(2,at=0:10,las=1,xpd=NA) }
    if (v==ernumv[length(ernumv)]) {
      mtext(paste("Grade",substr(grd,2,2),sep=" "),4,cex=1,line=1.0,xpd=NA)
    }
  }
}
mtext("Number of marked intervals",side=2,outer=T,line=2,xpd=NA)

```



```

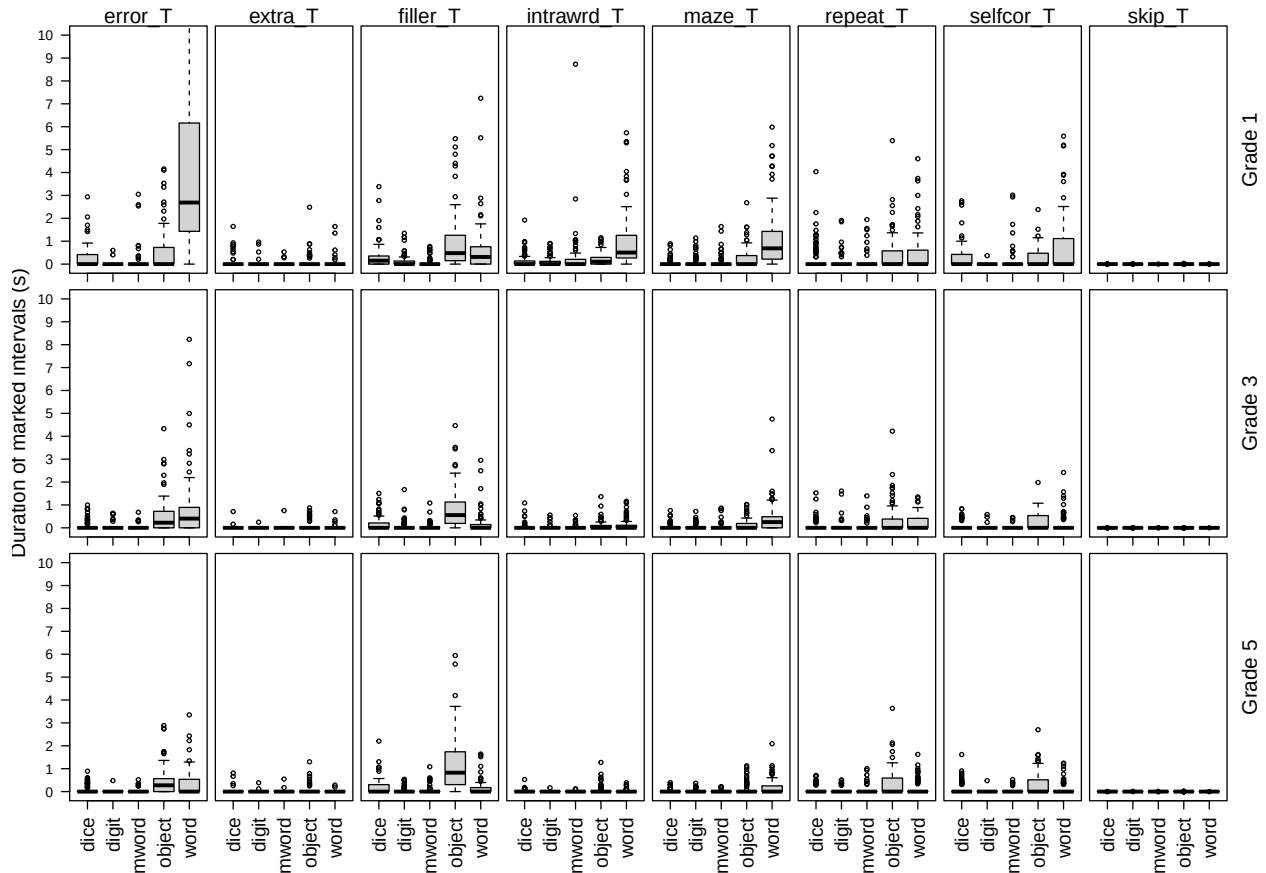
ertimv <- names(serd)[grepl("_T$",names(serd))]
par(mfrow=c(3,length(ertimv)))
par(mar=c(0.5,0.5,0.5,0))
par(oma=c(4,3,1,2))
for (grd in levels(serd$grade)) {
  for (v in ertimv) {
    frm <- as.formula(paste(v,"task",sep="~"))
    boxplot(frm,serd,subset= grade==grd, main="", ylim=c(0,10), xlab="", ylab="", yaxt="n", xaxt="n")
    if (grd=="G5") {
      axis(1,at=1:length(tasks),labels=tasks,las=2,cex.axis=1.4)
    } else {
      axis(1,at=1:length(tasks),labels=FALSE,las=2)
    }
    if (grd=="G1") { mtext(v,3,xpd=NA)}
    if (v==ertimv[1]) { axis(2,at=0:10,las=1,xpd=NA) }
    if (v==ertimv[length(ertimv)]) {
      mtext(paste("Grade",substr(grd,2,2),sep=" "),4,cex=1,line=1.0,xpd=NA)
    }
  }
}

```

```

}
}
mtext("Duration of marked intervals (s)",side=2,outer=T,line=2,xpd=NA)

```



Unsurprisingly, both counts and durations are higher in lower grades and highest for word reading, followed by object naming. Perhaps unexpectedly, instances of fillers continue to affect object naming to a substantial extent even in higher grades, indicating that this may be the most persistently challenging task.

3.2 Histograms by task and grade

```

vnam <- names(serd)
counts <- c("artNE", "pauNE", vnam[substr(vnam, nchar(vnam)-1, nchar(vnam))=="_N"])
times <- c("arttotE", "pautotE", vnam[substr(vnam, nchar(vnam)-1, nchar(vnam))=="_T"])

tnam <- levels(serd$task)
gnam <- sort(levels(serd$grade))

for (j in 1:(length(counts)+length(times))) {
  if (j<=length(counts)) {
    i <- j
    hvar <- counts[i]
  } else {
    i <- j-length(counts)
    hvar <- times[i]
  }
}

```

```

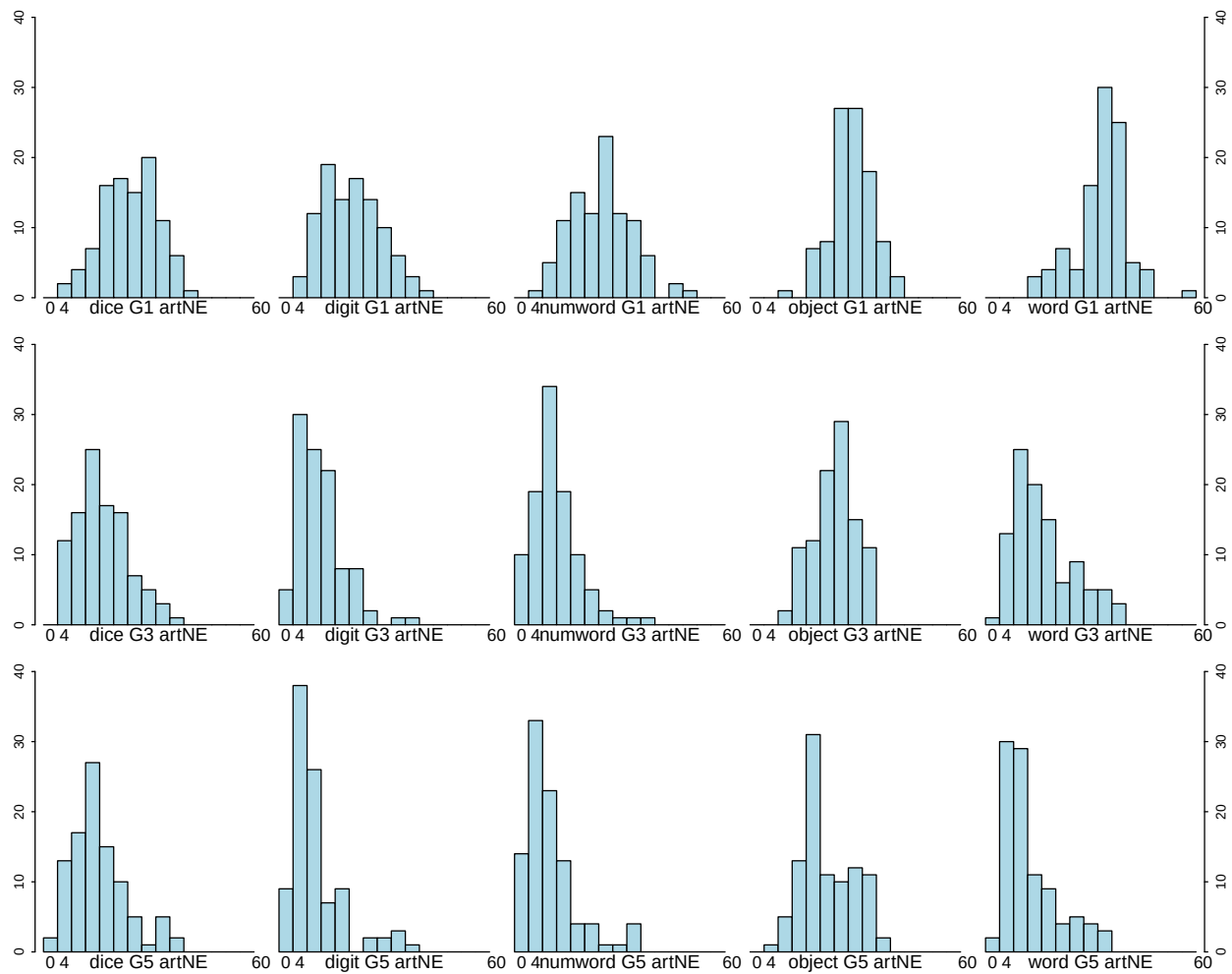
print("
print("=====")
print("==")
print(paste("== Histograms for",hvar))
par(mfcol=c(3,5))
par(oma=c(0,1.5,0,1.5))
par(mar=c(1,0,0.5,0.5))
par(mgp=c(2,0.5,0))
par(tcl= -0.2)
for (tsk in tnam) {
  for (grd in gnam) {
    wblk <- ifelse(i<=2,4,ifelse(i==3,ifelse(j==i,1,2),1))
    nbrk <- 15
    data <- serd[serd$task==tsk & serd$grade==grd,hvar]
    data[data>=nbrk*wbk] <- nbrk*wbk-1
    hist(data,
          ylim=c(0,40),breaks=(0:nbrk)*wbk,
          axes=FALSE,right=FALSE, # right=FALSE to distinguish zeros from ones
          main="",col="lightblue")
    title(sub=paste(tsk,grd,hvar),line= -0.5,cex.sub=1.35)
    if (tsk==tnam[1]) { axis(2,at=0:4*10) }
    if (tsk==tnam[length(tnam)]) { axis(4,at=0:4*10) }
    for (pnt in c(0,wbk,nbrk*wbk)){
      xpnt <- pnt+0.5*wbk
      mtext(as.character(pnt),side=1,line=-0.5,at=xpnt,adj=0.5,cex=0.8)
    }
  }
}
}

```

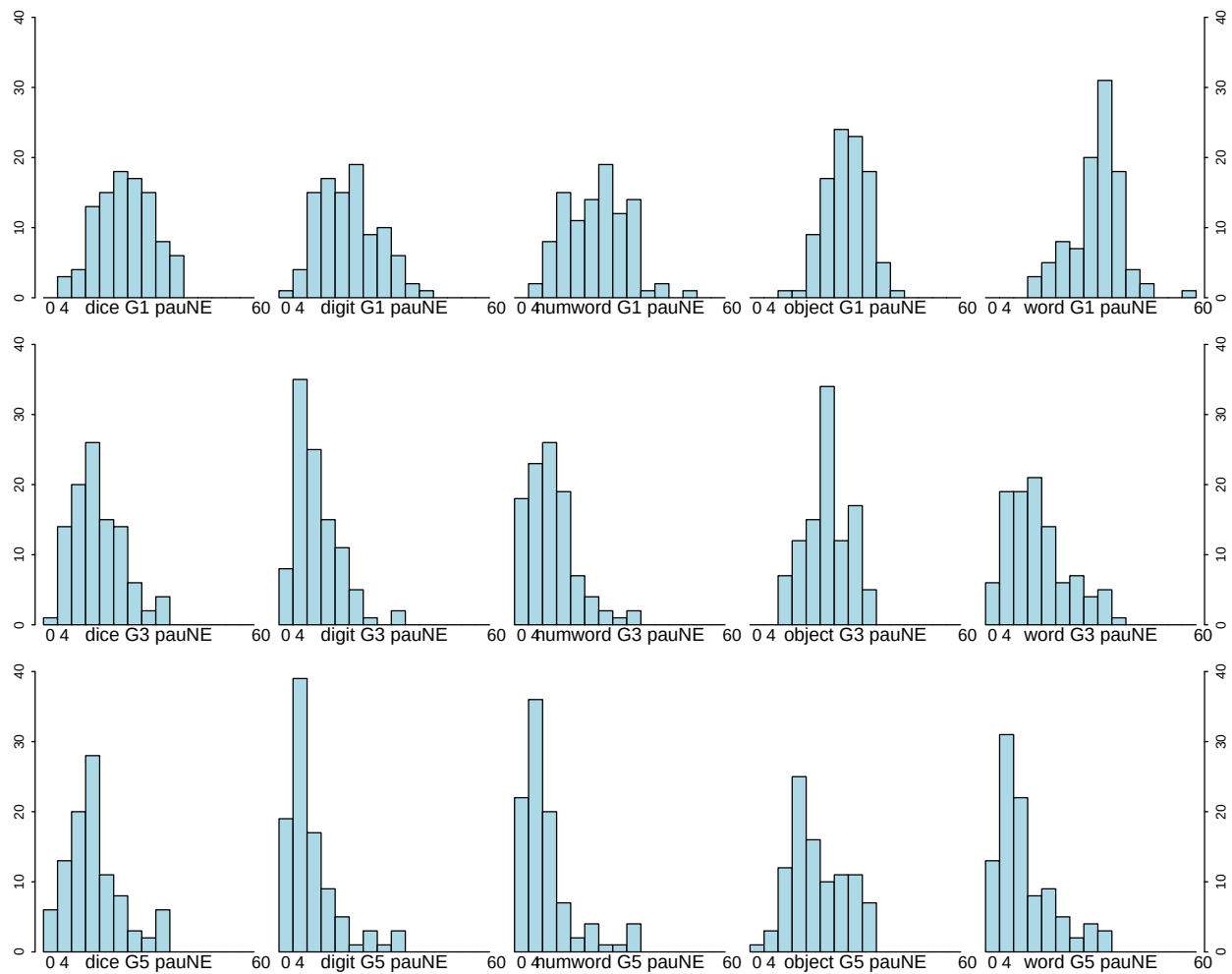
```

## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for artNE"

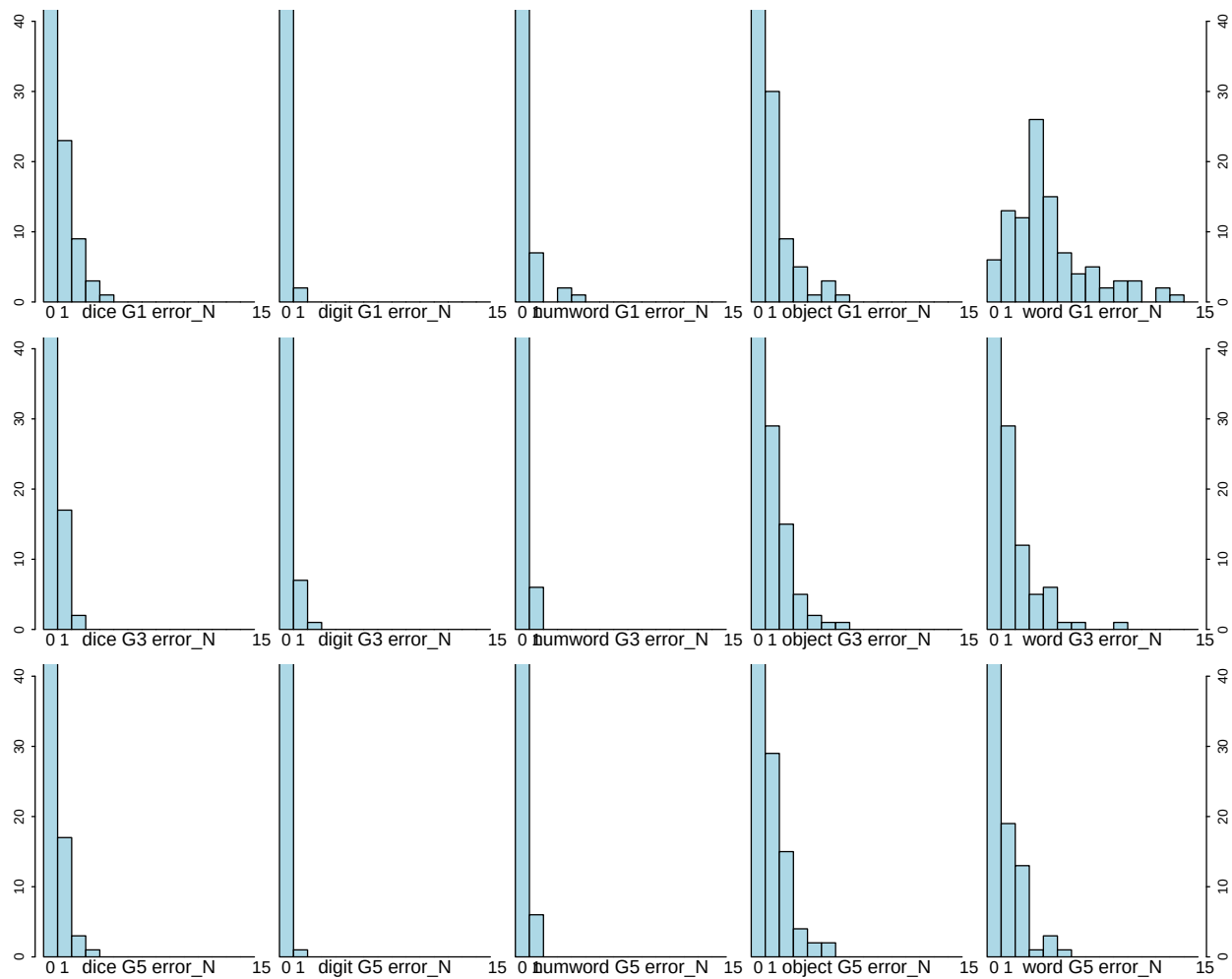
```



```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for pauNE"
```



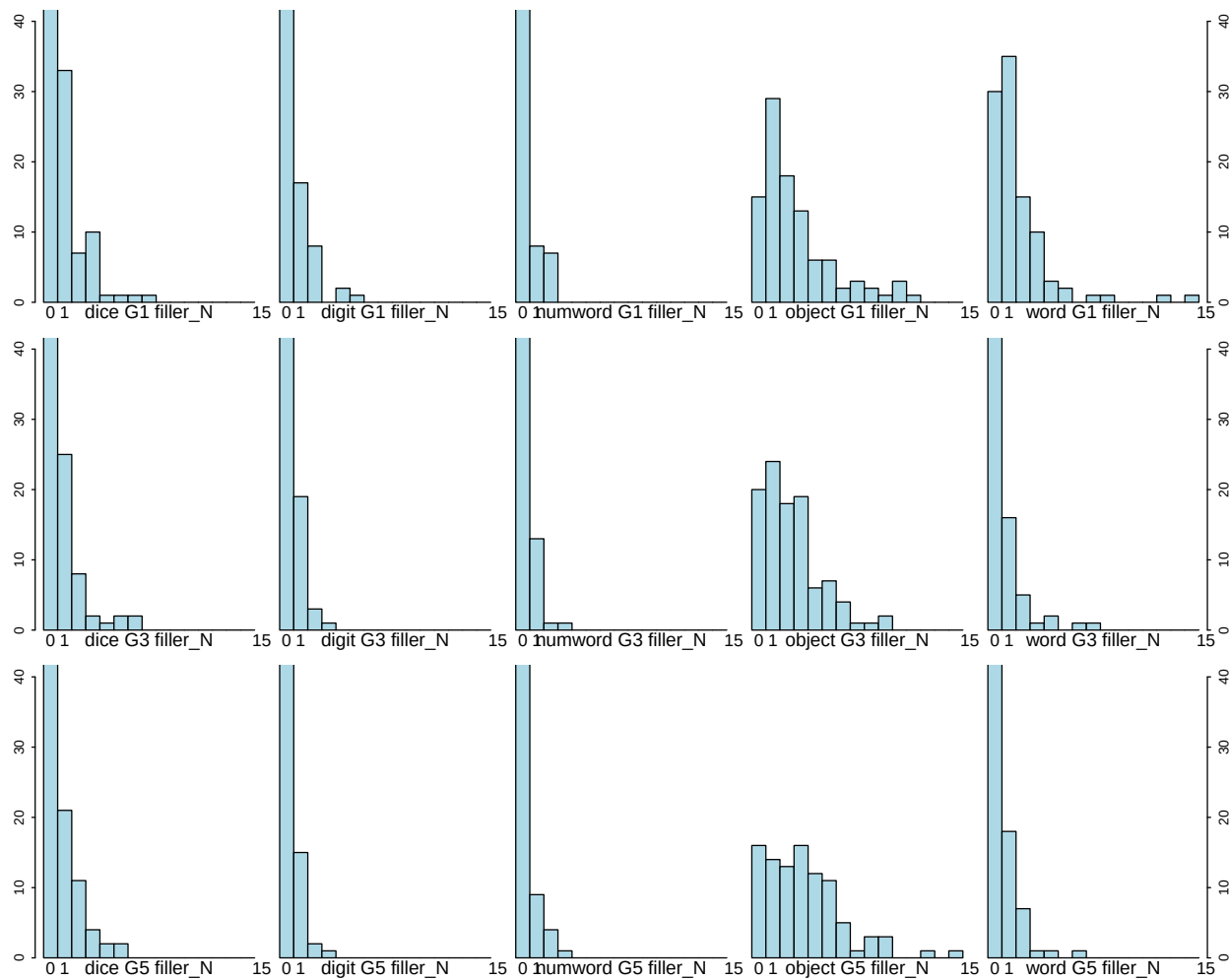
```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for error_N"
```



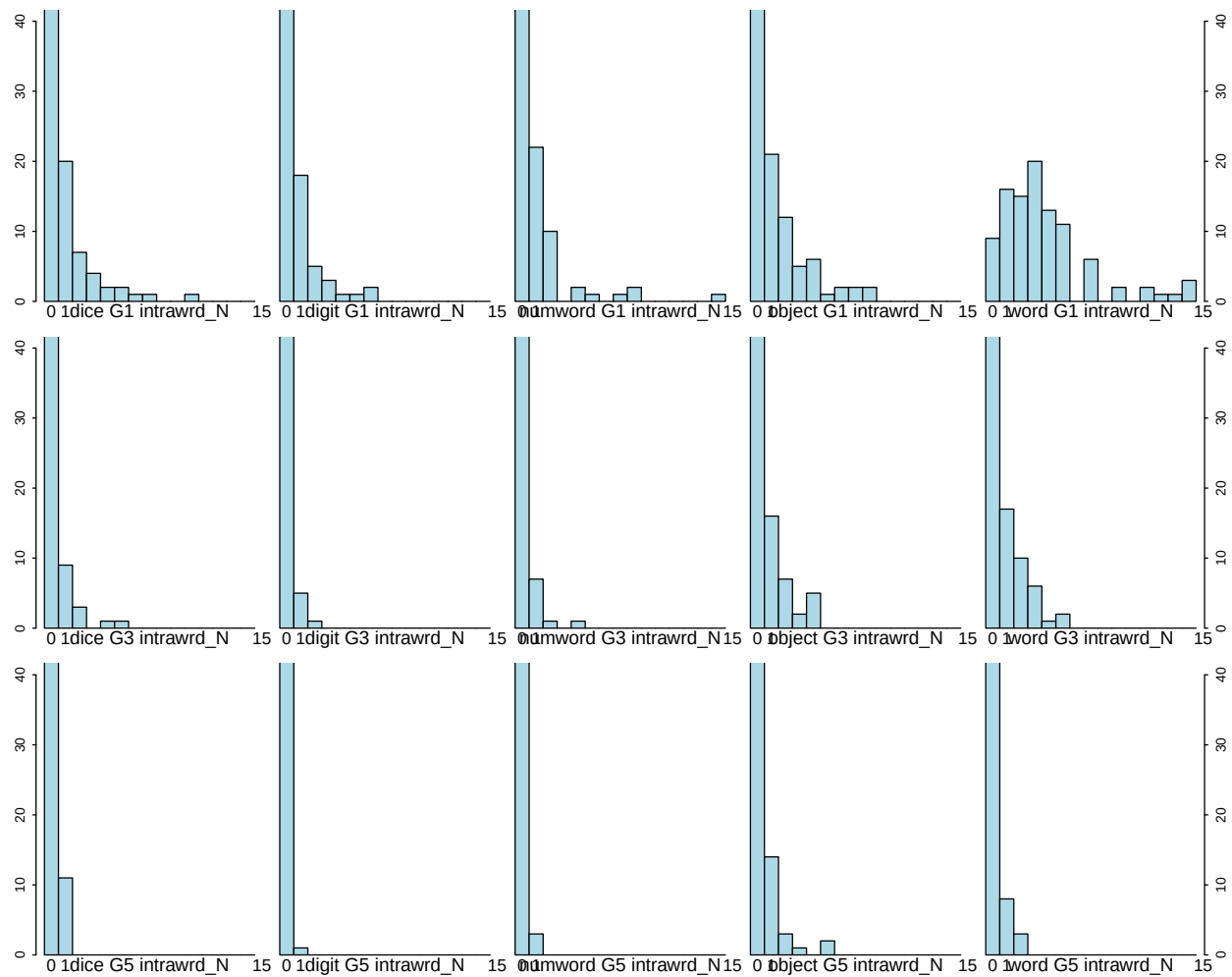
```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for extra_N"
```



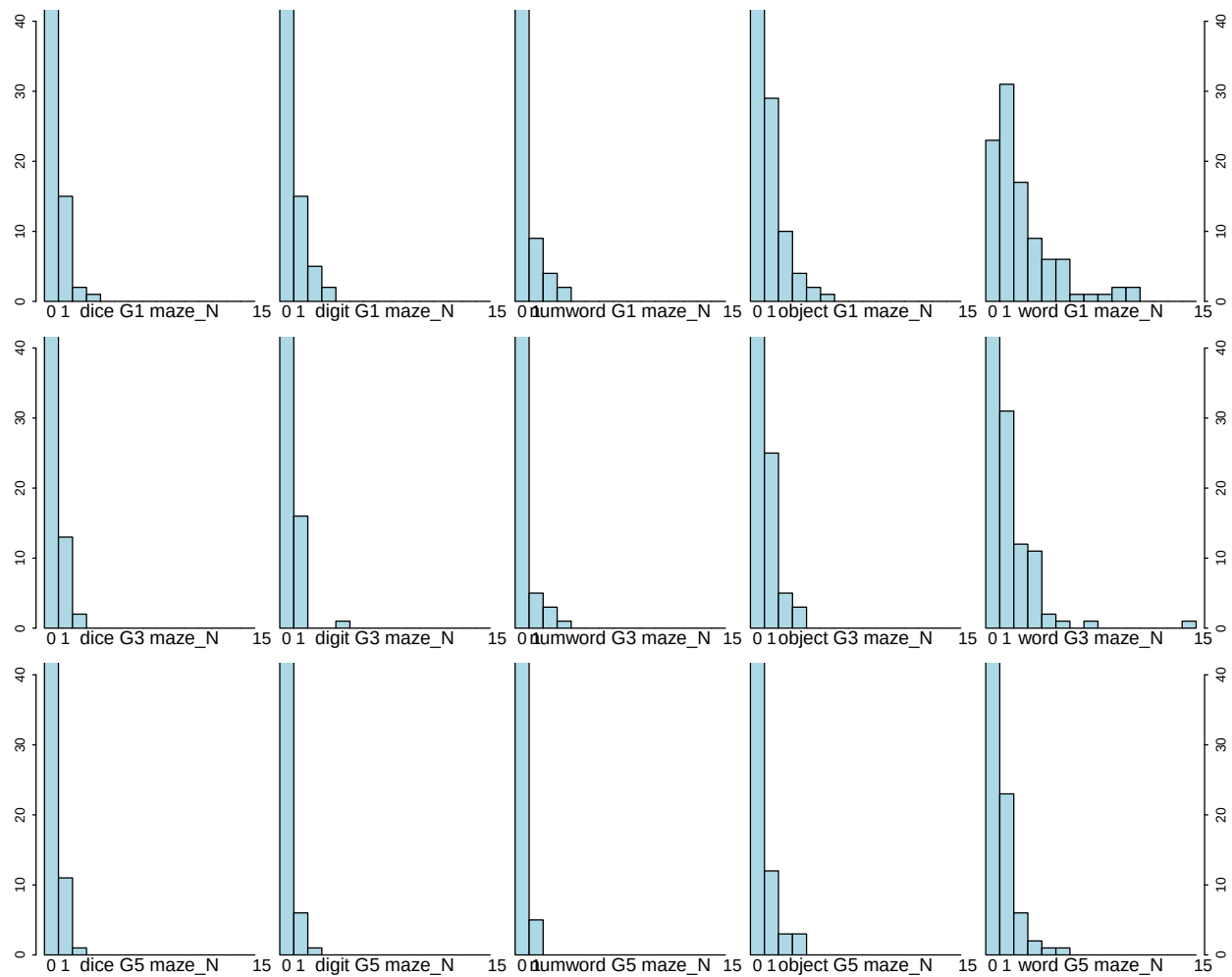
```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for filler_N"
```



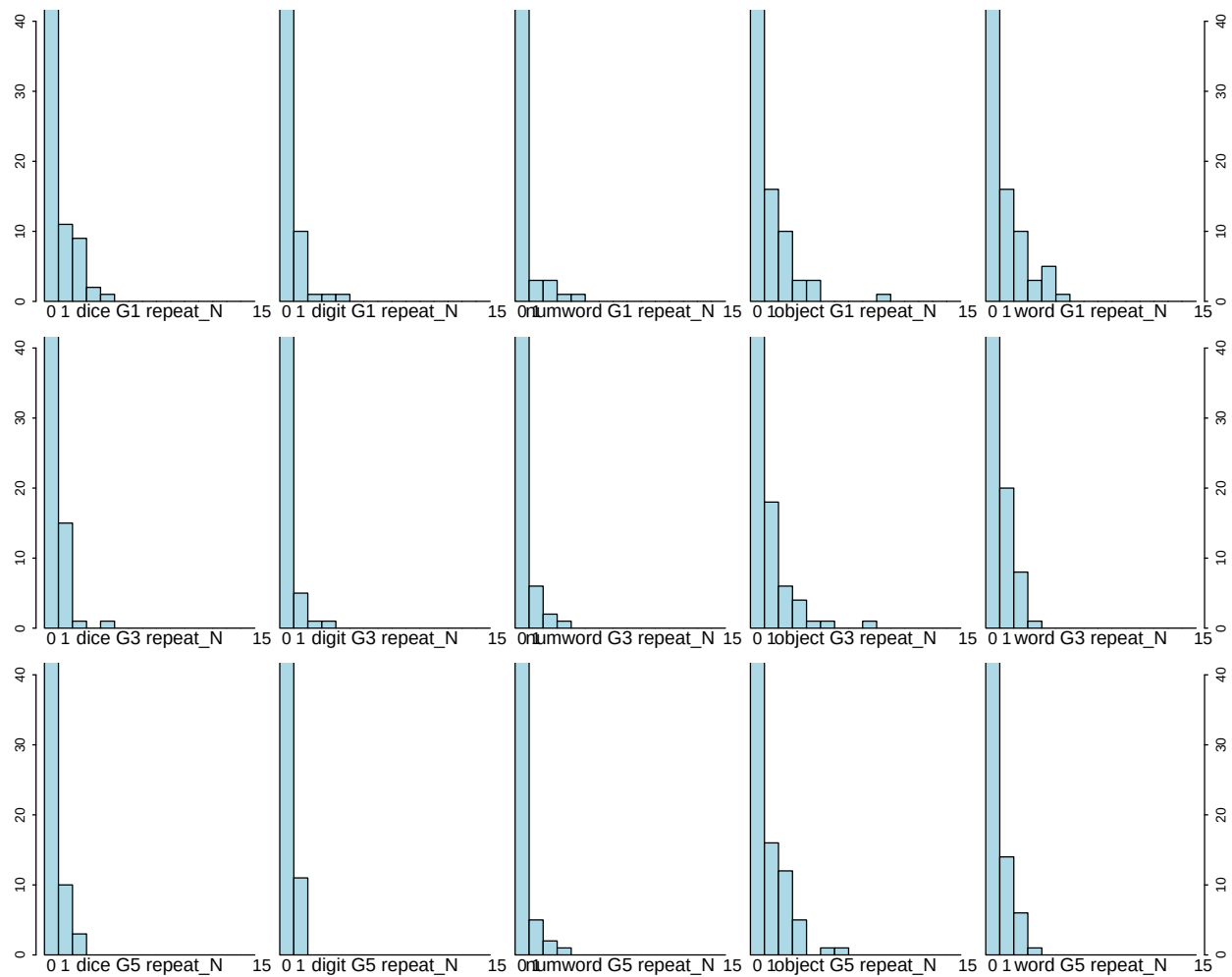
```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for intrawrd_N"
```



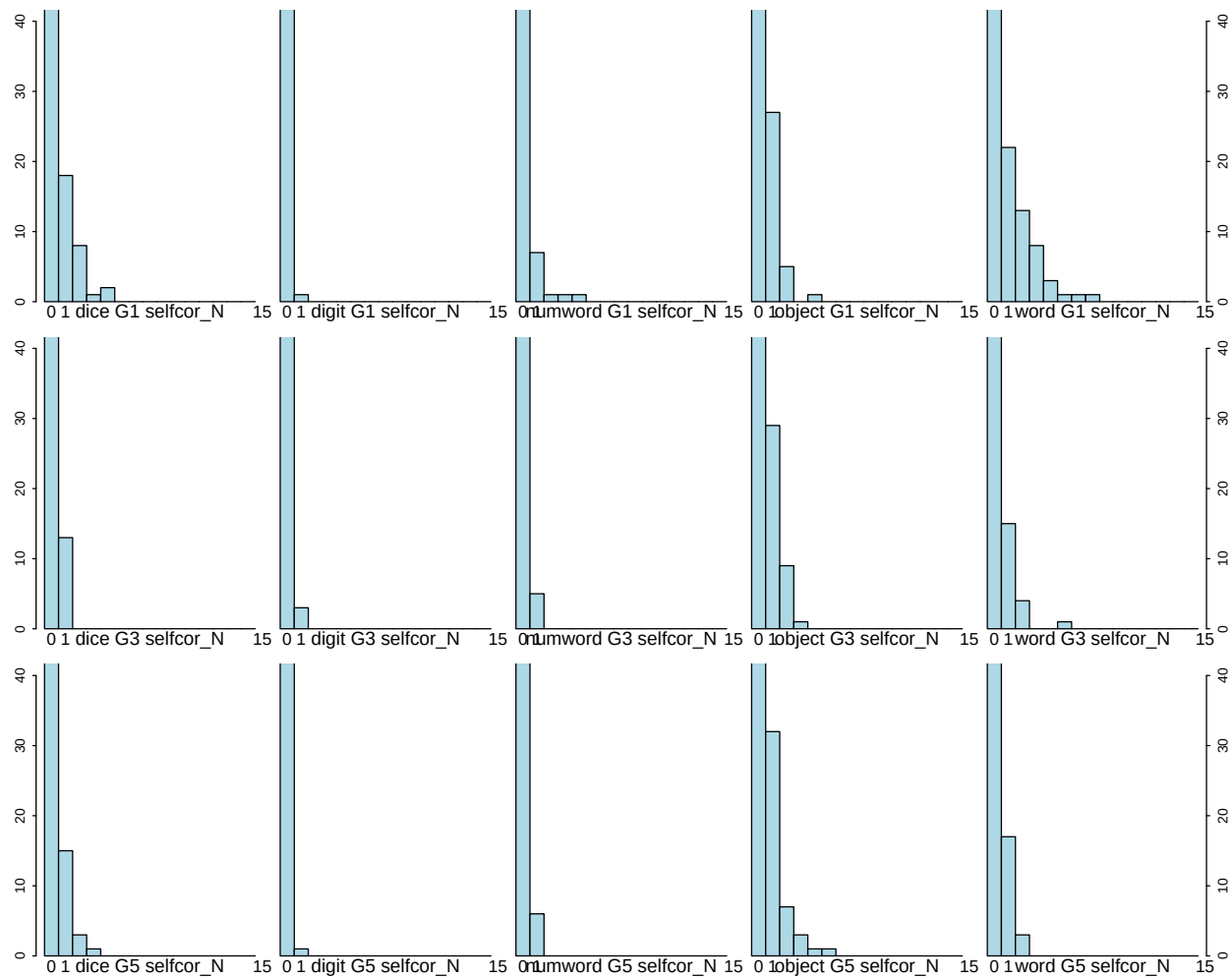
```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for maze_N"
```



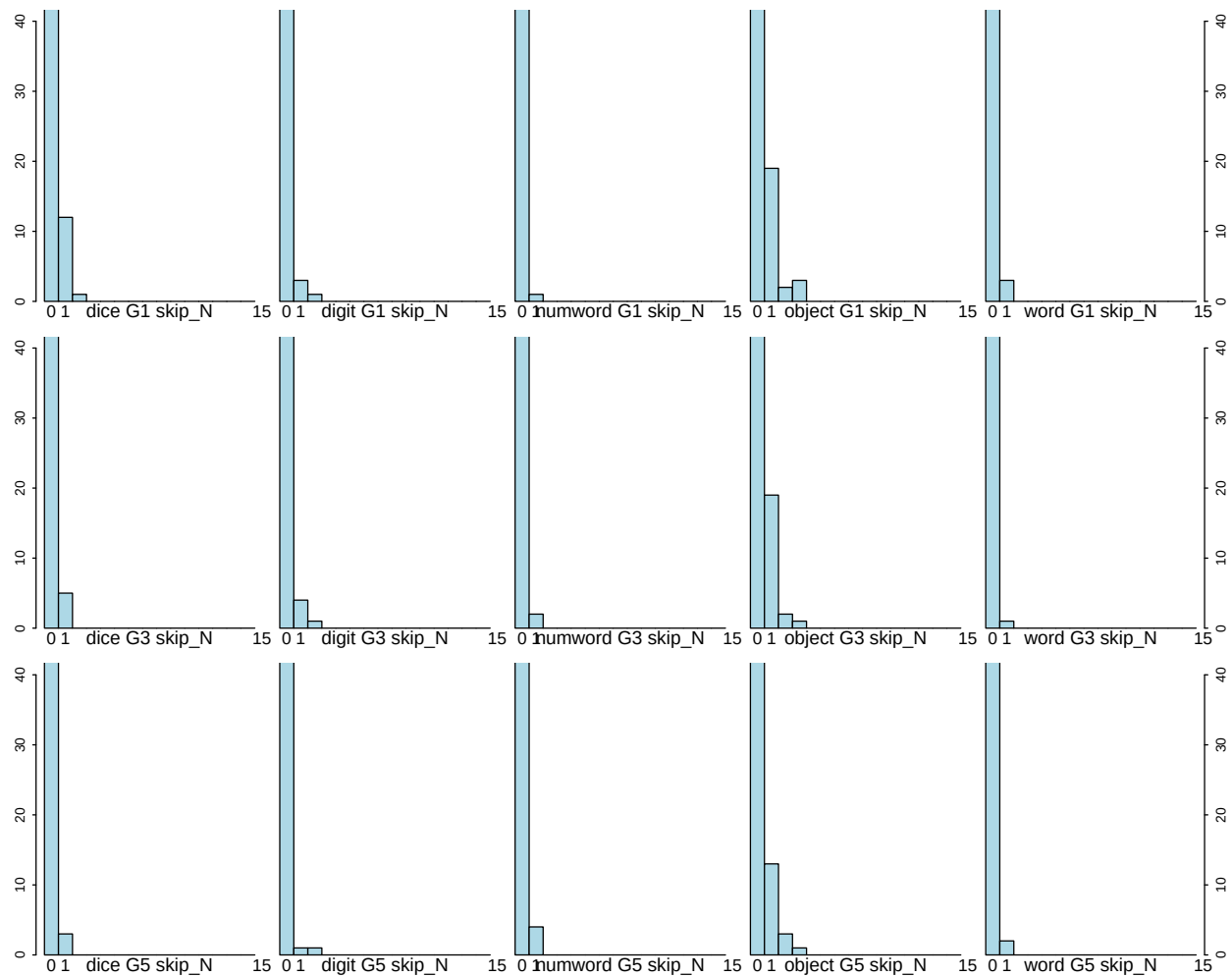
```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for repeat_N"
```



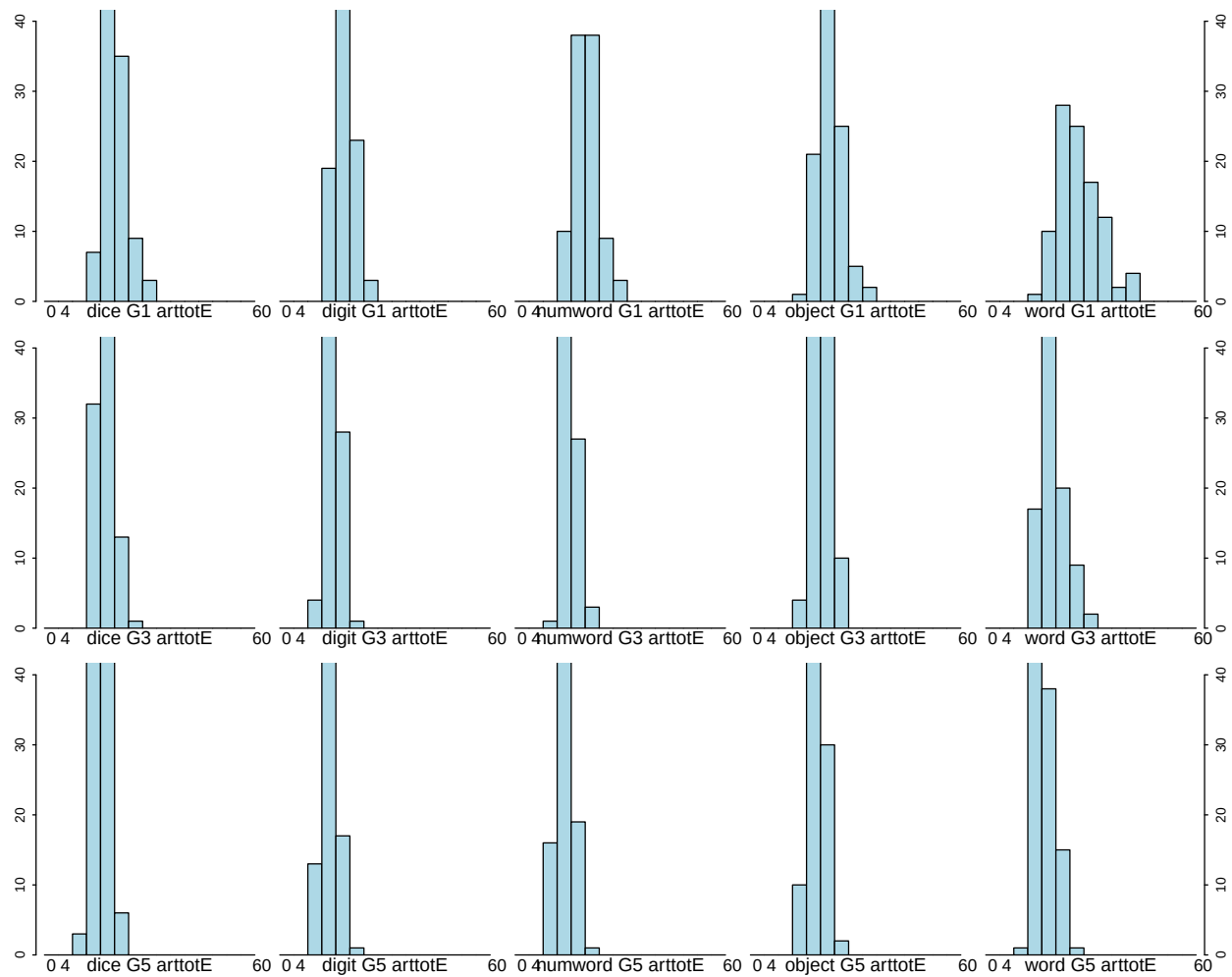
```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for selfcor_N"
```



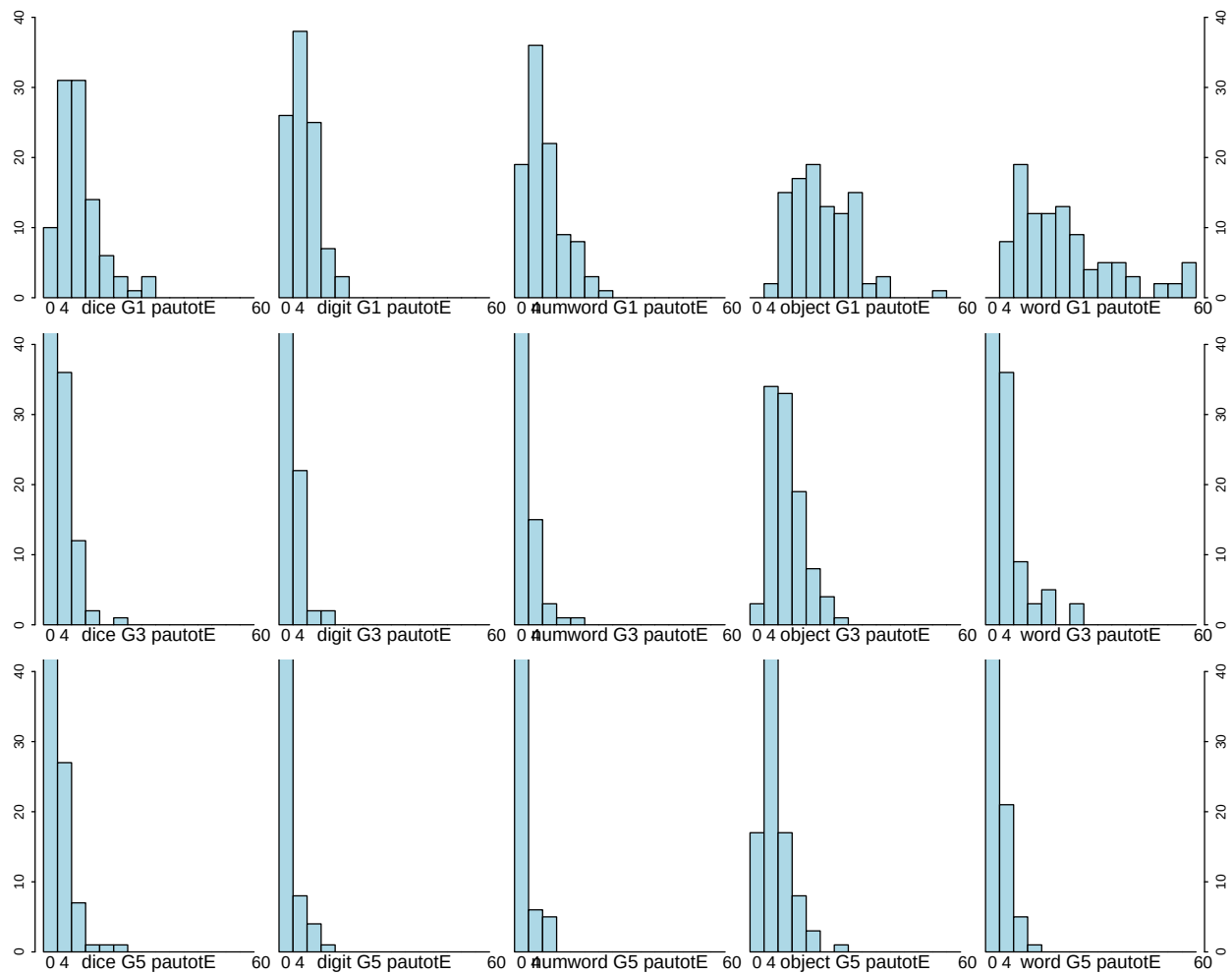
```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for skip_N"
```



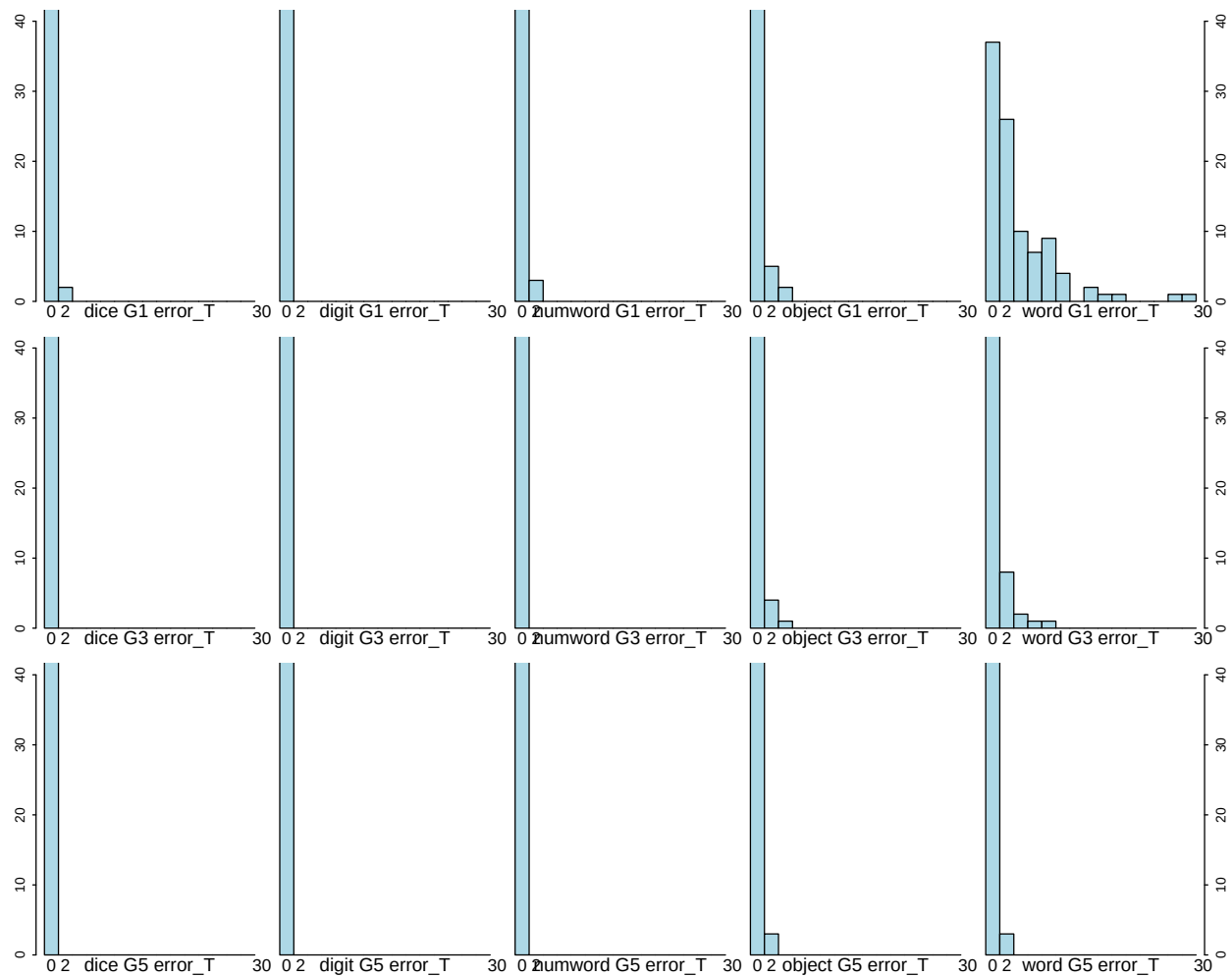
```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for arttotE"
```



```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for pautotE"
```



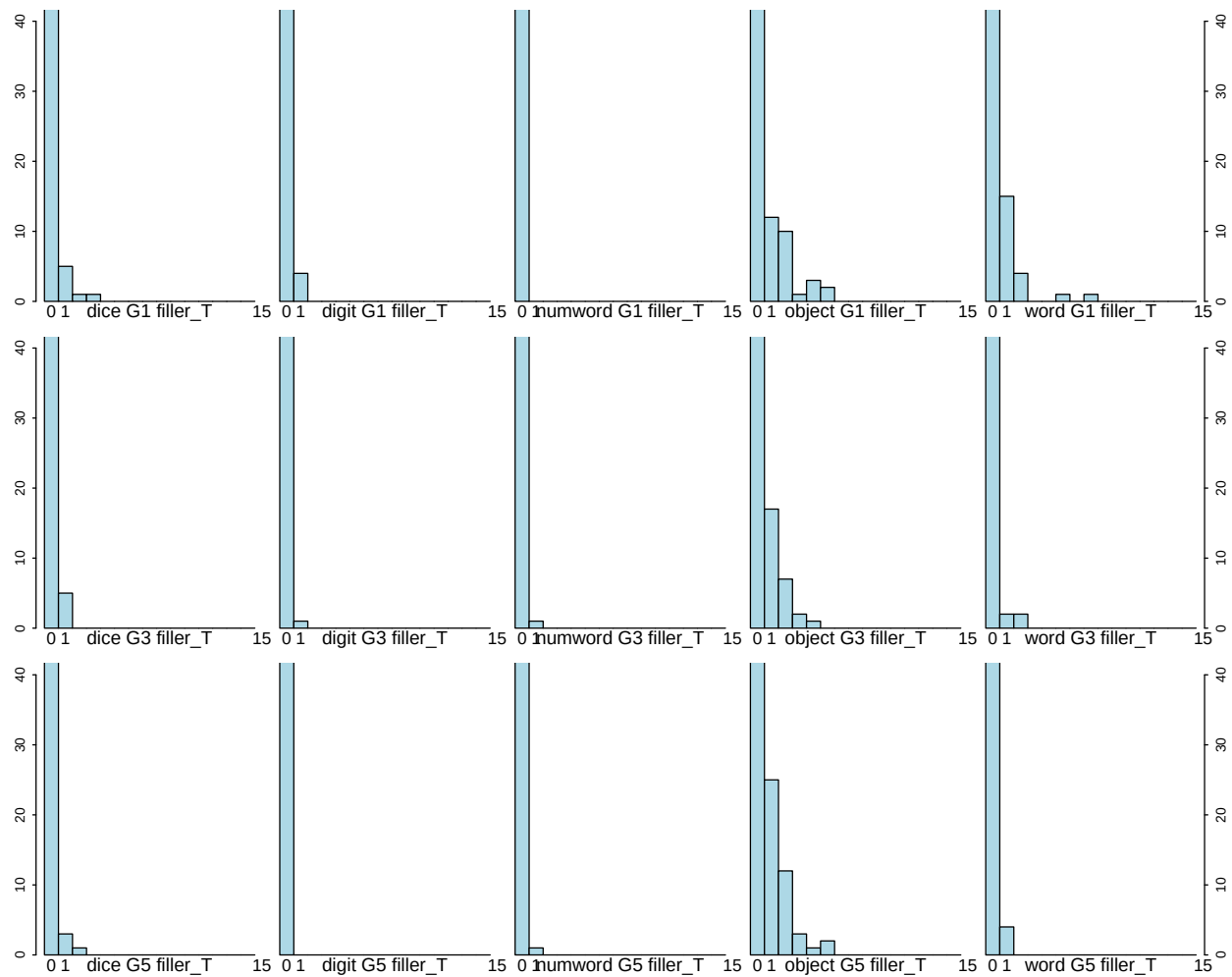
```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for error_T"
```



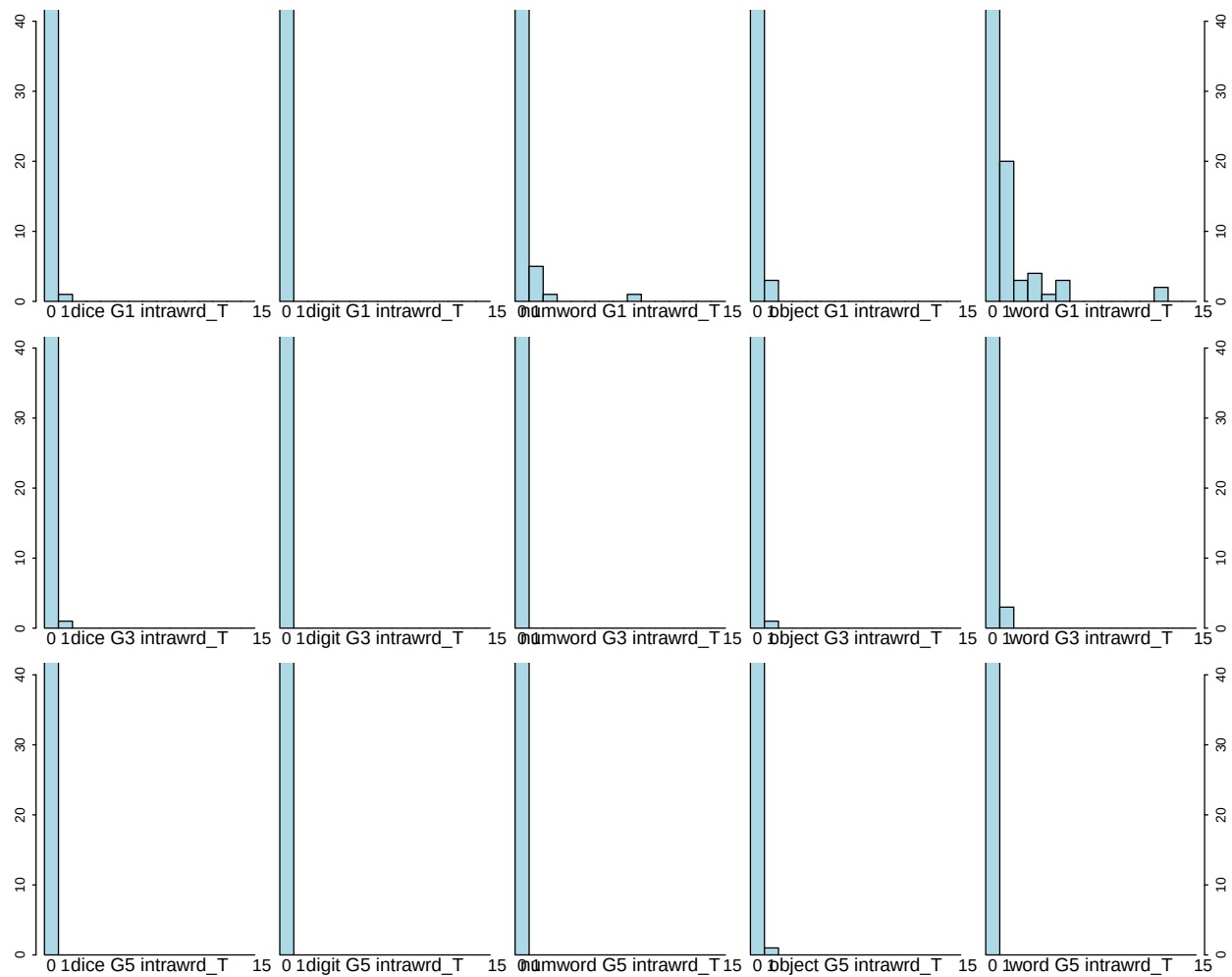
```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for extra_T"
```



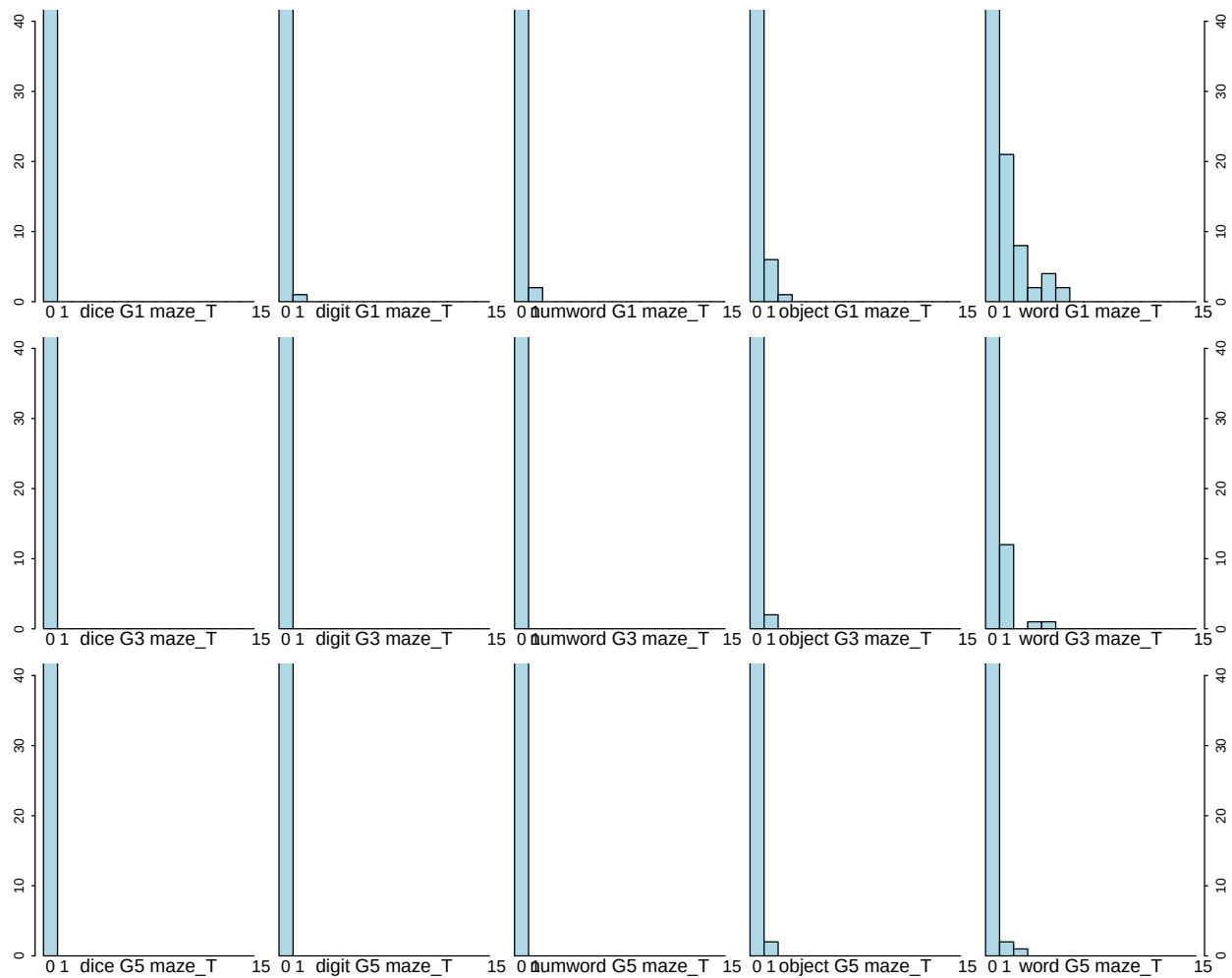
```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for filler_T"
```



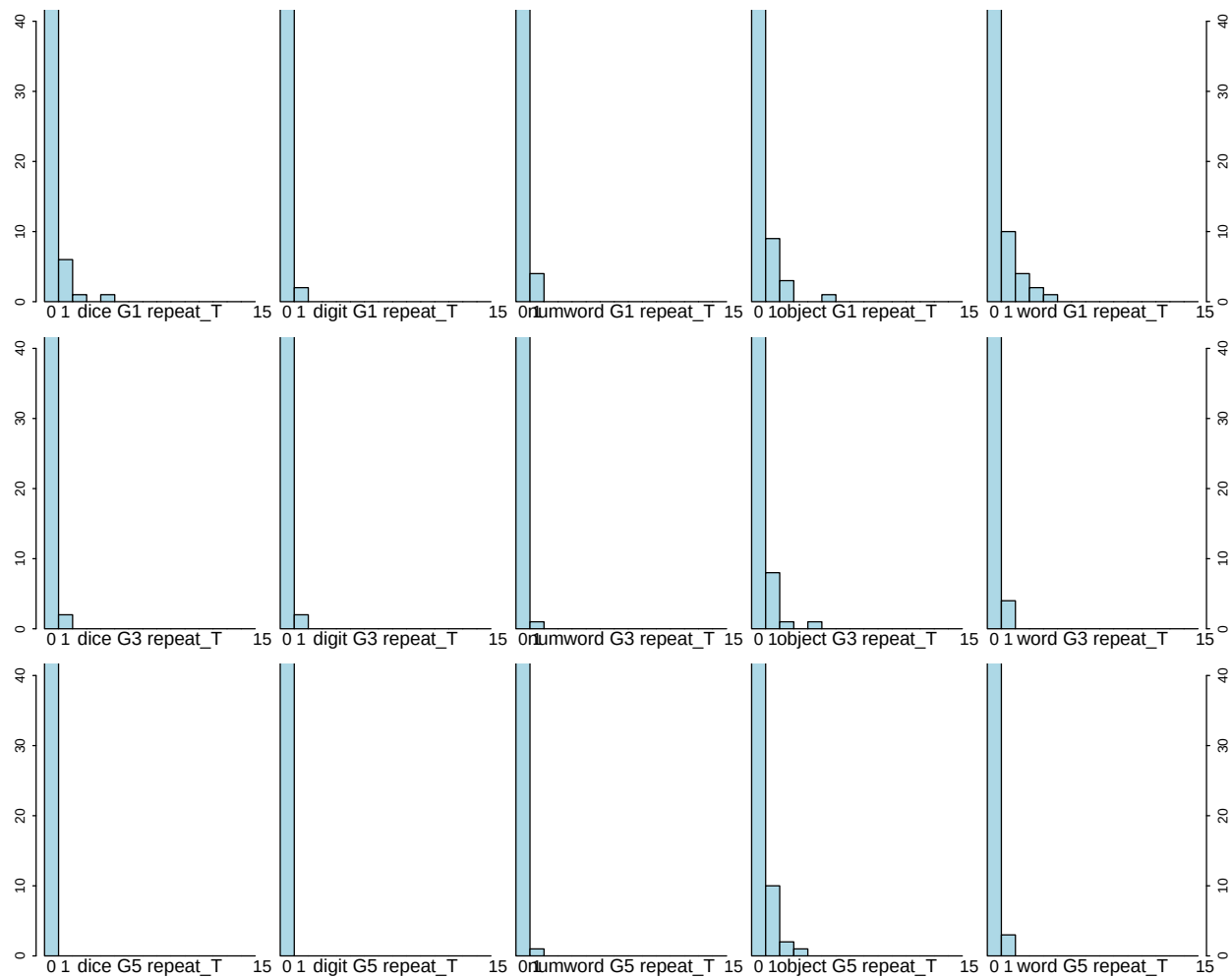
```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for intrawrd_T"
```



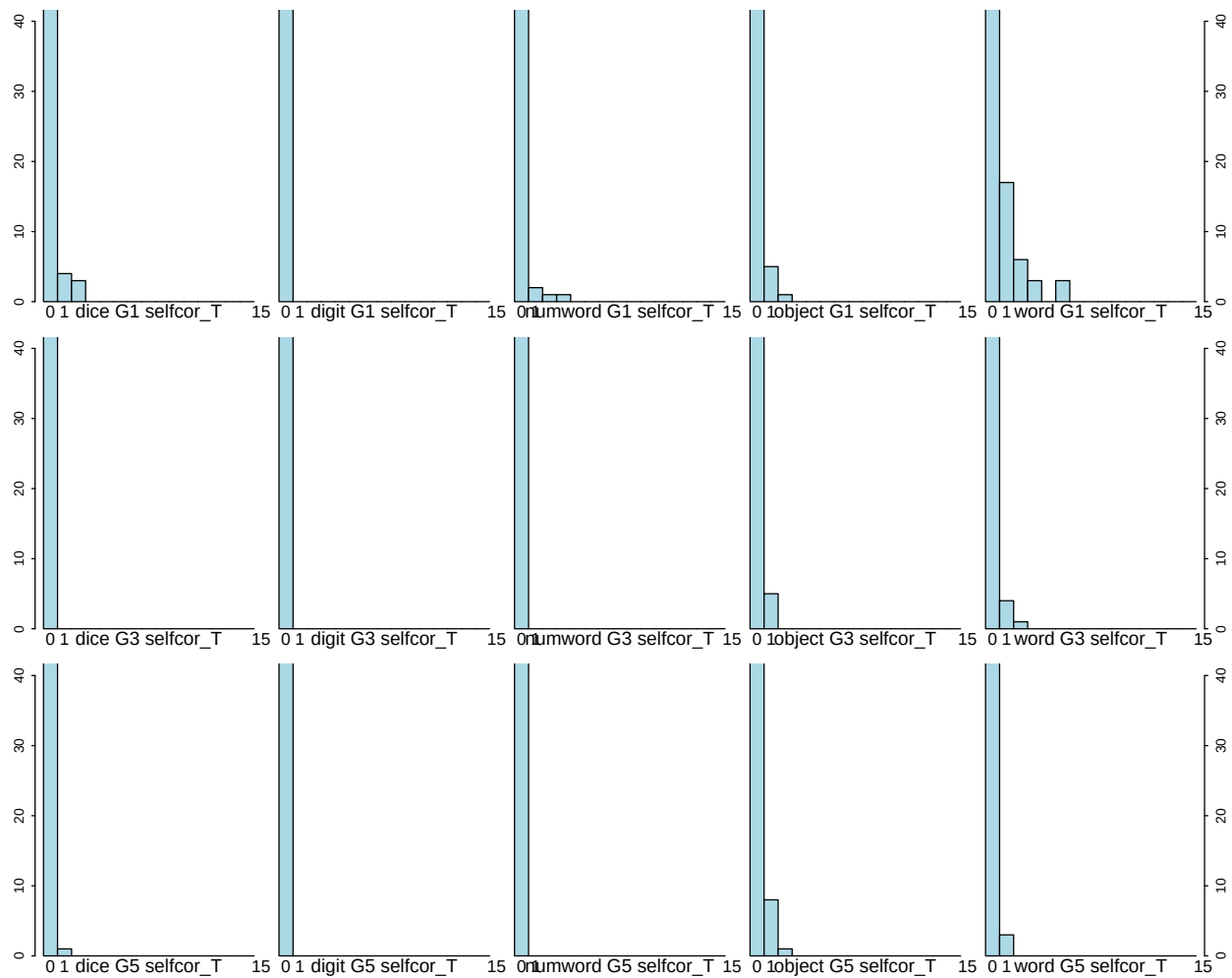
```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for maze_T"
```



```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for repeat_T"
```



```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for selfcor_T"
```



```
## [1] "
## [1] "=====
## [1] "=="
## [1] "== Histograms for skip_T"
```



3.3 Descriptives by task and grade

Here we report basic descriptive statistics for each variable (by grade and task), first for counts and then for durations.

```
describeBy(as.formula(paste(paste(eval(counts),collapse="+"), "grade+task", sep="~")), data=serd)
```

```
##
## Descriptive statistics by group
## grade: G1
## task: dice
##
```

	vars	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
artNE	1	99	24.32	7.72	25	24.43	7.41	7	41	34	-0.12	-0.63	0.78
pauNE	2	99	22.96	7.82	23	23.06	8.90	5	39	34	-0.13	-0.63	0.79
error_N	3	99	0.55	0.86	0	0.38	0.00	0	4	4	1.67	2.50	0.09
extra_N	4	99	0.13	0.42	0	0.01	0.00	0	2	2	3.27	10.17	0.04
filler_N	5	99	1.00	1.35	1	0.77	1.48	0	7	7	1.96	4.56	0.14
intrawrd_N	6	99	0.88	1.67	0	0.49	0.00	0	10	10	2.87	9.75	0.17
maze_N	7	99	0.22	0.53	0	0.11	0.00	0	3	3	2.70	8.25	0.05
repeat_N	8	99	0.39	0.82	0	0.21	0.00	0	4	4	2.16	4.31	0.08
selfcor_N	9	99	0.45	0.85	0	0.27	0.00	0	4	4	2.17	4.96	0.09
skip_N	10	99	0.14	0.38	0	0.05	0.00	0	2	2	2.57	6.12	0.04

```

## -----
## grade: G3
## task: dice
##      vars  n  mean   sd median trimmed  mad min max range skew kurtosis   se
## artNE      1 102 16.23 7.31   14.0   15.72 7.41   4 36   32 0.57   -0.31 0.72
## pauNE      2 102 14.95 7.16   13.5   14.43 8.15   3 35   32 0.62   -0.15 0.71
## error_N     3 102  0.21 0.45    0.0    0.11 0.00   0 2    2 2.05    3.46 0.04
## extra_N     4 102  0.02 0.14    0.0    0.00 0.00   0 1    1 6.83   45.06 0.01
## filler_N    5 102  0.72 1.26    0.0    0.43 0.00   0 6    6 2.47    6.45 0.12
## intrawrd_N  6 102  0.24 0.75    0.0    0.05 0.00   0 5    5 4.26   20.58 0.07
## maze_N      7 102  0.17 0.42    0.0    0.06 0.00   0 2    2 2.50    5.77 0.04
## repeat_N    8 102  0.21 0.55    0.0    0.09 0.00   0 4    4 3.93   20.77 0.05
## selfcor_N   9 102  0.13 0.34    0.0    0.04 0.00   0 1    1 2.20    2.88 0.03
## skip_N     10 102  0.05 0.22    0.0    0.00 0.00   0 1    1 4.12   15.09 0.02
## -----
## grade: G5
## task: dice
##      vars  n  mean   sd median trimmed  mad min max range skew kurtosis   se
## artNE      1 97 15.15 7.91    14   14.38 5.93   2 36   34 0.88    0.50 0.80
## pauNE      2 97 13.80 7.84    13   13.00 5.93   1 35   34 0.92    0.57 0.80
## error_N     3 97  0.27 0.57     0    0.15 0.00   0 3    3 2.31    5.68 0.06
## extra_N     4 97  0.04 0.20     0    0.00 0.00   0 1    1 4.54   18.84 0.02
## filler_N    5 97  0.75 1.15     0    0.52 0.00   0 5    5 1.77    2.91 0.12
## intrawrd_N  6 97  0.11 0.32     0    0.03 0.00   0 1    1 2.40    3.80 0.03
## maze_N      7 97  0.13 0.37     0    0.04 0.00   0 2    2 2.70    6.91 0.04
## repeat_N    8 97  0.16 0.45     0    0.05 0.00   0 2    2 2.73    6.87 0.05
## selfcor_N   9 97  0.25 0.56     0    0.13 0.00   0 3    3 2.48    6.55 0.06
## skip_N     10 97  0.03 0.17     0    0.00 0.00   0 1    1 5.34   26.74 0.02
## -----
## grade: G1
## task: digit
##      vars  n  mean   sd median trimmed  mad min max range skew kurtosis   se
## artNE      1 99 20.34 8.30    20   20.00 8.9   4 41   37 0.31   -0.69 0.83
## pauNE      2 99 19.21 8.30    19   18.85 8.9   3 40   37 0.32   -0.69 0.83
## error_N     3 99  0.02 0.14     0    0.00 0.0   0 1    1 6.72   43.57 0.01
## extra_N     4 99  0.04 0.20     0    0.00 0.0   0 1    1 4.60   19.33 0.02
## filler_N    5 99  0.46 0.93     0    0.26 0.0   0 5    5 2.59    7.63 0.09
## intrawrd_N  6 99  0.59 1.21     0    0.30 0.0   0 6    6 2.76    8.06 0.12
## maze_N      7 99  0.31 0.66     0    0.16 0.0   0 3    3 2.25    4.70 0.07
## repeat_N    8 99  0.19 0.60     0    0.05 0.0   0 4    4 4.10   19.32 0.06
## selfcor_N   9 99  0.01 0.10     0    0.00 0.0   0 1    1 9.65   92.06 0.01
## skip_N     10 99  0.05 0.26     0    0.00 0.0   0 2    2 5.57   32.97 0.03
## -----
## grade: G3
## task: digit
##      vars  n  mean   sd median trimmed  mad min max range skew kurtosis   se
## artNE      1 102 11.20 6.39    10   10.49 5.93   2 36   34 1.24    1.90 0.63
## pauNE      2 102 10.09 6.34     9    9.38 5.93   1 35   34 1.28    2.07 0.63
## error_N     3 102  0.09 0.32     0    0.00 0.00   0 2    2 3.73   14.48 0.03
## extra_N     4 102  0.01 0.10     0    0.00 0.00   0 1    1 9.80   95.06 0.01
## filler_N    5 102  0.27 0.57     0    0.16 0.00   0 3    3 2.24    5.38 0.06
## intrawrd_N  6 102  0.07 0.29     0    0.00 0.00   0 2    2 4.49   21.36 0.03
## maze_N      7 102  0.20 0.53     0    0.09 0.00   0 4    4 4.19   24.42 0.05
## repeat_N    8 102  0.10 0.41     0    0.00 0.00   0 3    3 4.95   27.15 0.04

```

```

## selfcor_N      9 102  0.03 0.17      0    0.00 0.00    0  1      1 5.49    28.41 0.02
## skip_N         10 102  0.06 0.28      0    0.00 0.00    0  2      2 5.00    26.65 0.03
## -----
## grade: G5
## task: digit
##           vars  n mean   sd median trimmed  mad min max range skew kurtosis  se
## artNE        1 97 9.97 7.38      8    8.65 4.45  2 36    34 1.76    2.79 0.75
## pauNE        2 97 8.87 7.38      7    7.53 4.45  1 35    34 1.77    2.81 0.75
## error_N       3 97 0.01 0.10      0    0.00 0.00  0  1     1 9.55   90.06 0.01
## extra_N       4 97 0.02 0.14      0    0.00 0.00  0  1     1 6.64   42.57 0.01
## filler_N      5 97 0.23 0.53      0    0.11 0.00  0  3     3 2.66    8.00 0.05
## intrawrd_N    6 97 0.01 0.10      0    0.00 0.00  0  1     1 9.55   90.06 0.01
## maze_N        7 97 0.08 0.31      0    0.00 0.00  0  2     2 3.95   16.36 0.03
## repeat_N      8 97 0.11 0.32      0    0.03 0.00  0  1     1 2.40    3.80 0.03
## selfcor_N     9 97 0.01 0.10      0    0.00 0.00  0  1     1 9.55   90.06 0.01
## skip_N       10 97 0.03 0.23      0    0.00 0.00  0  2     2 7.62   59.79 0.02
## -----
## grade: G1
## task: numword
##           vars  n mean   sd median trimmed  mad min max range skew kurtosis  se
## artNE        1 99 24.00 8.72     25   23.85 10.38  5 50    45 0.23   -0.23 0.88
## pauNE        2 99 22.93 8.71     23   22.78 10.38  4 49    45 0.24   -0.22 0.88
## error_N       3 99  0.17 0.62      0    0.01 0.00  0  4     4 4.37   20.16 0.06
## extra_N       4 99  0.03 0.17      0    0.00 0.00  0  1     1 5.40   27.41 0.02
## filler_N      5 99  0.22 0.56      0    0.07 0.00  0  2     2 2.38    4.32 0.06
## intrawrd_N    6 99  0.93 2.04      0    0.47 0.00  0 14    14 3.89   18.17 0.20
## maze_N        7 99  0.23 0.62      0    0.07 0.00  0  3     3 2.86    7.93 0.06
## repeat_N      8 99  0.16 0.62      0    0.00 0.00  0  4     4 4.26   19.02 0.06
## selfcor_N     9 99  0.16 0.58      0    0.01 0.00  0  4     4 4.53   22.80 0.06
## skip_N       10 99  0.01 0.10      0    0.00 0.00  0  1     1 9.65   92.06 0.01
## -----
## grade: G3
## task: numword
##           vars  n mean   sd median trimmed  mad min max range skew kurtosis  se
## artNE        1 102 11.14 6.77     10   10.34 5.93  2 36    34 1.25    2.03 0.67
## pauNE        2 102 10.06 6.75      9    9.26 5.93  1 35    34 1.26    2.07 0.67
## error_N       3 102  0.06 0.24      0    0.00 0.00  0  1     1 3.69   11.77 0.02
## extra_N       4 102  0.01 0.10      0    0.00 0.00  0  1     1 9.80   95.06 0.01
## filler_N      5 102  0.18 0.48      0    0.06 0.00  0  3     3 3.23   12.49 0.05
## intrawrd_N    6 102  0.13 0.50      0    0.00 0.00  0  4     4 5.39   34.57 0.05
## maze_N        7 102  0.14 0.49      0    0.00 0.00  0  3     3 3.86   15.30 0.05
## repeat_N      8 102  0.13 0.46      0    0.00 0.00  0  3     3 4.10   18.12 0.05
## selfcor_N     9 102  0.05 0.22      0    0.00 0.00  0  1     1 4.12   15.09 0.02
## skip_N       10 102  0.02 0.14      0    0.00 0.00  0  1     1 6.83   45.06 0.01
## -----
## grade: G5
## task: numword
##           vars  n mean   sd median trimmed  mad min max range skew kurtosis  se
## artNE        1 97 9.74 7.48      8    8.39 5.93  2 35    33 1.79    3.04 0.76
## pauNE        2 97 8.62 7.46      6    7.25 4.45  1 34    33 1.83    3.15 0.76
## error_N       3 97 0.06 0.24      0    0.00 0.00  0  1     1 3.58   10.94 0.02
## extra_N       4 97 0.02 0.14      0    0.00 0.00  0  1     1 6.64   42.57 0.01
## filler_N      5 97 0.21 0.56      0    0.06 0.00  0  3     3 2.89    8.29 0.06
## intrawrd_N    6 97 0.03 0.17      0    0.00 0.00  0  1     1 5.34   26.74 0.02

```

```

## maze_N      7 97 0.05 0.22      0      0.00 0.00      0      1      1 3.99      14.10 0.02
## repeat_N    8 97 0.12 0.46      0      0.00 0.00      0      3      3 4.20      18.72 0.05
## selfcor_N   9 97 0.06 0.24      0      0.00 0.00      0      1      1 3.58      10.94 0.02
## skip_N     10 97 0.04 0.20      0      0.00 0.00      0      1      1 4.54      18.84 0.02
## -----
## grade: G1
## task: object
##           vars  n mean   sd median trimmed  mad min max range  skew kurtosis   se
## artNE        1 99 28.47 5.82    29   28.64 5.93    9 41   32 -0.32    0.26 0.58
## pauNE        2 99 26.87 5.98    27   26.99 5.93    8 40   32 -0.24    0.02 0.60
## error_N       3 99  0.89 1.28     0    0.63 0.00    0  6    6  1.92    3.75 0.13
## extra_N       4 99  0.16 0.51     0    0.05 0.00    0  4    4  4.84   30.50 0.05
## filler_N      5 99  2.60 2.57     2    2.19 1.48    0 11   11  1.46    1.62 0.26
## intrawrd_N    6 99  1.32 1.92     1    0.94 1.48    0  8    8  1.79    2.77 0.19
## maze_N        7 99  0.75 1.04     0    0.56 0.00    0  5    5  1.68    2.92 0.10
## repeat_N      8 99  0.67 1.31     0    0.40 0.00    0  9    9  3.30   15.31 0.13
## selfcor_N     9 99  0.41 0.69     0    0.30 0.00    0  4    4  2.10    6.26 0.07
## skip_N       10 99  0.32 0.67     0    0.19 0.00    0  3    3  2.39    5.89 0.07
## -----
## grade: G3
## task: object
##           vars  n mean   sd median trimmed  mad min max range  skew kurtosis   se
## artNE        1 102 23.38 5.96   24.0   23.44 5.93   11 35   24 -0.10   -0.74 0.59
## pauNE        2 102 21.56 6.04   21.5   21.57 6.67   10 33   23 -0.01   -0.76 0.60
## error_N       3 102  0.91 1.19    1.0    0.70 1.48    0  6    6  1.68    3.34 0.12
## extra_N       4 102  0.19 0.58    0.0    0.01 0.00    0  3    3  3.07    8.57 0.06
## filler_N      5 102  2.28 2.05    2.0    2.02 1.48    0  9    9  1.13    1.12 0.20
## intrawrd_N    6 102  0.55 1.05    0.0    0.29 0.00    0  4    4  2.09    3.62 0.10
## maze_N        7 102  0.43 0.72    0.0    0.28 0.00    0  3    3  1.78    2.90 0.07
## repeat_N      8 102  0.58 1.21    0.0    0.29 0.00    0  8    8  3.27   13.80 0.12
## selfcor_N     9 102  0.49 0.70    0.0    0.35 0.00    0  3    3  1.23    0.76 0.07
## skip_N       10 102  0.25 0.54    0.0    0.15 0.00    0  3    3  2.37    6.45 0.05
## -----
## grade: G5
## task: object
##           vars  n mean   sd median trimmed  mad min max range  skew kurtosis   se
## artNE        1 96 21.45 7.54    19   21.27 7.41    5 37   32 0.27   -0.91 0.77
## pauNE        2 96 18.74 7.72    17   18.46 7.41    3 35   32 0.35   -0.94 0.79
## error_N       3 96  0.93 1.14     1    0.73 1.48    0  5    5  1.47    2.19 0.12
## extra_N       4 96  0.09 0.29     0    0.00 0.00    0  1    1  2.74    5.59 0.03
## filler_N      5 96  3.19 2.78     3    2.83 2.97    0 15   15  1.36    2.78 0.28
## intrawrd_N    6 96  0.34 0.88     0    0.14 0.00    0  5    5  3.59   14.61 0.09
## maze_N        7 96  0.28 0.68     0    0.12 0.00    0  3    3  2.64    6.67 0.07
## repeat_N      8 96  0.69 1.15     0    0.46 0.00    0  6    6  2.08    5.08 0.12
## selfcor_N     9 96  0.67 0.95     0    0.49 0.00    0  5    5  1.94    4.72 0.10
## skip_N       10 96  0.23 0.55     0    0.10 0.00    0  3    3  2.66    7.45 0.06
## -----
## grade: G1
## task: word
##           vars  n mean   sd median trimmed  mad min max range  skew kurtosis   se
## artNE        1 99 32.69 7.23    34   33.07 4.45   13 57   44 -0.39    1.20 0.73
## pauNE        2 99 31.31 7.33    33   31.64 5.93   12 56   44 -0.31    0.96 0.74
## error_N       3 99  3.83 2.81     3    3.48 1.48    0 13   13  1.19    1.18 0.28
## extra_N       4 99  0.07 0.29     0    0.00 0.00    0  2    2  4.41   20.58 0.03

```

```
## filler_N      5 99  1.64 2.47      1   1.17 1.48   0 18   18  3.95   20.34 0.25
## intrawrd_N    6 99  3.79 3.74      3   3.15 2.97   0 23   23  2.40    7.55 0.38
## maze_N        7 99  2.07 2.29      1   1.68 1.48   0 10   10  1.70    2.75 0.23
## repeat_N      8 99  0.71 1.19      0   0.44 0.00   0 5     5  1.76    2.33 0.12
## selfcor_N     9 99  1.03 1.42      0   0.78 0.00   0 7     7  1.73    3.25 0.14
## skip_N       10 99  0.03 0.17      0   0.00 0.00   0 1     1  5.40   27.41 0.02
```

```
## -----
## grade: G3
## task: word
##      vars  n mean  sd median trimmed  mad min max range skew kurtosis  se
## artNE      1 102 15.76 8.60      14   14.95 7.41   3 38   35 0.78   -0.21 0.85
## pauNE      2 102 14.39 8.52      13   13.55 7.41   2 37   35 0.82   -0.08 0.84
## error_N     3 102  1.10 1.53       1    0.79 1.48   0 9    9 2.18    6.39 0.15
## extra_N     4 102  0.04 0.20       0    0.00 0.00   0 1    1 4.68   20.08 0.02
## filler_N    5 102  0.49 1.17       0    0.20 0.00   0 7    7 3.43   13.36 0.12
## intrawrd_N  6 102  0.68 1.14       0    0.43 0.00   0 5    5 1.85    3.13 0.11
## maze_N      7 102  1.20 1.82       1    0.89 1.48   0 14   14 3.90   22.59 0.18
## repeat_N    8 102  0.38 0.68       0    0.23 0.00   0 3    3 1.67    2.00 0.07
## selfcor_N   9 102  0.27 0.69       0    0.12 0.00   0 5    5 3.86   20.08 0.07
## skip_N     10 102  0.01 0.10       0    0.00 0.00   0 1    1 9.80   95.06 0.01
```

```
## -----
## grade: G5
## task: word
##      vars  n mean  sd median trimmed  mad min max range skew kurtosis  se
## artNE      1 97 12.21 8.06      10   11.09 5.93   1 35   34 1.16    0.49 0.82
## pauNE      2 97 10.79 7.96       8    9.63 5.93   0 34   34 1.22    0.69 0.81
## error_N     3 97  0.67 1.07       0    0.47 0.00   0 5    5 1.84    3.37 0.11
## extra_N     4 97  0.02 0.14       0    0.00 0.00   0 1    1 6.64   42.57 0.01
## filler_N    5 97  0.46 0.95       0    0.25 0.00   0 6    6 3.05   12.12 0.10
## intrawrd_N  6 97  0.14 0.43       0    0.03 0.00   0 2    2 3.04    8.73 0.04
## maze_N      7 97  0.52 0.91       0    0.32 0.00   0 5    5 2.38    6.79 0.09
## repeat_N    8 97  0.30 0.63       0    0.15 0.00   0 3    3 2.13    3.95 0.06
## selfcor_N   9 97  0.24 0.50       0    0.14 0.00   0 2    2 1.95    2.99 0.05
## skip_N     10 97  0.02 0.14       0    0.00 0.00   0 1    1 6.64   42.57 0.01
```

```
describeBy(as.formula(paste(paste(eval(times),collapse="+"), "grade+task", sep="~")), data=serd)
```

```
##
## Descriptive statistics by group
## grade: G1
## task: dice
##      vars  n mean  sd median trimmed  mad  min  max range skew kurtosis  se
## arttotE    1 99 20.27 3.35  19.87   20.02 2.77 13.93 30.95 17.02 0.86    1.08 0.34
## pautotE    2 99 10.25 5.89   8.91    9.52 4.47  1.84 31.08 29.24 1.35    2.04 0.59
## error_T     3 99  0.27 0.50   0.00   0.16 0.00  0.00  2.94  2.94 2.68    8.83 0.05
## extra_T     4 99  0.07 0.25   0.00   0.00 0.00  0.00  1.64  1.64 4.00   17.66 0.02
## filler_T    5 99  0.31 0.54   0.15   0.20 0.22  0.00  3.39  3.39 3.30   13.45 0.05
## intrawrd_T  6 99  0.14 0.28   0.00   0.08 0.00  0.00  1.92  1.92 3.46   16.14 0.03
## maze_T      7 99  0.06 0.16   0.00   0.02 0.00  0.00  0.89  0.89 3.45   12.79 0.02
## repeat_T    8 99  0.24 0.58   0.00   0.11 0.00  0.00  4.04  4.04 3.67   17.44 0.06
## selfcor_T   9 99  0.27 0.56   0.00   0.15 0.00  0.00  2.77  2.77 2.72    8.09 0.06
## skip_T     10 99  0.00 0.00   0.00   0.00 0.00  0.00  0.00  0.00 2.57    6.12 0.00
```

```
## -----
## grade: G3
## task: dice
```

```

##      vars  n mean  sd median trimmed  mad   min   max range skew kurtosis  se
## arttotE    1 102 17.29 2.43 17.12 17.18 2.61 12.93 24.84 11.90 0.43   -0.24 0.24
## pautotE    2 102  5.01 3.23  4.06  4.57 2.46  1.00 20.89 19.89 1.76    4.73 0.32
## error_T    3 102  0.08 0.21  0.00  0.03 0.00  0.00  1.00  1.00 2.70    6.81 0.02
## extra_T    4 102  0.01 0.07  0.00  0.00 0.00  0.00  0.71  0.71 9.20   86.09 0.01
## filler_T   5 102  0.16 0.30  0.00  0.09 0.00  0.00  1.50  1.50 2.39    5.67 0.03
## intrawrd_T 6 102  0.04 0.15  0.00  0.00 0.00  0.00  1.09  1.09 4.78   25.34 0.02
## maze_T     7 102  0.04 0.12  0.00  0.01 0.00  0.00  0.76  0.76 3.53   13.90 0.01
## repeat_T   8 102  0.09 0.24  0.00  0.03 0.00  0.00  1.52  1.52 3.70   16.12 0.02
## selfcor_T  9 102  0.07 0.18  0.00  0.01 0.00  0.00  0.83  0.83 2.67    6.24 0.02
## skip_T    10 102  0.00 0.00  0.00  0.00 0.00  0.00  0.00  0.00 4.12   15.09 0.00
## -----
## grade: G5
## task: dice
##      vars  n mean  sd median trimmed  mad   min   max range skew kurtosis  se
## arttotE    1 97 16.05 2.20 15.99 15.98 1.94 10.65 21.98 11.33 0.29    0.36 0.22
## pautotE    2 97  4.21 3.32  3.26  3.66 1.77  0.41 20.63 20.22 2.51    8.25 0.34
## error_T    3 97  0.08 0.18  0.00  0.04 0.00  0.00  0.89  0.89 2.17    4.33 0.02
## extra_T    4 97  0.02 0.11  0.00  0.00 0.00  0.00  0.81  0.81 5.62   32.08 0.01
## filler_T   5 97  0.19 0.34  0.00  0.12 0.00  0.00  2.20  2.20 2.98   11.82 0.03
## intrawrd_T 6 97  0.02 0.07  0.00  0.00 0.00  0.00  0.53  0.53 5.19   33.63 0.01
## maze_T     7 97  0.03 0.07  0.00  0.00 0.00  0.00  0.40  0.40 3.15    9.74 0.01
## repeat_T   8 97  0.06 0.16  0.00  0.02 0.00  0.00  0.70  0.70 2.57    5.50 0.02
## selfcor_T  9 97  0.11 0.26  0.00  0.05 0.00  0.00  1.62  1.62 3.08   11.92 0.03
## skip_T    10 97  0.00 0.00  0.00  0.00 0.00  0.00  0.00  0.00 5.34   26.74 0.00
## -----
## grade: G1
## task: digit
##      vars  n mean  sd median trimmed  mad   min   max range skew kurtosis  se
## arttotE    1 99 18.39 2.66 17.83 18.26 2.47 13.02 24.76 11.74 0.49   -0.35 0.27
## pautotE    2 99  6.98 3.86  5.93  6.65 3.53  1.63 18.52 16.89 0.82    0.11 0.39
## error_T    3 99  0.01 0.07  0.00  0.00 0.00  0.00  0.60  0.60 7.10   50.57 0.01
## extra_T    4 99  0.03 0.14  0.00  0.00 0.00  0.00  0.96  0.96 5.63   31.56 0.01
## filler_T   5 99  0.12 0.26  0.00  0.05 0.00  0.00  1.35  1.35 3.04    9.66 0.03
## intrawrd_T 6 99  0.10 0.20  0.00  0.05 0.00  0.00  0.90  0.90 2.34    4.95 0.02
## maze_T     7 99  0.09 0.22  0.00  0.04 0.00  0.00  1.14  1.14 2.77    7.68 0.02
## repeat_T   8 99  0.10 0.31  0.00  0.02 0.00  0.00  1.91  1.91 4.10   18.64 0.03
## selfcor_T  9 99  0.00 0.04  0.00  0.00 0.00  0.00  0.37  0.37 9.65   92.06 0.00
## skip_T    10 99  0.00 0.00  0.00  0.00 0.00  0.00  0.00  0.00 5.57   32.97 0.00
## -----
## grade: G3
## task: digit
##      vars  n mean  sd median trimmed  mad   min   max range skew kurtosis  se
## arttotE    1 102 15.09 1.88 15.02 15.01 1.85 11.23 20.25  9.02 0.40   -0.11 0.19
## pautotE    2 101  3.14 2.37  2.46  2.75 1.68  0.54 15.36 14.81 2.36    7.73 0.24
## error_T    3 102  0.04 0.14  0.00  0.00 0.00  0.00  0.64  0.64 3.40   10.17 0.01
## extra_T    4 102  0.00 0.02  0.00  0.00 0.00  0.00  0.25  0.25 9.80   95.06 0.00
## filler_T   5 102  0.08 0.22  0.00  0.03 0.00  0.00  1.67  1.67 4.78   28.53 0.02
## intrawrd_T 6 102  0.02 0.08  0.00  0.00 0.00  0.00  0.56  0.56 4.90   24.05 0.01
## maze_T     7 102  0.05 0.12  0.00  0.02 0.00  0.00  0.72  0.72 2.87    9.33 0.01
## repeat_T   8 102  0.05 0.23  0.00  0.00 0.00  0.00  1.61  1.61 5.53   31.84 0.02
## selfcor_T  9 102  0.01 0.08  0.00  0.00 0.00  0.00  0.58  0.58 6.24   39.06 0.01
## skip_T    10 102  0.00 0.00  0.00  0.00 0.00  0.00  0.00  0.00 5.00   26.65 0.00
## -----

```

```

## grade: G5
## task: digit
##      vars  n mean  sd median trimmed  mad   min    max range skew kurtosis   se
## arttotE    1 97 14.17 2.25  13.59   13.95 1.93 10.13 22.06 11.93 0.96    0.72 0.23
## pautotE    2 97  2.52 2.28   1.82    2.06 1.20  0.39 12.46 12.07 2.37    6.01 0.23
## error_T    3 97  0.00 0.05   0.00    0.00 0.00  0.00  0.48  0.48 9.55   90.06 0.00
## extra_T    4 97  0.01 0.04   0.00    0.00 0.00  0.00  0.38  0.38 8.52   74.80 0.00
## filler_T   5 97  0.05 0.12   0.00    0.02 0.00  0.00  0.54  0.54 2.65    6.49 0.01
## intrawrd_T 6 97  0.00 0.02   0.00    0.00 0.00  0.00  0.17  0.17 9.55   90.06 0.00
## maze_T     7 97  0.02 0.06   0.00    0.00 0.00  0.00  0.37  0.37 4.04   16.79 0.01
## repeat_T   8 97  0.04 0.12   0.00    0.01 0.00  0.00  0.51  0.51 2.59    5.13 0.01
## selfcor_T  9 97  0.00 0.05   0.00    0.00 0.00  0.00  0.48  0.48 9.55   90.06 0.00
## skip_T    10 97  0.00 0.00   0.00    0.00 0.00  0.00  0.01  0.01 9.06   83.13 0.00
## -----
## grade: G1
## task: numword
##      vars  n mean  sd median trimmed  mad   min    max range skew kurtosis   se
## arttotE    1 98 20.43 3.40  20.20   20.26 3.29 13.79 30.19 16.40 0.49    0.08 0.34
## pautotE    2 98  8.54 5.24   7.06    7.92 4.48  1.41 27.97 26.56 1.14    1.07 0.53
## error_T    3 99  0.12 0.49   0.00    0.00 0.00  0.00  3.05  3.05 4.85   23.38 0.05
## extra_T    4 99  0.01 0.07   0.00    0.00 0.00  0.00  0.53  0.53 6.14   38.91 0.01
## filler_T   5 99  0.06 0.17   0.00    0.01 0.00  0.00  0.77  0.77 2.82    6.92 0.02
## intrawrd_T 6 99  0.27 0.95   0.00    0.10 0.00  0.00  8.73  8.73 7.47   62.33 0.10
## maze_T     7 99  0.09 0.26   0.00    0.02 0.00  0.00  1.64  1.64 4.01   17.60 0.03
## repeat_T   8 99  0.09 0.34   0.00    0.00 0.00  0.00  1.94  1.94 3.96   15.29 0.03
## selfcor_T  9 99  0.12 0.48   0.00    0.00 0.00  0.00  3.01  3.01 4.75   23.40 0.05
## skip_T    10 99  0.00 0.00   0.00    0.00 0.00  0.00  0.00  0.00 9.65   92.06 0.00
## -----
## grade: G3
## task: numword
##      vars  n mean  sd median trimmed  mad   min    max range skew kurtosis   se
## arttotE    1 102 15.29 1.96  15.25   15.14 1.75 11.75 21.52  9.77 0.75    0.49 0.19
## pautotE    2 102  2.96 2.45   2.30    2.54 1.47  0.44 16.30 15.86 2.74    9.85 0.24
## error_T    3 102  0.02 0.09   0.00    0.00 0.00  0.00  0.68  0.68 4.77   24.92 0.01
## extra_T    4 102  0.01 0.07   0.00    0.00 0.00  0.00  0.75  0.75 9.80   95.06 0.01
## filler_T   5 102  0.04 0.14   0.00    0.01 0.00  0.00  1.08  1.08 4.80   27.67 0.01
## intrawrd_T 6 102  0.02 0.08   0.00    0.00 0.00  0.00  0.54  0.54 4.32   20.07 0.01
## maze_T     7 102  0.04 0.15   0.00    0.00 0.00  0.00  0.86  0.86 4.32   18.62 0.01
## repeat_T   8 102  0.05 0.19   0.00    0.00 0.00  0.00  1.40  1.40 5.03   28.78 0.02
## selfcor_T  9 102  0.02 0.09   0.00    0.00 0.00  0.00  0.45  0.45 4.34   17.47 0.01
## skip_T    10 102  0.00 0.00   0.00    0.00 0.00  0.00  0.00  0.00 6.83   45.06 0.00
## -----
## grade: G5
## task: numword
##      vars  n mean  sd median trimmed  mad   min    max range skew kurtosis   se
## arttotE    1 97 14.14 2.11  13.76   13.95 1.99 10.79 20.82 10.03 0.78    0.04 0.21
## pautotE    2 97  2.22 1.99   1.64    1.84 0.97  0.22 11.10 10.88 2.50    6.88 0.20
## error_T    3 97  0.02 0.08   0.00    0.00 0.00  0.00  0.52  0.52 4.15   17.19 0.01
## extra_T    4 97  0.01 0.06   0.00    0.00 0.00  0.00  0.54  0.54 8.47   73.96 0.01
## filler_T   5 97  0.05 0.17   0.00    0.01 0.00  0.00  1.08  1.08 3.75   15.59 0.02
## intrawrd_T 6 97  0.00 0.02   0.00    0.00 0.00  0.00  0.11  0.11 5.35   26.91 0.00
## maze_T     7 97  0.01 0.04   0.00    0.00 0.00  0.00  0.21  0.21 4.17   15.89 0.00
## repeat_T   8 97  0.05 0.18   0.00    0.00 0.00  0.00  1.01  1.01 3.86   14.77 0.02
## selfcor_T  9 97  0.02 0.09   0.00    0.00 0.00  0.00  0.53  0.53 3.88   14.07 0.01

```

```

## skip_T      10 97  0.00 0.00  0.00  0.00 0.00  0.00  0.00  0.00  0.00 4.54  18.84 0.00
## -----
## grade: G1
## task: object
##          vars  n mean  sd median trimmed  mad   min   max range skew kurtosis  se
## arttotE      1 99 22.67 3.37 22.12 22.49 3.32 14.41 32.74 18.33 0.51  0.32 0.34
## pautotE      2 99 20.49 8.36 19.54 20.02 9.07  6.79 54.17 47.39 0.79  1.20 0.84
## error_T      3 99  0.58 0.90  0.00  0.39 0.00  0.00  4.16  4.16 2.19  4.92 0.09
## extra_T      4 99  0.08 0.30  0.00  0.02 0.00  0.00  2.48  2.48 5.78 40.56 0.03
## filler_T     5 99  0.95 1.19  0.48  0.72 0.56  0.00  5.48  5.48 1.97  3.71 0.12
## intrawrd_T   6 99  0.20 0.28  0.10  0.14 0.15  0.00  1.15  1.15 1.67  2.17 0.03
## maze_T       7 99  0.26 0.44  0.00  0.17 0.00  0.00  2.68  2.68 2.71  9.43 0.04
## repeat_T     8 99  0.39 0.79  0.00  0.21 0.00  0.00  5.39  5.39 3.42 15.79 0.08
## selfcor_T    9 99  0.24 0.41  0.00  0.16 0.00  0.00  2.38  2.38 2.18  6.40 0.04
## skip_T      10 99  0.00 0.00  0.00  0.00 0.00  0.00  0.03  0.03 7.84 68.17 0.00
## -----
## grade: G3
## task: object
##          vars  n mean  sd median trimmed  mad   min   max range skew kurtosis  se
## arttotE      1 102 20.25 2.64 20.01 20.17 2.67 13.49 26.77 13.28 0.29  0.02 0.26
## pautotE      2 102 10.33 4.80 10.08  9.87 5.12  3.38 25.24 21.86 0.79  0.23 0.48
## error_T      3 102  0.48 0.76  0.22  0.32 0.33  0.00  4.33  4.33 2.45  7.18 0.08
## extra_T      4 102  0.06 0.18  0.00  0.00 0.00  0.00  0.87  0.87 2.99  7.90 0.02
## filler_T     5 102  0.79 0.86  0.56  0.65 0.60  0.00  4.47  4.47 1.72  3.41 0.08
## intrawrd_T   6 102  0.08 0.20  0.00  0.04 0.00  0.00  1.36  1.36 3.95 19.23 0.02
## maze_T       7 102  0.13 0.23  0.00  0.07 0.00  0.00  1.02  1.02 2.14  4.29 0.02
## repeat_T     8 102  0.29 0.62  0.00  0.14 0.00  0.00  4.22  4.22 3.37 15.01 0.06
## selfcor_T    9 102  0.26 0.38  0.00  0.19 0.00  0.00  1.98  1.98 1.53  2.80 0.04
## skip_T      10 102  0.00 0.00  0.00  0.00 0.00  0.00  0.01  0.01 2.37  6.45 0.00
## -----
## grade: G5
## task: object
##          vars  n mean  sd median trimmed  mad   min   max range skew kurtosis  se
## arttotE      1 96 18.98 2.50 18.84 18.88 2.51 14.38 25.72 11.33 0.40 -0.21 0.25
## pautotE      2 96  7.37 4.30  6.62  6.75 3.01  1.07 27.65 26.58 1.73  4.23 0.44
## error_T      3 96  0.44 0.62  0.27  0.32 0.41  0.00  2.88  2.88 2.03  4.57 0.06
## extra_T      4 96  0.05 0.19  0.00  0.00 0.00  0.00  1.30  1.30 4.37 21.38 0.02
## filler_T     5 96  1.16 1.17  0.82  0.98 0.97  0.00  5.94  5.94 1.65  3.44 0.12
## intrawrd_T   6 96  0.06 0.18  0.00  0.02 0.00  0.00  1.27  1.27 4.19 20.53 0.02
## maze_T       7 96  0.10 0.25  0.00  0.03 0.00  0.00  1.13  1.13 2.62  6.22 0.03
## repeat_T     8 96  0.36 0.61  0.00  0.23 0.00  0.00  3.64  3.64 2.42  7.90 0.06
## selfcor_T    9 96  0.34 0.49  0.00  0.25 0.00  0.00  2.70  2.70 1.92  4.86 0.05
## skip_T      10 96  0.00 0.00  0.00  0.00 0.00  0.00  0.01  0.01 2.66  7.45 0.00
## -----
## grade: G1
## task: word
##          vars  n mean  sd median trimmed  mad   min   max range skew kurtosis  se
## arttotE      1 99 26.72 5.98 25.66 26.31 5.84 15.44 43.95 28.52 0.68  0.10 0.60
## pautotE      2 99 22.92 14.83 19.49 20.84 12.52  4.51 69.88 65.37 1.24  1.14 1.49
## error_T      3 99  4.55 5.21  2.69  3.62 2.62  0.00 30.30 30.30 2.53  8.06 0.52
## extra_T      4 99  0.05 0.23  0.00  0.00 0.00  0.00  1.64  1.64 5.77 34.33 0.02
## filler_T     5 99  0.62 1.04  0.31  0.42 0.46  0.00  7.24  7.24 3.84 18.76 0.10
## intrawrd_T   6 99  1.19 2.05  0.50  0.75 0.57  0.00 12.94 12.94 3.98 18.46 0.21
## maze_T       7 99  1.09 1.27  0.69  0.84 1.02  0.00  5.98  5.98 1.83  3.21 0.13

```

```
## repeat_T      8 99  0.46  0.88   0.00   0.26  0.00  0.00  4.60  4.60 2.54      6.87 0.09
## selfcor_T     9 99  0.80  1.22   0.00   0.55  0.00  0.00  5.59  5.59 2.05      4.27 0.12
## skip_T       10 99  0.00  0.00   0.00   0.00  0.00  0.00  0.00  0.00 5.40     27.41 0.00
## -----
## grade: G3
## task: word
##          vars  n mean  sd median trimmed  mad   min   max range skew kurtosis  se
## arttotE      1 102 18.94 3.43  18.19   18.59 3.11 12.11 28.74 16.63 0.85     0.31 0.34
## pautotE      2 102  5.91 5.34   4.46   4.81 2.71  0.78 27.27 26.49 2.18     4.81 0.53
## error_T      3 102  0.76 1.37   0.40   0.45 0.60  0.00  8.23  8.23 3.22    12.17 0.14
## extra_T      4 102  0.01 0.08   0.00   0.00 0.00  0.00  0.71  0.71 6.75    49.28 0.01
## filler_T     5 102  0.16 0.45   0.00   0.05 0.00  0.00  2.95  2.95 4.30    20.50 0.04
## intrawrd_T   6 102  0.12 0.25   0.00   0.06 0.00  0.00  1.16  1.16 2.56     6.32 0.02
## maze_T       7 102  0.41 0.68   0.25   0.28 0.37  0.00  4.75  4.75 3.60    17.66 0.07
## repeat_T     8 102  0.18 0.32   0.00   0.11 0.00  0.00  1.35  1.35 1.81     2.71 0.03
## selfcor_T    9 102  0.15 0.38   0.00   0.05 0.00  0.00  2.42  2.42 3.33    12.99 0.04
## skip_T      10 102  0.00 0.00   0.00   0.00 0.00  0.00  0.00  0.00 9.80    95.06 0.00
## -----
## grade: G5
## task: word
##          vars  n mean  sd median trimmed  mad   min   max range skew kurtosis  se
## arttotE      1 97 17.12 2.82  16.56   16.91 2.67 11.69 26.40 14.70 0.74     0.25 0.29
## pautotE      2 96  3.47 2.60   2.64   3.05 1.67  0.42 14.87 14.45 1.69     3.21 0.27
## error_T      3 97  0.35 0.60   0.00   0.23 0.00  0.00  3.35  3.35 2.35     6.82 0.06
## extra_T      4 97  0.00 0.03   0.00   0.00 0.00  0.00  0.28  0.28 6.96    48.29 0.00
## filler_T     5 97  0.14 0.32   0.00   0.06 0.00  0.00  1.64  1.64 3.14    10.30 0.03
## intrawrd_T   6 97  0.02 0.07   0.00   0.00 0.00  0.00  0.39  0.39 3.69    14.03 0.01
## maze_T       7 97  0.17 0.33   0.00   0.10 0.00  0.00  2.09  2.09 2.86    10.77 0.03
## repeat_T     8 97  0.15 0.31   0.00   0.07 0.00  0.00  1.62  1.62 2.29     5.24 0.03
## selfcor_T    9 97  0.12 0.27   0.00   0.05 0.00  0.00  1.24  1.24 2.53     6.19 0.03
## skip_T      10 97  0.00 0.00   0.00   0.00 0.00  0.00  0.00  0.00 6.64    42.57 0.00
```

3.4 Compute adjusted times per task and grade

Adjusted rates can be calculated using the number of correctly produced items and response times adjusted for incorrect responses. Times can be adjusted by removing articulation times for incorrect items and any silent intervals preceding them (following Georgiou, 2006, but without removing silent intervals *following* incorrect articulations). This approach has some face validity but is clearly an approximation given that processing of individual items in a serial task cannot be cleanly distinguished in the recorded responses due to rampant processing overlap.

Total incorrect instances per run are computed by adding the number of uncorrected errors (i.e., errors minus self-corrections) plus the number of skips. (Note that a self-correction is logically possible after a maze, so this is an approximation.)

```
totinc <- aggregate(error_N-selfcor_N~sID+task,serd,sum,na.rm=T)
skips <- aggregate(skip_N~sID+task,serd,sum,na.rm=T)
names(totinc)[3] <- "incN"
totinc$incN[totinc$incN<0] <- 0
totinc <- merge(totinc,skips,by=c("sID","task"))
totinc$incN = totinc$incN+totinc$skip_N
totinc$skip_N <- NULL
totinc$totcor <- 36-totinc$incN

totadj <- aggregate(cbind(tottim,onlat+arttotE+pautotE)~sID+task,serd,sum,na.rm=T)
```

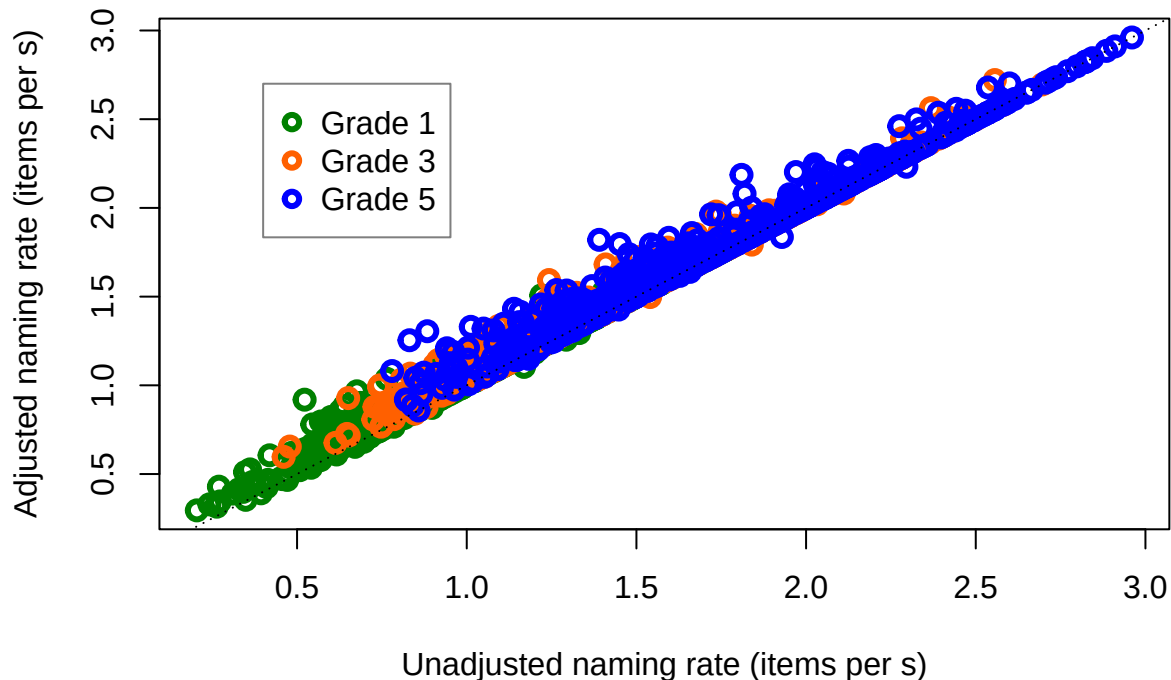
```
names(totadj)[4] <- "adjtim"
totadj <- merge(totadj,totinc,by=c("sID","task"))
totadj$invraw <- 36.0/totadj$tottim
totadj$invadj <- totadj$totcor/totadj$adjtim

totadj$grade <- as.factor(paste("G",substr(as.character(totadj$sID),2,2),sep=""))
```

Adjusted rates track unadjusted rates very closely, due to the small number of errors. When they diverge, they tend to be higher, as the time interval removed seems to overestimate the impact of the error.

```
par(mfrow=c(1,1))
plot(invadj~invraw,totadj,main="Raw vs. adjusted serial naming rate (all tasks)",type="n",xlab="Unadjusted naming rate (items per s)",ylab="Adjusted naming rate (items per s)")
points(invadj~invraw,totadj,subset=grade=="G1",cex=1.25,col="#008000",lwd=3)
points(invadj~invraw,totadj,subset=grade=="G3",cex=1.25,col="#FF6000",lwd=3)
points(invadj~invraw,totadj,subset=grade=="G5",cex=1.25,col="#0000FF",lwd=3)
abline(0,1,lty=3)
legend(0.4,2.7,c("Grade 1","Grade 3","Grade 5"),col=c("#008000","#FF6000","#0000FF"),pch=1,pt.lwd=3,box=FALSE)
```

Raw vs. adjusted serial naming rate (all tasks)



The following tables display the correlations between raw and adjusted serial naming rates, as a measure of the effect of adjustment. Most correlations are extremely high (0.95–0.99), with the notable exception of objects (below 0.90). Note that these are nonparametric correlation coefficients, so they are not distorted by nonlinearities.

```
cor(totadj$invraw, totadj$invadj,method="spearman") ## all together
```

```
## [1] 0.9917019
```

```
corarr <- with(totadj,by(totadj,list(grade,task),function(x){cor(x$invraw,x$invadj,method="spearman",us
round(corarr[,],3)
```

```
##      dice digit numword object  word
## G1 0.977 0.984   0.993  0.843 0.975
## G3 0.990 0.990   0.985  0.938 0.977
## G5 0.969 0.985   0.981  0.893 0.966
```

The discrepancy for objects is not due to particularly high error rates, as those are lower than for words (especially in G1, where the discrepancy is largest). The following table displays mean number incorrect items per run for each grade and task.

```
prperr <- with(totadj,by(totadj,list(grade,task),function(x){mean(x$incN,na.rm=T)/36.0}))
round(prperr[,],3)
```

```
##      dice digit numword object  word
## G1 0.007 0.001   0.000  0.024 0.079
## G3 0.004 0.003   0.001  0.020 0.023
## G5 0.001 0.001   0.001  0.018 0.013
```

Instead, the greater effect of adjustment on objects than on other tasks seems to be due to the time adjustment itself. The following table displays the correlations between total nonadjusted and adjusted times per run for each grade and task.

```
cortim <- with(totadj,by(totadj,list(grade,task),function(x){cor(x$tottim,x$adjtim,method="spearman",us
round(cortim[,],3)
```

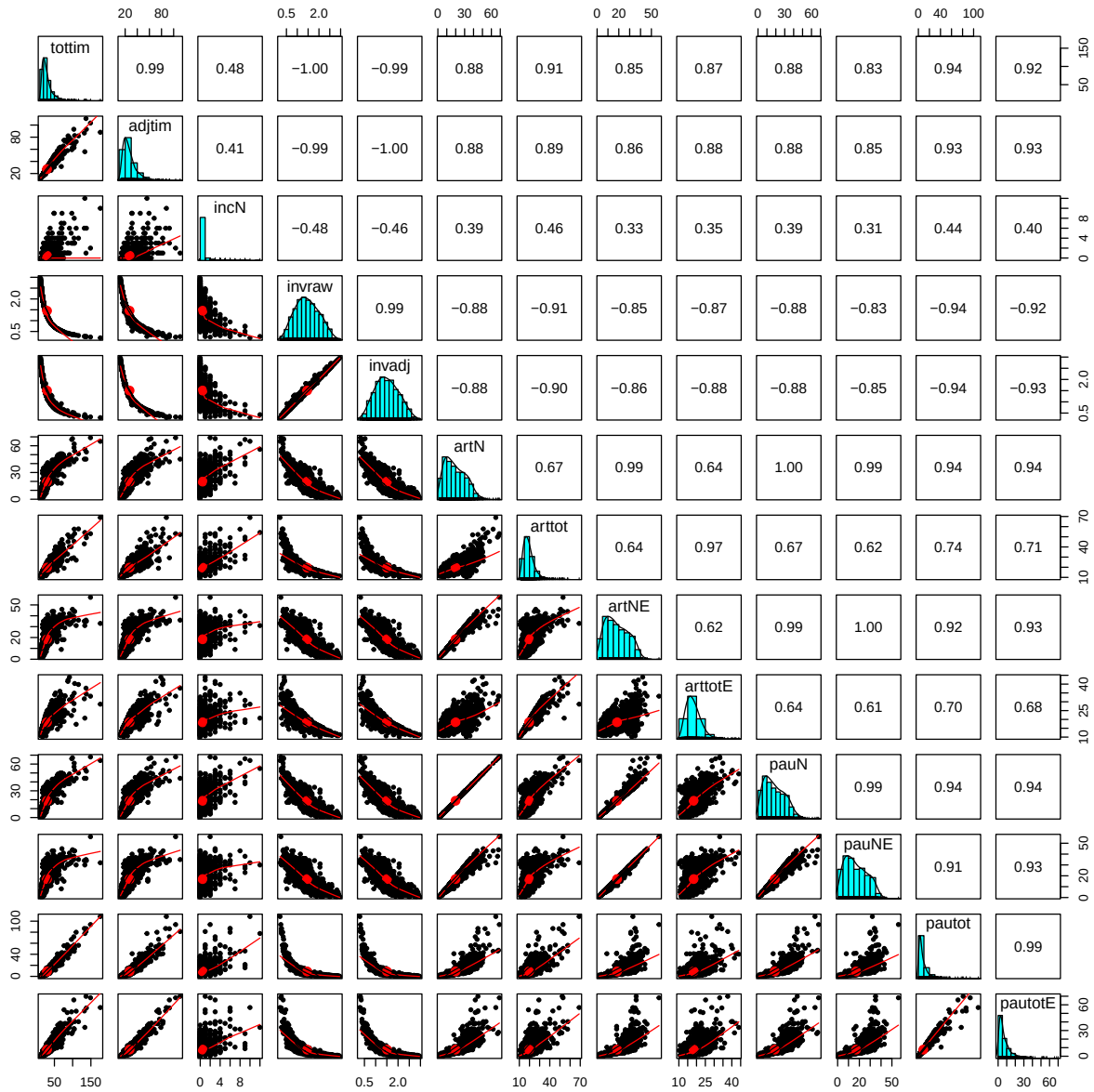
```
##      dice digit numword object  word
## G1 0.969 0.985   0.993  0.795 0.954
## G3 0.987 0.986   0.984  0.910 0.962
## G5 0.969 0.985   0.975  0.862 0.943
```

This may be associated with a high rate of fillers in object naming (see graphs above), in that the proportion of filler time in serial object naming runs can vary unrelated to the total naming time.

3.5 Intercorrelations

Here we display a general overview of correlations among serial naming variables (across grades and tasks). To compute these, we join data frames of interval counts and durations with total articulation and pause data (raw and adjusted).

```
artpau <- merge(totadj,aggregate(cbind(artN,arttot,artNE,arttotE,pauN,pauNE,pautot,pautotE)~sID+task,se
pairs.panels(artpau[,c(3:5,7:8,10:17)],cex.cor=0.85,method="spearman")
```



3.6 Scaling considerations

The scale on which these data should be analyzed is an important issue, which must be considered in conjunction with measures from discrete naming. In the following graphs we overlay the QQ-plot data of the five different tasks (d=digit, n=number word, w=word, c=dice, o=object) for each type of measure (total time, pause time, articulation time), untransformed, log-transformed, and inverted (to rate). All metrics are per correct item. Each 3×3 panel array displays data for one grade.

```
artpau$itmarttE <- artpau$arttotE/artpau$totcor
artpau$logarttE <- ifelse(artpau$arttotE>0, log(artpau$arttotE/artpau$totcor), NA)
artpau$invarttE <- ifelse(artpau$arttotE>0, artpau$totcor/artpau$arttotE, NA)

artpau$itmpautE <- artpau$pautotE/artpau$totcor
artpau$logpautE <- ifelse(artpau$pautotE>0, log(artpau$pautotE/artpau$totcor), NA)
```

```

artpau$invpautE <- ifelse(artpau$pautotE>0, artpau$totcor/artpau$pautotE, NA)

artpau$itmadj <- artpau$adjtim/artpau$totcor
artpau$logadj <- ifelse(artpau$adjtim >0, log(artpau$adjtim/artpau$totcor), NA)

tasks <- levels(artpau$task)
ids <- levels(artpau$ID)

for (grd in levels(artpau$grade)) {

  par(mfcol=c(3,3))
  par(oma=c(0,2,2,0))
  par(mai=c(0.25,0.2,0.1,0.1))
  par(mgp=c(2,0.5,0))
  par(tcl= -0.3)

  ncset <- c("adj","pautE","arttE")

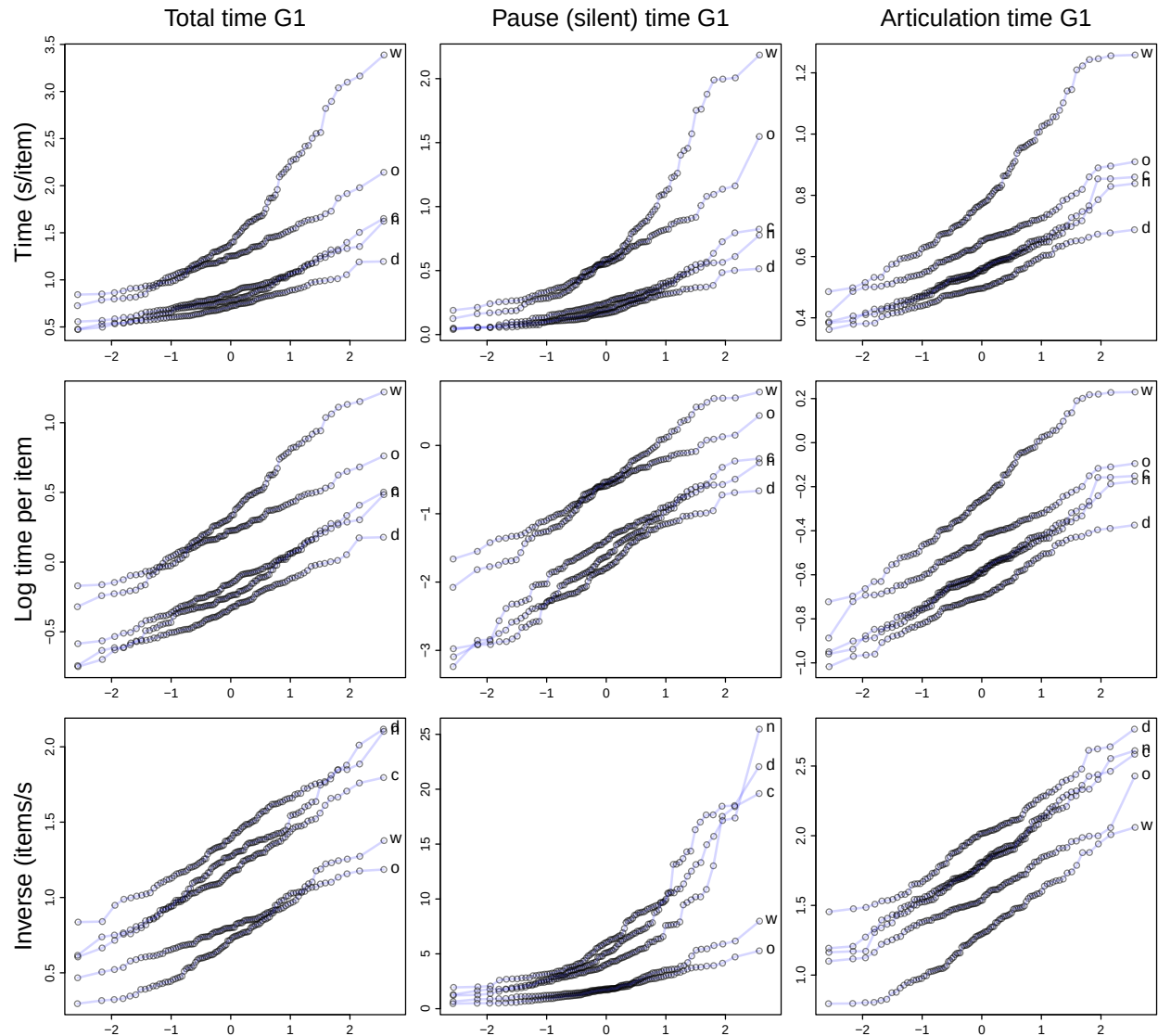
  for (ii in ncset) {

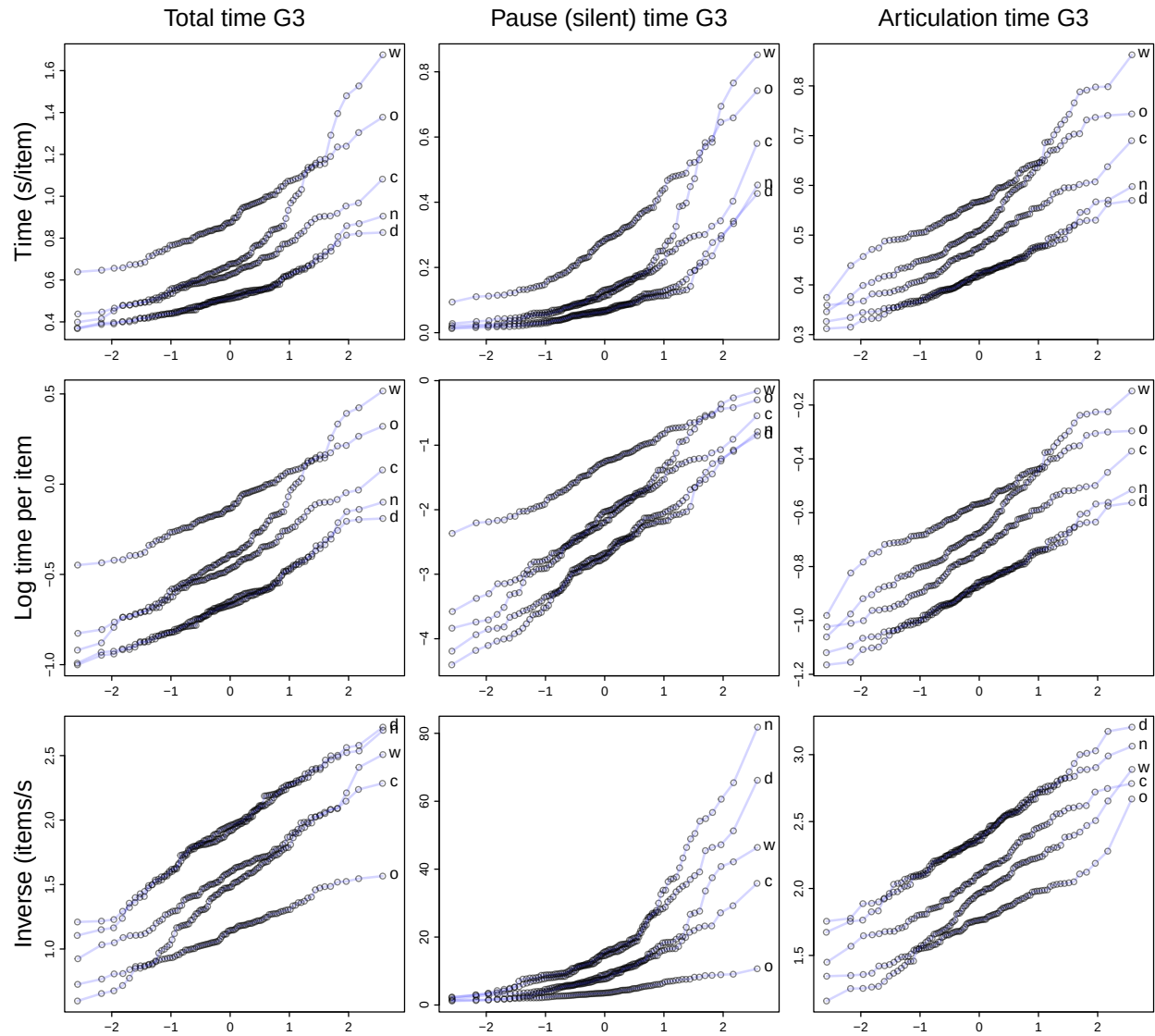
    trdat <- paste(c("itm","log","inv"),ii,sep="")

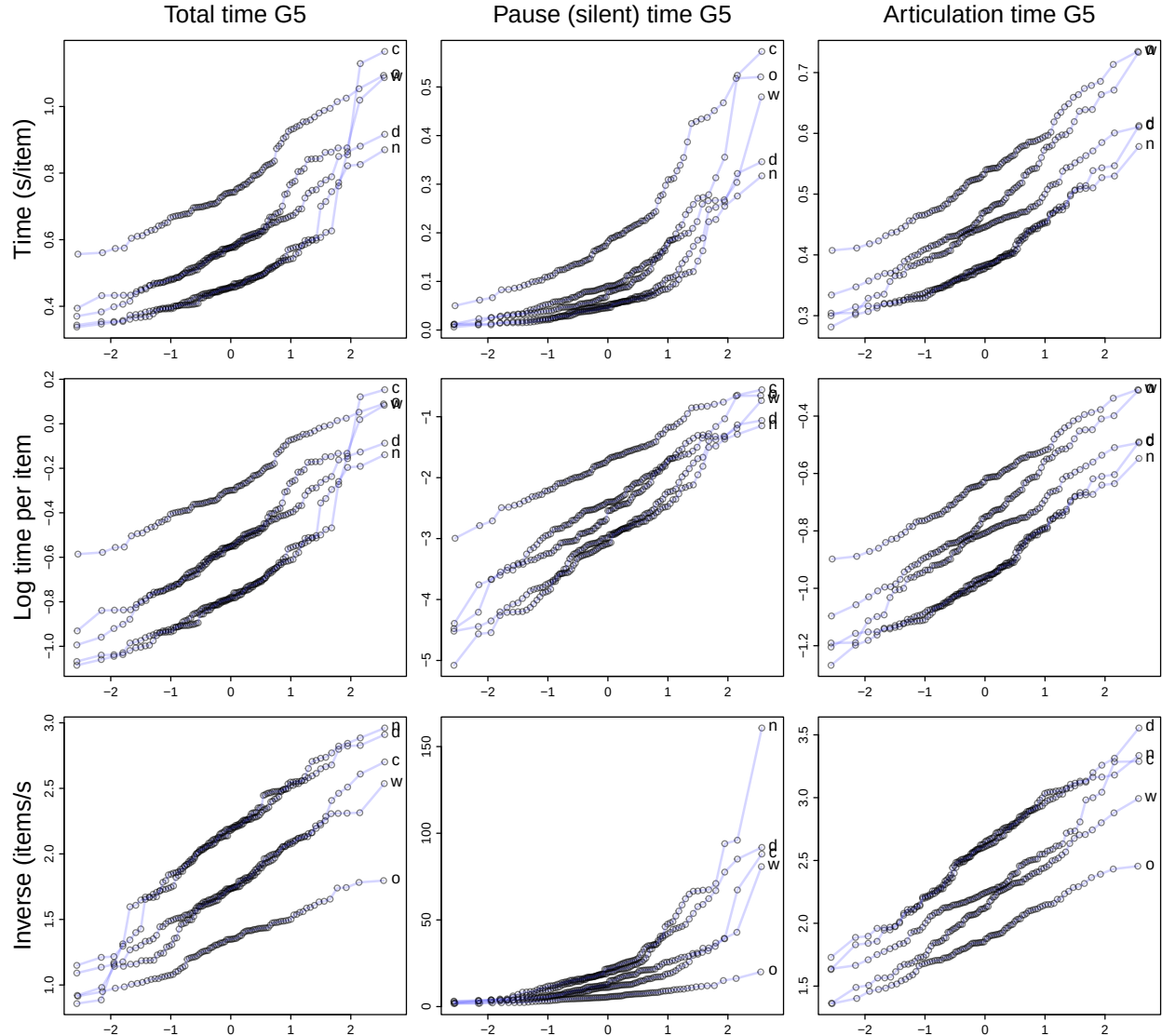
    for (rtv in trdat) {

      qqxy <- list()
      for (tt in tasks) {
        qqxy[[tt]] <- qqnorm(artpau[artpau$grade==grd & artpau$task==tt,rtv],plot.it=F)
      }
      xmm <- fivenum(unlist(lapply(qqxy,function(l){l[["x"]]})))[c(1,5)]
      xmm[2] <- xmm[2]+0.15 # extend slightly to allow space for labels
      ymm <- fivenum(unlist(lapply(qqxy,function(l){l[["y"]]})))[c(1,5)]
      plot(NA,NA,xlim=xmm,ylim=ymm,xlab="",ylab="")
      for (tt in tasks) {
        points(qqxy[[tt]],col="#00000080")
        sortl <- lapply(qqxy[[tt]],function(l){l[order(qqxy[[tt]][["x"]])]}))
        lines(sortl,col="#2020FF30",lwd=2)
        text(xmm[2],sortl$y[length(sortl$y)],ifelse(tt=="dice","c",substr(tt,1,1)),adj=c(0.25,0.25),cex=1)
      }
      if ( ii=="adj" ) {
        mtext(c("Time (s/item)","Log time per item","Inverse (items/s)")[grep(rtv,trdat)],2,line=2,cex=1)
      }
      if ( rtv==trdat[1] ) {
        mtext(paste(c("Total time","Pause (silent) time","Articulation time")[grep(ii,ncset)],grd),3,line=1)
      }
    }
  }
}

```





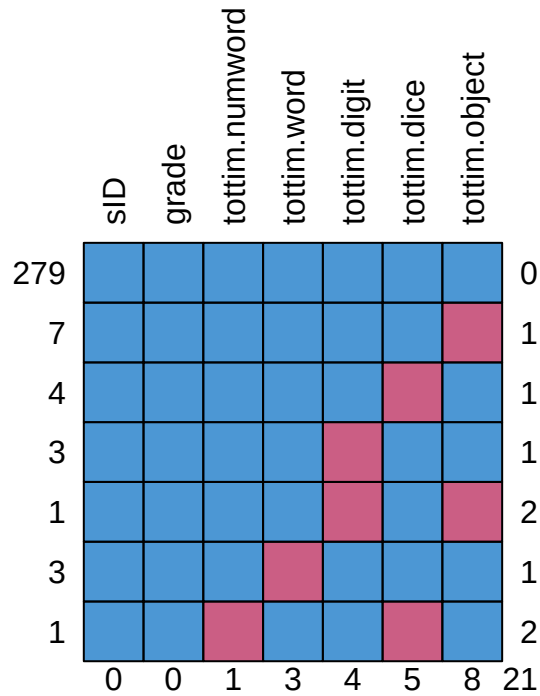


Distributions of rate (inverse-transformed data) deviate severely from normal in the case of pause times (i.e., silent intervals), perhaps because those tend to shrink a lot with increasing skill. It seems that log-transformed data may be the best compromise, as the corresponding distributions are not bad for articulation times (speech intervals) even if they are not optimal.

3.7 Missing data report

Showing missing data pattern for one measure only (total time); the rest are the same as they are all derived from the same response.

```
artpauw <- reshape(artpau,direction="wide",idvar=c("sID","grade"),timevar="task")
attr(artpauw,"reshapeWide")<-NULL
md.pattern(artpauw[,c(1,2,which(substr(names(artpauw),1,7)=="tottim."))],rotate.names=T)
```



```
##      sID grade tottim.numword tottim.word tottim.digit tottim.dice tottim.object
## 279   1     1             1             1             1             1             1  0
## 7     1     1             1             1             1             1             0  1
## 4     1     1             1             1             1             0             1  1
## 3     1     1             1             1             0             1             1  1
## 1     1     1             1             1             0             1             0  2
## 3     1     1             1             0             1             1             1  1
## 1     1     1             0             1             1             0             1  2
##      0     0             1             3             4             5             8  21
```

```
write.table(artpauw,file="serial_artpau_wide.txt")
```

4 Discrete data

In this section we consider data from the discrete naming tasks, which have been manually processed to mark onsets and offsets of spoken intervals in addition to accuracy of the response (the first whole word present in the recording). A more detailed description of each variable is reported in the descriptives document.

```
read.table("discrete_bytrial_long.txt",stringsAsFactors=TRUE) -> discd
str(discd)
```

```
## 'data.frame':   53640 obs. of  20 variables:
## $ sID      : Factor w/ 298 levels "S1101","S1102",...: 2 2 2 2 2 2 2 2 2 2 ...
## $ sitem    : int   1201 1202 1203 1204 1205 1206 1207 1208 1209 1210 ...
## $ subject  : Factor w/ 298 levels "a-26i_xp_rh",...: 2 2 2 2 2 2 2 2 2 2 ...
## $ date     : Factor w/ 48 levels "04/01/2001","04/08/2001",...: 40 40 40 40 40 40 40 40 40 40 ...
## $ time     : Factor w/ 298 levels "00:04:51","00:18:08",...: 125 125 125 125 125 125 125 125 125 125 ...
```

```
## $ order : int 87 88 89 90 91 92 93 94 95 96 ...
## $ item : int 1201 1202 1203 1204 1205 1206 1207 1208 1209 1210 ...
## $ RT : num 896 874 976 930 910 ...
## $ task : int 1 1 1 1 1 1 1 1 1 1 ...
## $ stask : Factor w/ 5 levels "dice","digit",...: 2 2 2 2 2 2 2 2 2 2 ...
## $ cRT : num 896 874 976 930 910 ...
## $ logRT : num 6.8 6.77 6.88 6.83 6.81 ...
## $ invRT : num 1.12 1.14 1.02 1.08 1.1 ...
## $ grade : Factor w/ 3 levels "G1","G3","G5": 1 1 1 1 1 1 1 1 1 1 ...
## $ format : Factor w/ 1 level "discrete": 1 1 1 1 1 1 1 1 1 1 ...
## $ acc : int 1 1 1 1 1 1 1 1 1 1 ...
## $ sdtask : Factor w/ 5 levels "d_dice","d_digit",...: 2 2 2 2 2 2 2 2 2 2 ...
## $ onsRT : num 550 508 521 511 488 ...
## $ filext : int 0 0 0 0 0 0 0 0 0 0 ...
## $ artic : num 346 367 455 419 421 ...
```

```
options(width=100)
summary(discd)
```

```
##      sID      sitem      subject      date      time
## S1101 : 180 Min. :1201 a-26i_xp_rh: 180 06/12/2014: 2880 00:04:51: 180
## S1102 : 180 1st Qu.:2210 a_12i_ap_m : 180 06/11/2014: 2340 00:18:08: 180
## S1103 : 180 Median :3218 a_12i_as_sm: 180 06/10/2014: 2160 01:23:29: 180
## S1104 : 180 Mean :4018 a_12i_bg : 180 05/30/2014: 1620 02:46:40: 180
## S1105 : 180 3rd Qu.:6227 a_12i_ee_b : 180 05/05/2015: 1440 03:32:18: 180
## S1106 : 180 Max. :7236 a_12i_ek_t : 180 05/14/2014: 1440 04:17:31: 180
## (Other):52560 (Other) :52560 (Other) :41760 (Other) :52560
##      order      item      RT      task      stask      cRT
## Min. : 2 Min. :1201 Min. : -120000.0 Min. :1.0 dice :10728 Min. : 449.5
## 1st Qu.: 70 1st Qu.:2210 1st Qu.: 873.0 1st Qu.:2.0 digit :10728 1st Qu.: 880.7
## Median :140 Median :3218 Median : 1026.3 Median :3.0 numword:10728 Median :1031.5
## Mean :140 Mean :4018 Mean : 473.2 Mean :3.8 object :10728 Mean :1160.0
## 3rd Qu.:210 3rd Qu.:6227 3rd Qu.: 1252.9 3rd Qu.:6.0 word :10728 3rd Qu.:1258.0
## Max. :276 Max. :7236 Max. : 120000.0 Max. :7.0 NA's :840
##      logRT      invRT      grade      format      acc      sdtask
## Min. :6.108 Min. :0.0831 G1:17820 discrete:53640 Min. :0.0000 d_dice :10728
## 1st Qu.:6.781 1st Qu.:0.7949 G3:18360 1st Qu.:1.0000 d_digit :10728
## Median :6.939 Median :0.9694 G5:17460 Median :1.0000 d_numword:10728
## Mean :6.992 Mean :0.9637 Mean :0.9846 d_object :10728
## 3rd Qu.:7.137 3rd Qu.:1.1355 3rd Qu.:1.0000 d_word :10728
## Max. :9.396 Max. :2.2247 Max. :1.0000
## NA's :840 NA's :840
##      onsRT      filext      artic
## Min. : 250.6 Min. : 0.0000 Min. : -1874.2
## 1st Qu.: 494.7 1st Qu.: 0.0000 1st Qu.: 336.3
## Median : 597.1 Median : 0.0000 Median : 417.7
## Mean : 712.6 Mean : 0.5505 Mean : 446.5
## 3rd Qu.: 760.0 3rd Qu.: 0.0000 3rd Qu.: 518.3
## Max. :9964.2 Max. :42.0000 Max. :10818.9
## NA's :687 NA's :989
```

4.1 Within-participant distributions per task

Discrete naming data differ from serial naming data in that the response to each item is recorded and processed individually. This makes it easier to select or discard intervals based on accuracy, but it entails the additional step of computing a summary value per task for each participant based on the individual items. To select the most appropriate measure of central tendency for onset latency and articulation times we must first consider their within-participant distributions.

4.1.1 Superimposed individual distributions

The following graphs display superimposed Q-Q plots from individual participants (faint gray lines) and their mean (thick blue line), for each type of measure (RT=total time, artic=articulation duration, onsRT=onset latency) and each task. Participants from the three grades are considered together.

```
discd$logartic <- ifelse(discd$artic>0, log(discd$artic), NA)
discd$invartic <- ifelse(discd$artic>0, 1000.0/discd$artic, NA)

discd$logonsRT <- ifelse(discd$onsRT>0, log(discd$onsRT), NA)
discd$invonsRT <- ifelse(discd$onsRT>0, 1000.0/discd$onsRT, NA)

tasks <- levels(discd$stask)
ids <- levels(discd$sID)

for (ii in c("RT","artic","onsRT")) {

  trdat <- paste(c(ifelse(ii=="RT","c",""),"log","inv"),ii,sep="")

  par(mfcol=c(3,length(tasks)))
  par(mai=c(0.1,0.1,0.1,0.1))
  par(oma=c(0,1.75,1.75,0))
  par(mgp=c(2,0.75,0))

  for (tt in tasks) {
    for (rtv in trdat) {

      n <- 0
      allq <- data.frame(x=1:36)
      plot(NA,NA,xlim=c(-2.2,2.2),ylim=c(-2.2,2.2),xlab="",ylab="",main="",xaxt="n",yaxt="n")
      if (rtv==trdat[1]) { mtext(tt,3,line=1,cex=1.25) }
      if (tt==tasks[1]) { mtext(rtv,2,line=1,cex=1.25) }

      for (pp in ids) {
        dd <- discd[discd$sID==pp & discd$stask==tt,rtv]
        if (sum(!is.na(dd))==36) {
          n <- n+1
          qq <- as.data.frame(qqnorm(scale(dd),plot.it=FALSE))
          qq <- qq[order(qq$x),]
          allq[pp] <- qq$y
        }
      }
      text(-2,2,paste("n",n,sep=""),adj=0)
      allq["x"] <- qq$x
      for (r in names(allq[,-1])) {
        lines(allq$x,allq[r],col="#60606030") # was grey50 ; made darker but mostly transparent
      }
    }
  }
}
```

```

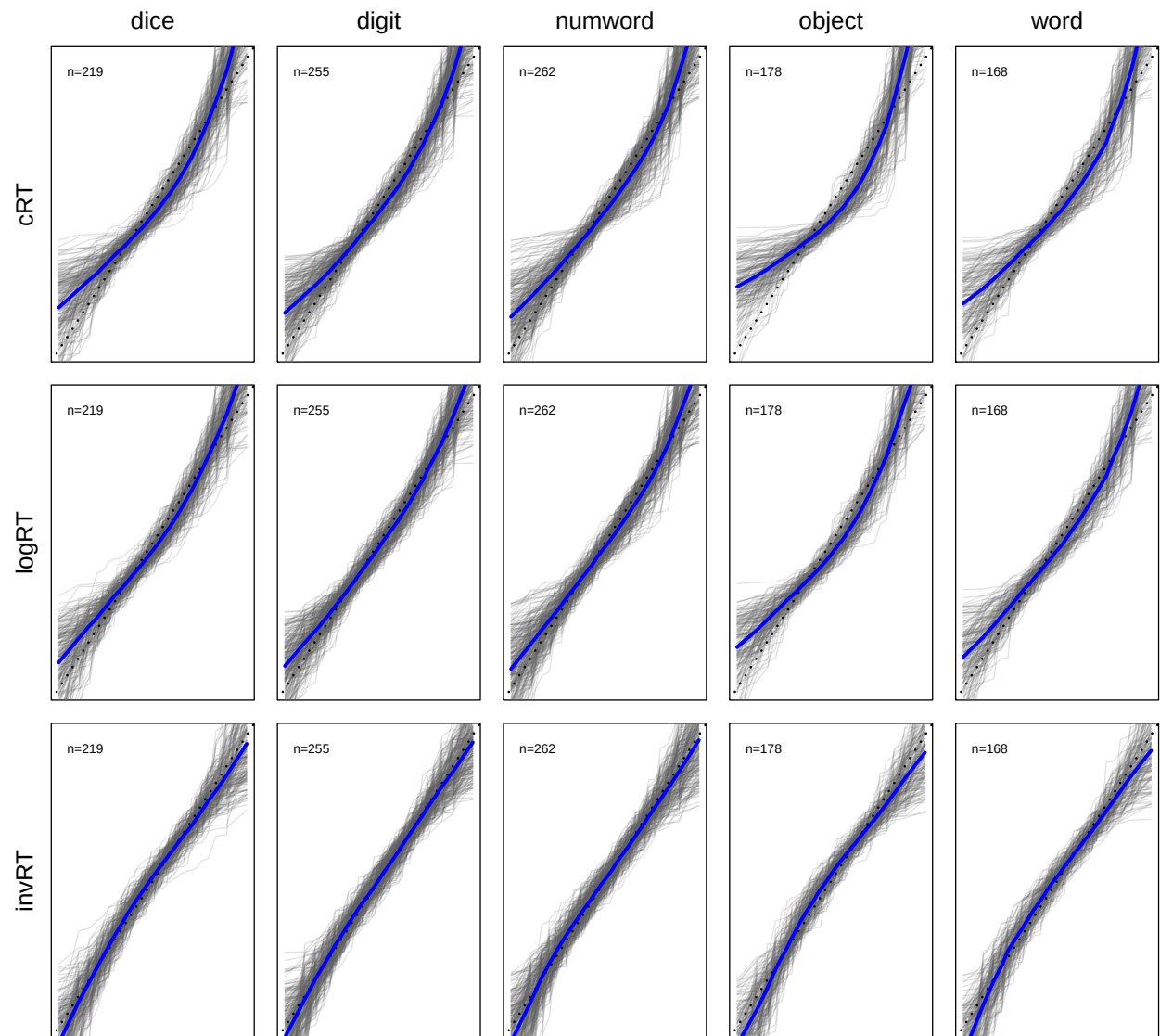
abline(0,1,lty=3,lwd=2)
lines(allq$x,apply(allq[, -1],1,mean,na.rm=T),lwd=3,col="blue")

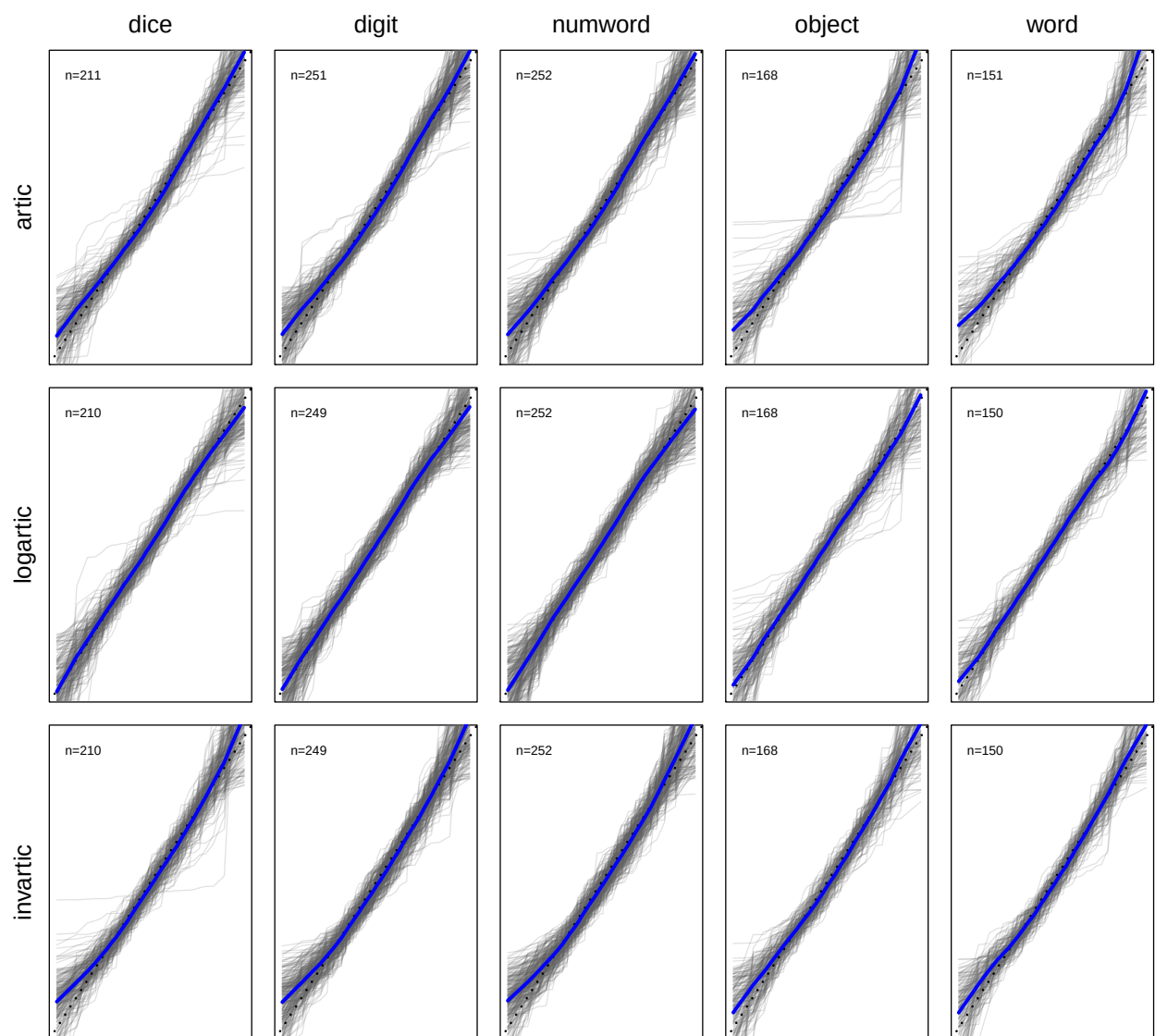
}

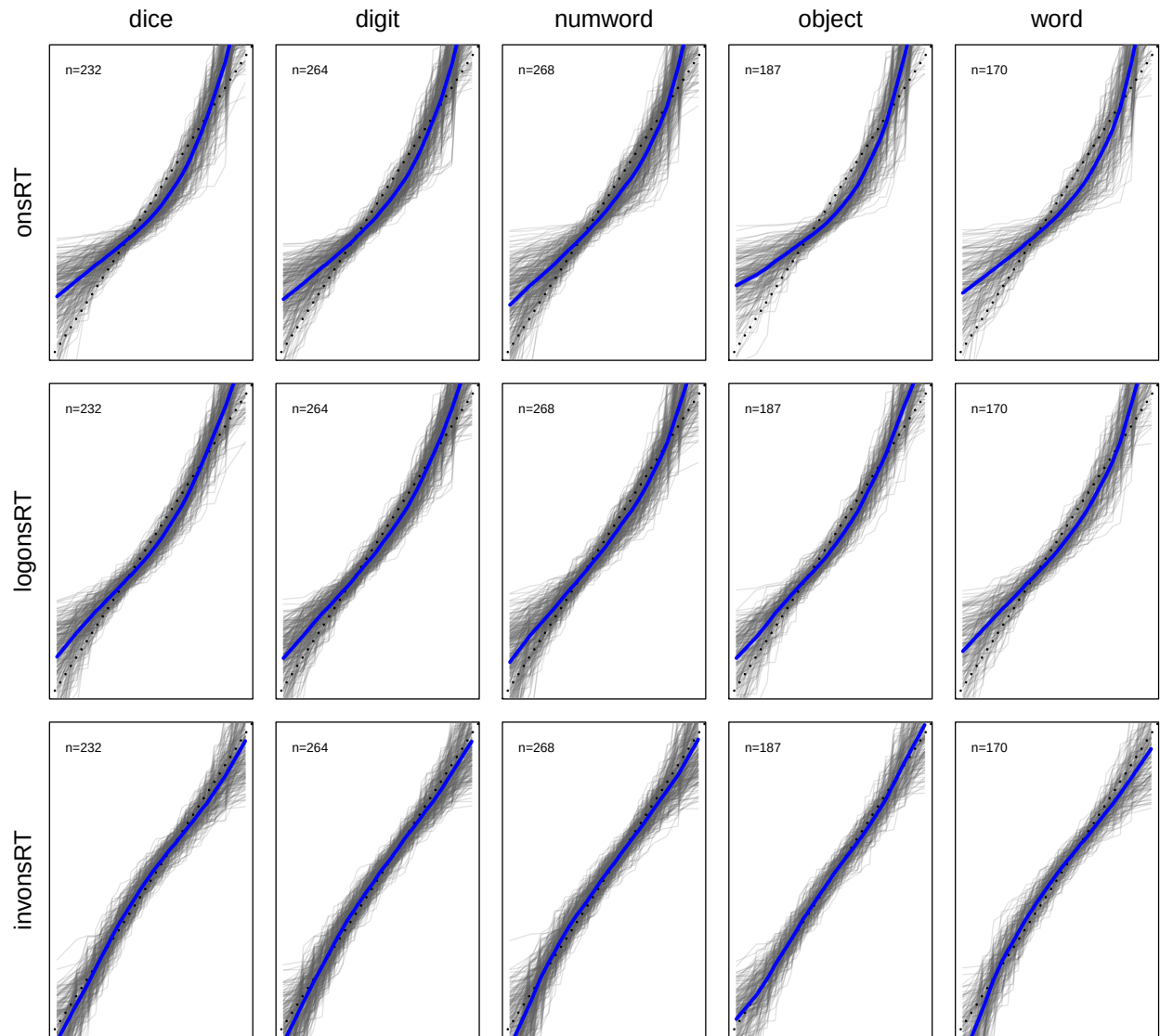
}

}

```



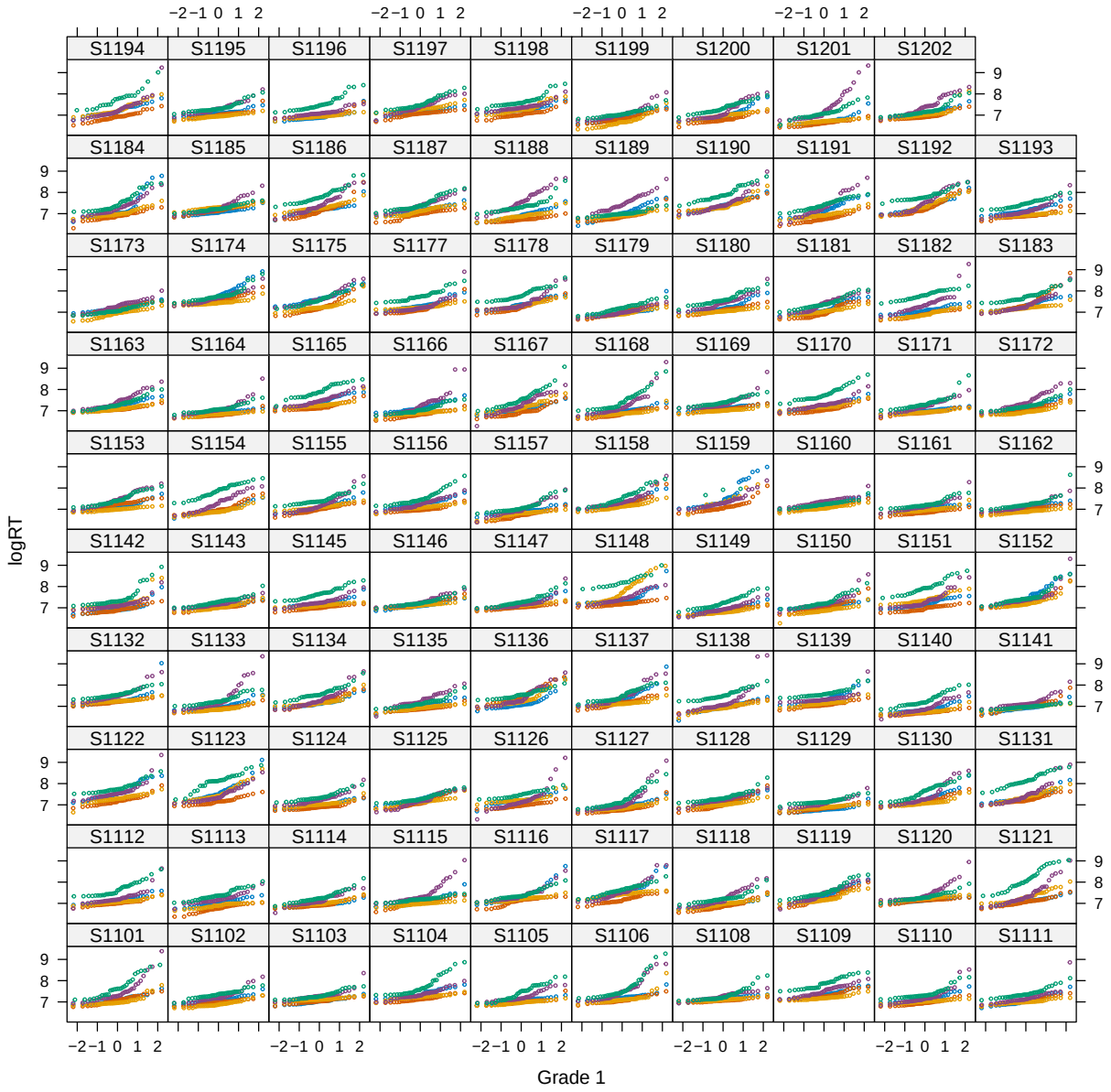




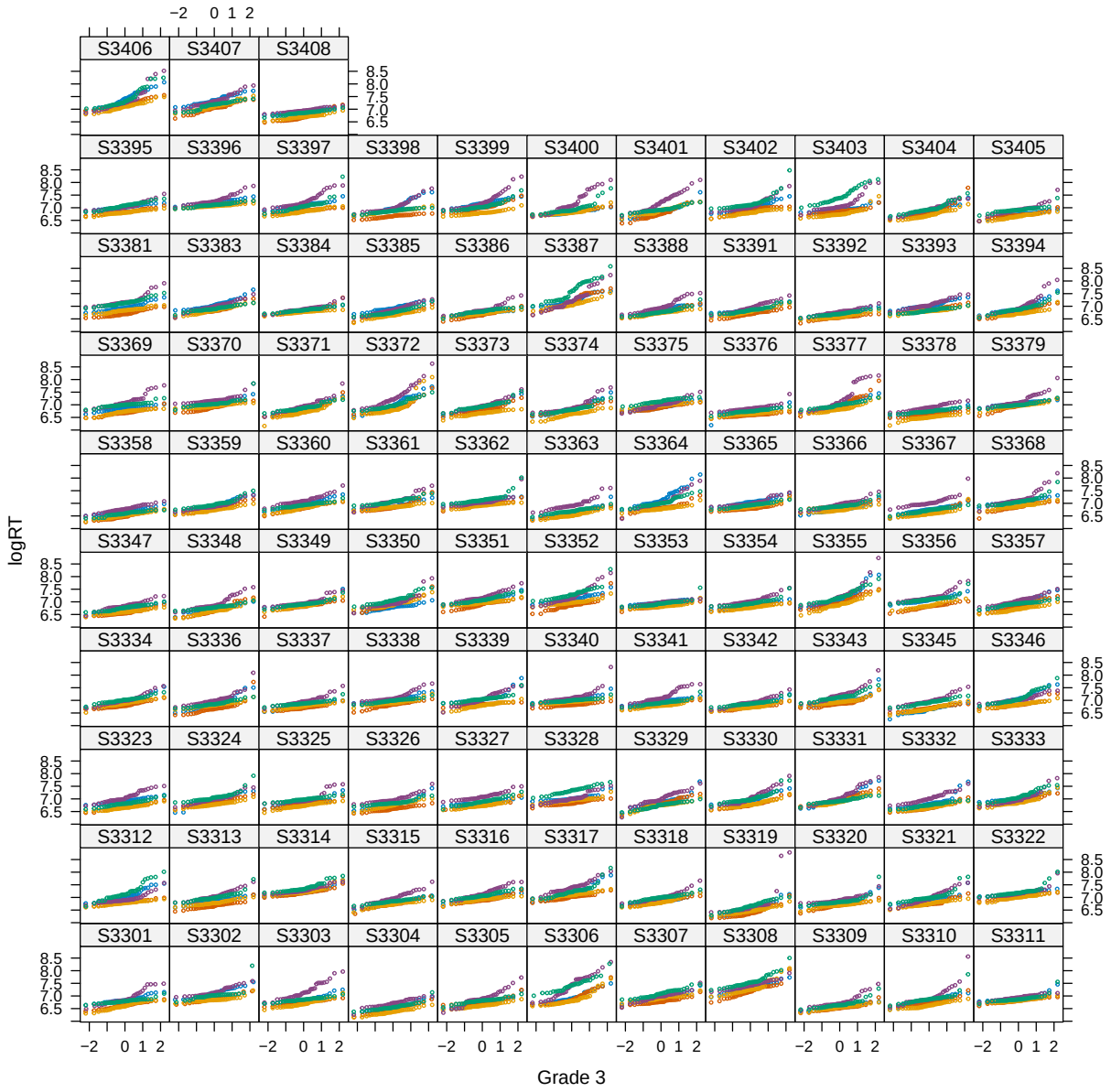
4.1.2 Lattice plots per participant

Preliminary exploration shown above indicates that log-transformed values present the best compromise for within-participant averaging. The following plots display the distributions of log-transformed individual response times for each participant (one panel) across tasks (different colors within the panel).

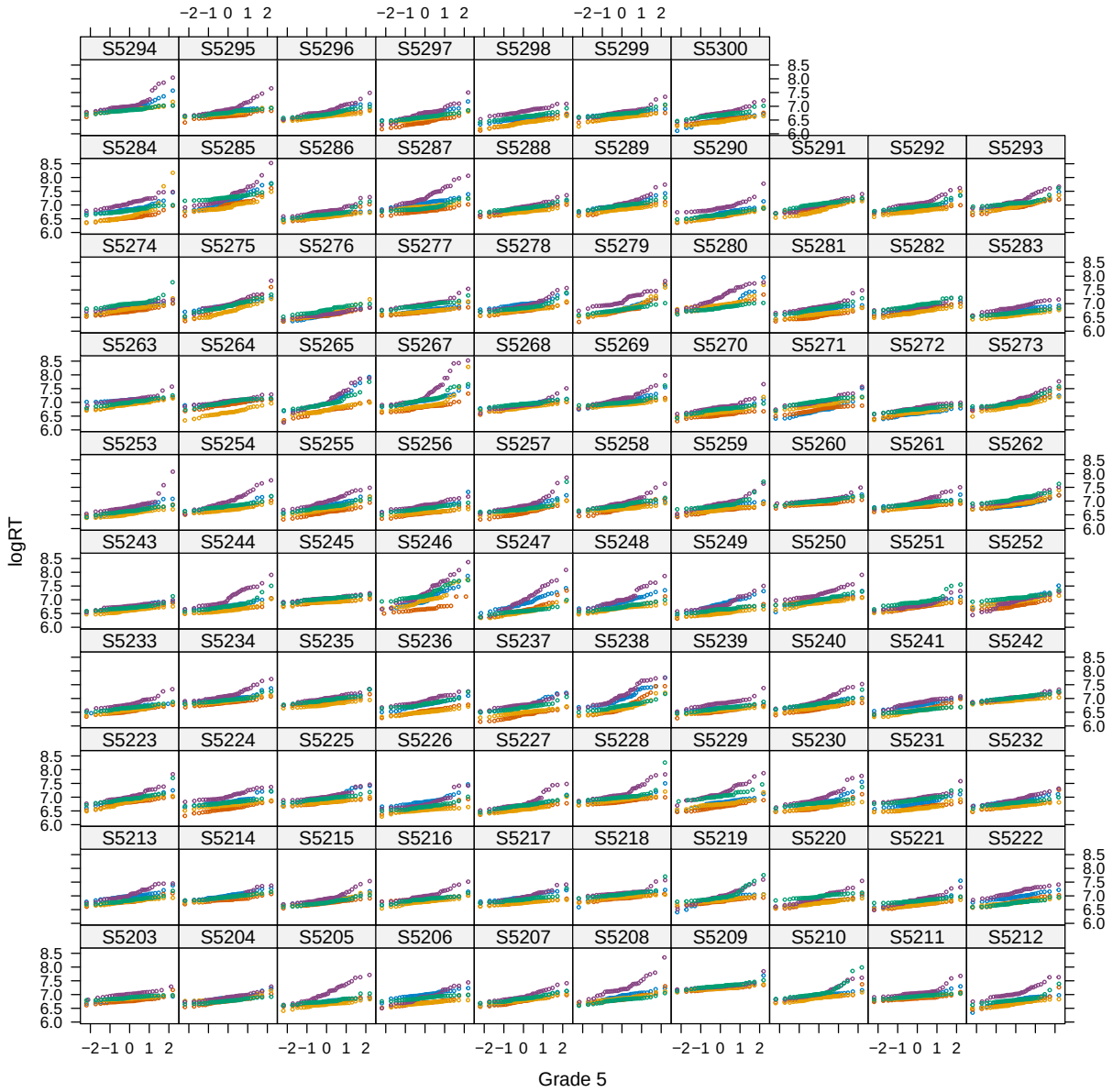
```
colors <- c("#D55E00", "#E69F00", "#009E73", "#0180C7", "#884584")[c(4,1,2,5,3)] # tasks in other docs
qqmath(~logRT|sID,discd,groups=stask,cex=0.35,subset=grade=="G1",xlab="Grade 1",col=colors)
```



```
qqmath(~logRT|sID,discd,groups=stask,cex=0.35,subset=grade=="G3",xlab="Grade 3",col=colors)
```



```
qqmath(~logRT|sID,discd,groups=stask,cex=0.35,subset=grade=="G5",xlab="Grade 5",col=colors)
```



4.2 Between-participant distributions of geometric means

We compute within-participant averages for each task as geometric means, that is, the means of log-transformed values back-transformed to times. We then consider the (between-participant) distribution of these geometric means, untransformed and after transformations. A corresponding Shapiro-Wilk test is displayed along with each Q-Q plot.

```
meanrt <- aggregate(cbind(logRT,logonsRT,logartic,acc)~sID+grade+stask,discd,na.action=na.pass,FUN=mean
# na.pass is needed to retain rows with NAs in some variables (but possibly not others)
```

```
meanrt$RT <- exp(meanrt$logRT)
meanrt$onsRT <- exp(meanrt$logonsRT)
meanrt$artic <- exp(meanrt$logartic)
```

```

par(mfcol=c(3,3))

par(oma=c(0,2,2,0))
par(mai=c(0.25,0.2,0.1,0.1))
par(mgp=c(2,0.5,0))
par(tcl= -0.3)

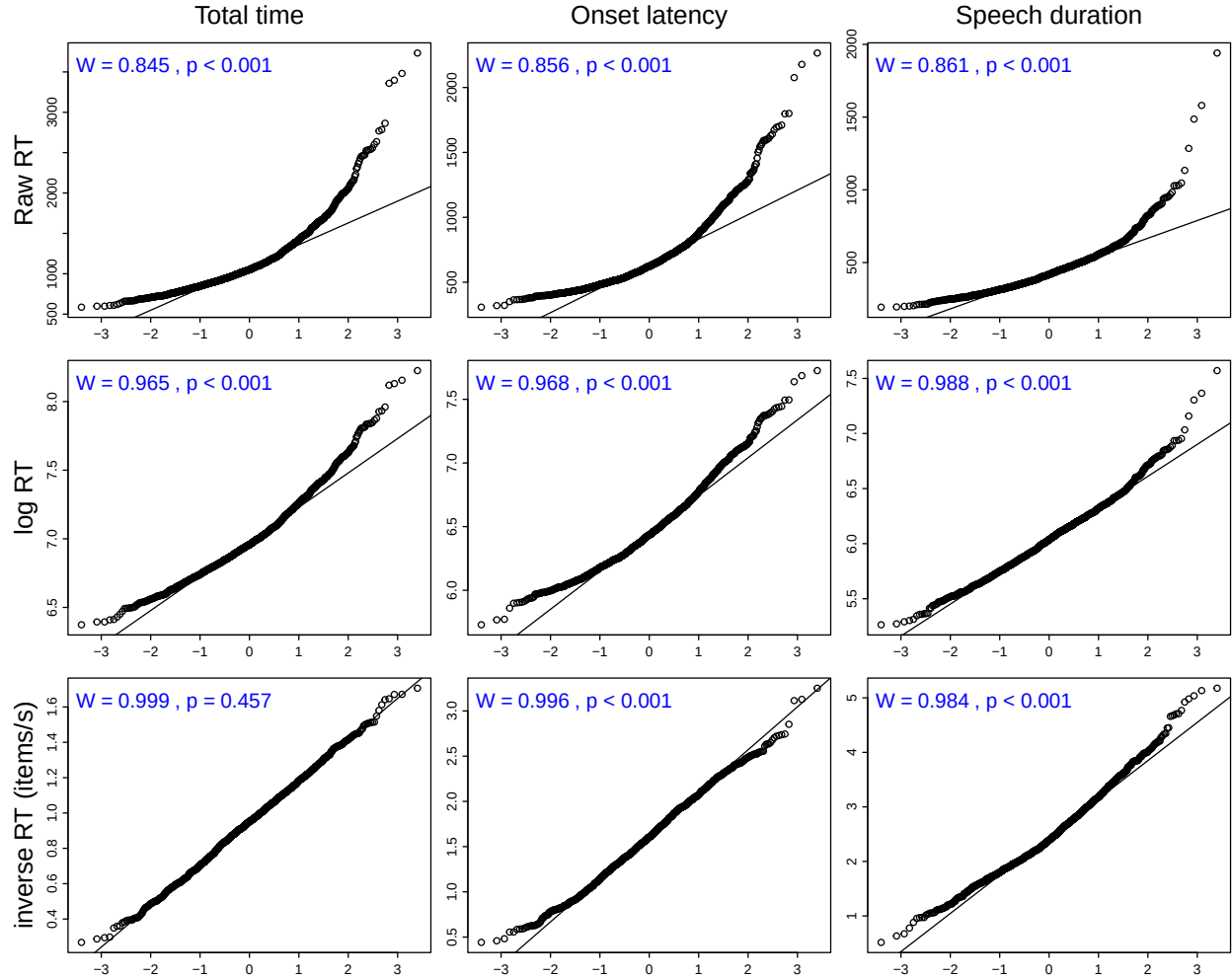
qqpanel <- function(x) {
  qqnorm(x,main="",xlab="",ylab="")
  qqline(x)
  xm <- par('usr')[1]
  ym <- par('usr')[3]+0.9*diff(par('usr')[c(3,4)])
  shapiro.test(x) -> st
  if ( st$p.value >= 0.001 ) {
    ttt <- bquote("W ="~.(round(st$statistic,3))~", p ="~.(round(st$p.value,3)))
  } else {
    ttt <- bquote("W ="~.(round(st$statistic,3))~", p < 0.001")
  }
  text(xm,ym,ttt,pos=4,col="blue",xpd=NA,cex=1.5)
}

qqpanel(meanrt$RT)
mtext("Total time",3,line=1,cex=1.25)
mtext("Raw RT",2,line=2,cex=1.25)
qqpanel(log(meanrt$RT))
mtext("log RT",2,line=2,cex=1.25)
qqpanel(1000.0/meanrt$RT)
mtext("inverse RT (items/s)",2,line=2,cex=1.25)

qqpanel(meanrt$onsRT)
mtext("Onset latency",3,line=1,cex=1.25)
qqpanel(log(meanrt$onsRT))
qqpanel(1000.0/meanrt$onsRT)

qqpanel(meanrt$artic)
mtext("Speech duration",3,line=1,cex=1.25)
qqpanel(log(meanrt$artic))
qqpanel(1000.0/meanrt$artic)

```



It seems that an inverse transformation of individual means, that is, the computation of rates (items per second) presents the best approximation to the normal distribution for these measures, in agreement with previous work on naming tasks.

4.3 Descriptives by task and grade

The following tables display descriptive statistics for each type of measure by task and grade.

```
meanrt$invRT <- 1000.0/meanrt$RT
meanrt$invonsRT <- 1000.0/meanrt$onsRT
meanrt$invartic <- 1000.0/meanrt$artic
describeBy(acc+RT+onsRT+artic+invRT+invonsRT+invartic~grade+stask,data=meanrt)
```

```
##
## Descriptive statistics by group
## grade: G1
## stask: dice
##
```

	vars	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
acc	1	99	0.99	0.02	1.00	0.99	0.00	0.89	1.00	0.11	-2.11	4.12	0.00
RT	2	99	1324.84	289.32	1266.22	1289.73	227.23	841.08	2541.52	1700.43	1.41	2.69	29.08
onsRT	3	99	845.14	198.47	806.61	821.76	164.62	550.00	1594.23	1044.23	1.36	2.22	19.95
artic	4	99	461.66	127.62	442.88	450.22	111.87	246.09	872.32	626.24	0.92	0.89	12.83
invRT	5	99	0.79	0.15	0.79	0.79	0.15	0.39	1.19	0.80	-0.11	0.01	0.01

```

## invonsRT      6 99      1.24  0.25      1.24      1.24  0.27  0.63      1.82      1.19 -0.18      -0.42  0.03
## invartic      7 99      2.32  0.61      2.26      2.29  0.57  1.15      4.06      2.92  0.56      0.16  0.06
## -----
## grade: G3
## stask: dice
##      vars  n    mean    sd median trimmed    mad    min    max range skew kurtosis    se
## acc      1 102    0.99  0.02    1.00    0.99  0.00  0.92    1.00  0.08 -1.89    3.30  0.00
## RT       2 102 1045.51 180.52 1025.79 1033.16 160.74 697.57 1661.44 963.87 0.74    0.90 17.87
## onsRT    3 102  652.67 129.03  647.06  645.11 121.66 369.85 1179.88 810.03 0.93    2.49 12.78
## artic    4 102  384.46  91.05  369.03  376.63  85.06 224.61  655.15 430.54 0.78    0.23  9.02
## invRT    5 102    0.98  0.16    0.97    0.98  0.15  0.60    1.43  0.83 0.32    0.08  0.02
## invonsRT 6 102    1.59  0.31    1.55    1.57  0.28  0.85    2.70  1.86 0.78    1.47  0.03
## invartic 7 102    2.74  0.61    2.71    2.72  0.66  1.53    4.45  2.93 0.23   -0.46  0.06
## -----
## grade: G5
## stask: dice
##      vars  n    mean    sd median trimmed    mad    min    max range skew kurtosis    se
## acc      1 97    0.99  0.05    1.00    0.99  0.00  0.56    1.00  0.44 -7.44   62.43  0.00
## RT       2 97 969.33 135.98 942.96 967.71 148.42 669.12 1457.74 788.62 0.40    0.41 13.81
## onsRT    3 97 582.47  79.19 578.70 579.98  76.91 422.06  773.13 351.07 0.27   -0.33  8.04
## artic    4 97 379.94  94.94 357.46 375.10 107.21 213.52  706.74 493.23 0.58    0.03  9.64
## invRT    5 97    1.05  0.15    1.06    1.04  0.17  0.69    1.49  0.81 0.41    0.02  0.02
## invonsRT 6 97    1.75  0.24    1.73    1.74  0.24  1.29    2.37  1.08 0.40   -0.18  0.02
## invartic 7 97    2.80  0.69    2.80    2.76  0.81  1.41    4.68  3.27 0.44   -0.38  0.07
## -----
## grade: G1
## stask: digit
##      vars  n    mean    sd median trimmed    mad    min    max range skew kurtosis    se
## acc      1 99    0.99  0.02    1.00    1.00  0.00  0.86    1.00  0.14 -5.22   33.54  0.00
## RT       2 99 1159.76 211.90 1138.58 1144.22 205.80 754.36 1989.37 1235.02 1.04    2.05 21.30
## onsRT    3 99  683.85 129.96  658.58  669.06 104.14 481.97 1179.40 697.44 1.36    2.45 13.06
## artic    4 99  463.50 119.91  462.26  458.25 115.46 231.48  983.05 751.58 0.85    2.12 12.05
## invRT    5 99    0.89  0.15    0.88    0.89  0.16  0.50    1.33  0.82 0.22    0.16  0.02
## invonsRT 6 99    1.51  0.25    1.52    1.51  0.22  0.85    2.07  1.23 -0.19   -0.01  0.03
## invartic 7 99    2.30  0.60    2.16    2.26  0.50  1.02    4.32  3.30 0.76    0.39  0.06
## -----
## grade: G3
## stask: digit
##      vars  n    mean    sd median trimmed    mad    min    max range skew kurtosis    se
## acc      1 102    0.99  0.04    1.00    1.00  0.00  0.72    1.00  0.28 -5.68   34.19  0.00
## RT       2 102 914.71 137.82 912.89 905.06 107.23 609.18 1338.66 729.47 0.84    1.52 13.65
## onsRT    3 102 530.55  81.73 521.20 528.13  60.36 307.61  816.86 509.25 0.41    0.97  8.09
## artic    4 102 377.98  88.14 371.44 371.69  72.30 214.02  659.86 445.84 0.82    0.98  8.73
## invRT    5 102    1.12  0.16    1.10    1.11  0.12  0.75    1.64  0.89 0.35    0.82  0.02
## invonsRT 6 102    1.93  0.31    1.92    1.91  0.22  1.22    3.25  2.03 1.03    2.82  0.03
## invartic 7 102    2.78  0.63    2.69    2.75  0.56  1.52    4.67  3.16 0.52    0.14  0.06
## -----
## grade: G5
## stask: digit
##      vars  n    mean    sd median trimmed    mad    min    max range skew kurtosis    se
## acc      1 97    0.99  0.03    1.00    1.00  0.00  0.75    1.00  0.25 -6.10   44.43  0.00
## RT       2 97 850.09 127.02 833.66 845.06 144.99 598.29 1358.02 759.74 0.66    1.15 12.90
## onsRT    3 97 475.79  62.60 466.44 470.04  57.61 367.58  677.42 309.84 0.90    0.74  6.36
## artic    4 97 368.85  97.33 361.15 363.71 112.15 194.81  676.55 481.73 0.49   -0.20  9.88

```

```

## invRT      5 97   1.20   0.18   1.20   1.20   0.19   0.74   1.67   0.94   0.25   -0.15   0.02
## invonsRT   6 97   2.14   0.26   2.14   2.14   0.27   1.48   2.72   1.24  -0.23   -0.31   0.03
## invartic   7 97   2.91   0.78   2.77   2.86   0.84   1.48   5.13   3.66   0.65    0.06   0.08
## -----
## grade: G1
## stask: numword
##      vars  n    mean    sd median trimmed   mad    min    max    range skew kurtosis   se
## acc      1 99    0.99    0.07    1.00    1.00    0.00    0.33    1.00    0.67 -8.66    78.72  0.01
## RT       2 99 1221.77 257.33 1172.26 1197.91 239.38 809.63 2475.08 1665.45 1.46    4.26 25.86
## onsRT    3 99  722.54 163.42  698.62  701.14 133.49 489.45 1547.68 1058.23 1.84    5.55 16.42
## artic    4 99  488.14 140.31  471.00  478.60 115.97 247.95  901.13  653.19  0.75    0.57 14.10
## invRT     5 99    0.85    0.16    0.85    0.85    0.18    0.40    1.24    0.83 -0.02   -0.27  0.02
## invonsRT  6 99    1.44    0.27    1.43    1.45    0.28    0.65    2.04    1.40 -0.29   -0.16  0.03
## invartic  7 99    2.22    0.64    2.12    2.17    0.54    1.11    4.03    2.92  0.74    0.18  0.06
## -----
## grade: G3
## stask: numword
##      vars  n    mean    sd median trimmed   mad    min    max    range skew kurtosis   se
## acc      1 102    0.99    0.03    1.00    1.00    0.00    0.72    1.00    0.28 -6.50    48.70  0.00
## RT       2 102  906.80 145.87  894.28  896.18 118.43 586.09 1486.87  900.78  1.02    2.39 14.44
## onsRT    3 102  518.80  75.96  513.40  515.30  66.27 319.75  711.61  391.86  0.34    0.36  7.52
## artic    4 102  382.92  93.49  369.10  373.35  79.95 232.92  766.02  533.09  1.20    2.26  9.26
## invRT     5 102    1.13    0.17    1.12    1.13    0.15    0.67    1.71    1.03  0.32    0.82  0.02
## invonsRT  6 102    1.97    0.30    1.95    1.96    0.26    1.41    3.13    1.72  0.93    2.66  0.03
## invartic  7 102    2.75    0.61    2.71    2.74    0.59    1.31    4.29    2.99  0.24   -0.15  0.06
## -----
## grade: G5
## stask: numword
##      vars  n    mean    sd median trimmed   mad    min    max    range skew kurtosis   se
## acc      1 97    1.00    0.02    1.00    1.00    0.00    0.92    1.00    0.08 -4.13    17.16  0.00
## RT       2 97  859.55 131.10  850.76  855.11 142.56 598.47 1376.40  777.94  0.64    0.91 13.31
## onsRT    3 97  469.77  62.57  457.96  464.50  69.58 365.41  668.86  303.45  0.84    0.58  6.35
## artic    4 97  385.00  99.03  369.09  381.43 112.19 193.18  703.47  510.29  0.41   -0.25 10.06
## invRT     5 97    1.19    0.18    1.18    1.18    0.20    0.73    1.67    0.94  0.19   -0.41  0.02
## invonsRT  6 97    2.16    0.27    2.18    2.17    0.34    1.50    2.74    1.24 -0.23   -0.58  0.03
## invartic  7 97    2.78    0.74    2.71    2.72    0.85    1.42    5.18    3.75  0.68    0.05  0.08
## -----
## grade: G1
## stask: object
##      vars  n    mean    sd median trimmed   mad    min    max    range skew kurtosis   se
## acc      1 99    0.98    0.03    1.00    0.98    0.00    0.86    1.00    0.14 -1.51    2.12  0.00
## RT       2 99 1551.64 230.95 1545.81 1545.39 232.32 1033.68 2205.96 1172.28 0.26   -0.04 23.21
## onsRT    3 99 1012.84 165.25  970.59 1004.51 182.41  727.52 1572.60  845.07  0.55   -0.08 16.61
## artic    4 99  496.12 128.25  483.09  487.67 113.79  244.66  886.73  642.07  0.72    0.65 12.89
## invRT     5 99    0.66    0.10    0.65    0.65    0.10    0.45    0.97    0.51  0.61    0.49  0.01
## invonsRT  6 99    1.01    0.16    1.03    1.01    0.19    0.64    1.37    0.74  0.06   -0.90  0.02
## invartic  7 99    2.15    0.56    2.07    2.11    0.49    1.13    4.09    2.96  0.80    0.74  0.06
## -----
## grade: G3
## stask: object
##      vars  n    mean    sd median trimmed   mad    min    max    range skew kurtosis   se
## acc      1 102    0.98    0.02    1.00    0.99    0.00    0.86    1.00    0.14 -1.90    4.76  0.00
## RT       2 102 1178.29 181.25 1141.37 1166.03 158.61 818.80 1681.51  862.70  0.66    0.10 17.95
## onsRT    3 102  758.62 129.71  749.65  749.41 109.37 482.61 1227.14  744.53  0.83    1.29 12.84

```

```

## artic      4 102 402.04 98.83 381.84 393.97 83.64 212.33 806.32 593.99 1.03 1.74 9.79
## invRT      5 102 0.87 0.13 0.88 0.87 0.12 0.59 1.22 0.63 0.14 -0.02 0.01
## invonsRT   6 102 1.35 0.22 1.33 1.35 0.19 0.81 2.07 1.26 0.37 0.55 0.02
## invartic   7 102 2.63 0.61 2.62 2.60 0.55 1.24 4.71 3.47 0.50 0.57 0.06
## -----
## grade: G5
## stask: object
##      vars  n    mean    sd median trimmed  mad   min    max  range  skew kurtosis  se
## acc      1 97 0.98 0.03 1.00 0.99 0.00 0.83 1.00 0.17 -2.42 6.66 0.00
## RT       2 97 1108.08 164.00 1101.09 1094.94 133.70 752.55 1568.08 815.53 0.66 0.34 16.65
## onsRT    3 97 695.15 124.89 673.18 680.24 100.47 476.45 1082.32 605.86 1.10 1.01 12.68
## artic    4 97 398.20 92.55 381.50 394.37 99.60 203.14 705.56 502.42 0.47 0.10 9.40
## invRT    5 97 0.92 0.13 0.91 0.92 0.12 0.64 1.33 0.69 0.15 -0.05 0.01
## invonsRT 6 97 1.48 0.24 1.49 1.49 0.24 0.92 2.10 1.17 -0.20 -0.12 0.02
## invartic 7 97 2.65 0.64 2.62 2.60 0.64 1.42 4.92 3.51 0.82 0.87 0.06
## -----
## grade: G1
## stask: word
##      vars  n    mean    sd median trimmed  mad   min    max  range  skew kurtosis  se
## acc      1 99 0.93 0.11 0.97 0.96 0.04 0.08 1.00 0.92 -4.72 29.38 0.01
## RT       2 99 1869.60 543.00 1751.61 1812.08 444.84 1063.58 3734.31 2670.73 1.15 1.27 54.57
## onsRT    3 99 1118.74 354.08 1026.27 1082.54 317.74 600.01 2265.61 1665.60 1.01 0.67 35.59
## artic    4 99 702.87 249.60 635.43 668.21 165.53 374.14 1940.75 1566.61 2.12 6.43 25.09
## invRT    5 99 0.57 0.15 0.57 0.57 0.15 0.27 0.94 0.67 0.12 -0.53 0.01
## invonsRT 6 99 0.98 0.28 0.97 0.97 0.31 0.44 1.67 1.23 0.18 -0.72 0.03
## invartic 7 99 1.56 0.42 1.57 1.55 0.45 0.52 2.67 2.16 0.04 -0.24 0.04
## -----
## grade: G3
## stask: word
##      vars  n    mean    sd median trimmed  mad   min    max  range  skew kurtosis  se
## acc      1 102 0.98 0.03 1.00 0.99 0.00 0.83 1.00 0.17 -2.49 6.94 0.00
## RT       2 102 1100.13 237.58 1054.70 1069.86 188.89 713.57 2008.78 1295.21 1.46 2.81 23.52
## onsRT    3 102 622.04 167.01 584.42 596.01 103.24 366.61 1356.41 989.79 2.05 5.47 16.54
## artic    4 102 467.37 105.81 456.60 459.85 101.94 264.46 943.72 679.26 1.13 2.88 10.48
## invRT    5 102 0.94 0.18 0.95 0.95 0.16 0.50 1.40 0.90 -0.10 0.12 0.02
## invonsRT 6 102 1.70 0.36 1.71 1.70 0.33 0.74 2.73 1.99 -0.11 0.66 0.04
## invartic 7 102 2.24 0.48 2.19 2.22 0.51 1.06 3.78 2.72 0.41 0.16 0.05
## -----
## grade: G5
## stask: word
##      vars  n    mean    sd median trimmed  mad   min    max  range  skew kurtosis  se
## acc      1 97 0.99 0.02 1.00 0.99 0.00 0.83 1.00 0.17 -4.24 25.22 0.00
## RT       2 97 974.08 154.95 958.14 963.79 161.38 706.66 1497.47 790.82 0.79 0.87 15.73
## onsRT    3 97 512.56 77.52 496.14 504.64 80.17 383.03 816.28 433.25 1.07 1.38 7.87
## artic    4 97 454.91 109.12 452.25 451.21 121.00 230.38 831.82 601.44 0.62 1.06 11.08
## invRT    5 97 1.05 0.16 1.04 1.05 0.17 0.67 1.42 0.75 0.03 -0.53 0.02
## invonsRT 6 97 1.99 0.27 2.02 2.00 0.31 1.23 2.61 1.39 -0.30 -0.41 0.03
## invartic 7 97 2.33 0.57 2.21 2.28 0.59 1.20 4.34 3.14 0.76 0.44 0.06

discw <- reshape(meanrt[,c("sID","grade","stask","acc","RT","onsRT","artic","invRT","invonsRT","invartic"),
attr(discw,"reshapeWide")<-NULL
#str(discw)
names(discw)[names(discw)=="stask"] <- "task"

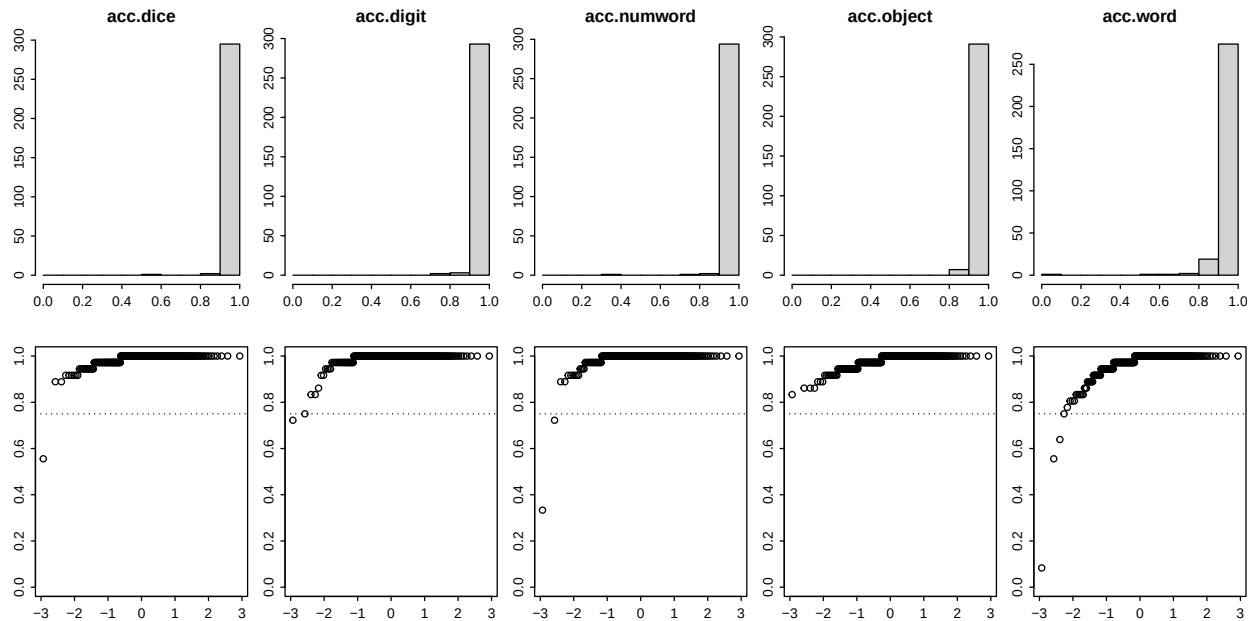
```

4.4 Accuracy screening

```
accv <- names(discw)[substr(names(discw),1,4)=="acc."]
RTv <- names(discw)[substr(names(discw),1,3)=="RT."]
onsv <- names(discw)[substr(names(discw),1,6)=="onsRT."]
artv <- names(discw)[substr(names(discw),1,6)=="artic."]
```

It seems that there are a number of very low accuracy points; these should be removed because the mean-RT calculation is also invalidated due to the small number and questionable representativeness of the data points it is based on.

```
minacc <- 0.75
par(mfcol=c(2,5))
par(oma=c(0,0,0,0))
par(mai=c(0.2,0.3,0.3,0))
par(mgp=c(2,0.5,0))
par(tcl= -0.25)
for (v in accv) {
  hist(discw[,v],xlim=c(0,1),breaks=0:10/10,main=v,xlab="",ylab="")
  qqnorm(discw[,v],ylim=c(0,1),main="",xlab="",ylab="",xpd=NA)
  abline(h=minacc,lty=3)
}
```



We remove points based on less than 75% correct responses. The number of points removed for each task is listed below.

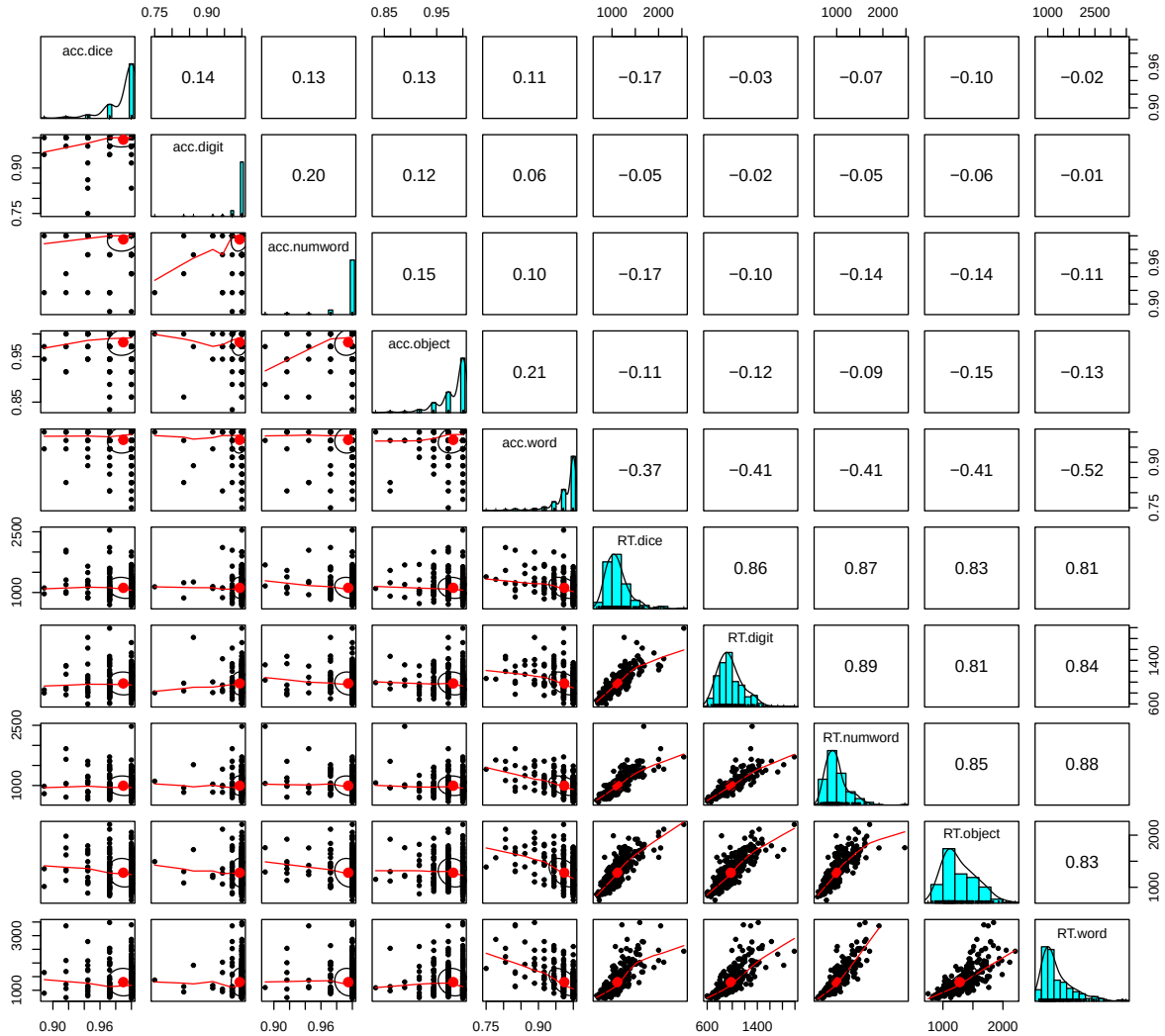
```
for (tsk in tasks) {
  # including the preceding dot in the match to avoid "word" matching "numword"
  vars <- names(discw[grepl(paste("\\.",tsk,"$",sep=""),names(discw))])
  lowacc <- discw[paste("acc",tsk,sep=".")<minacc]
  print(paste(tsk,sum(lowacc)))
  discw[lowacc ,vars] <- NA
}
```

```
## [1] "dice 1"
## [1] "digit 1"
```

```
## [1] "numword 2"
## [1] "object 0"
## [1] "word 3"
```

Note that (after removing these very few points) the (nonparametric) correlation between accuracy and (total) naming time is negligible, except for words.

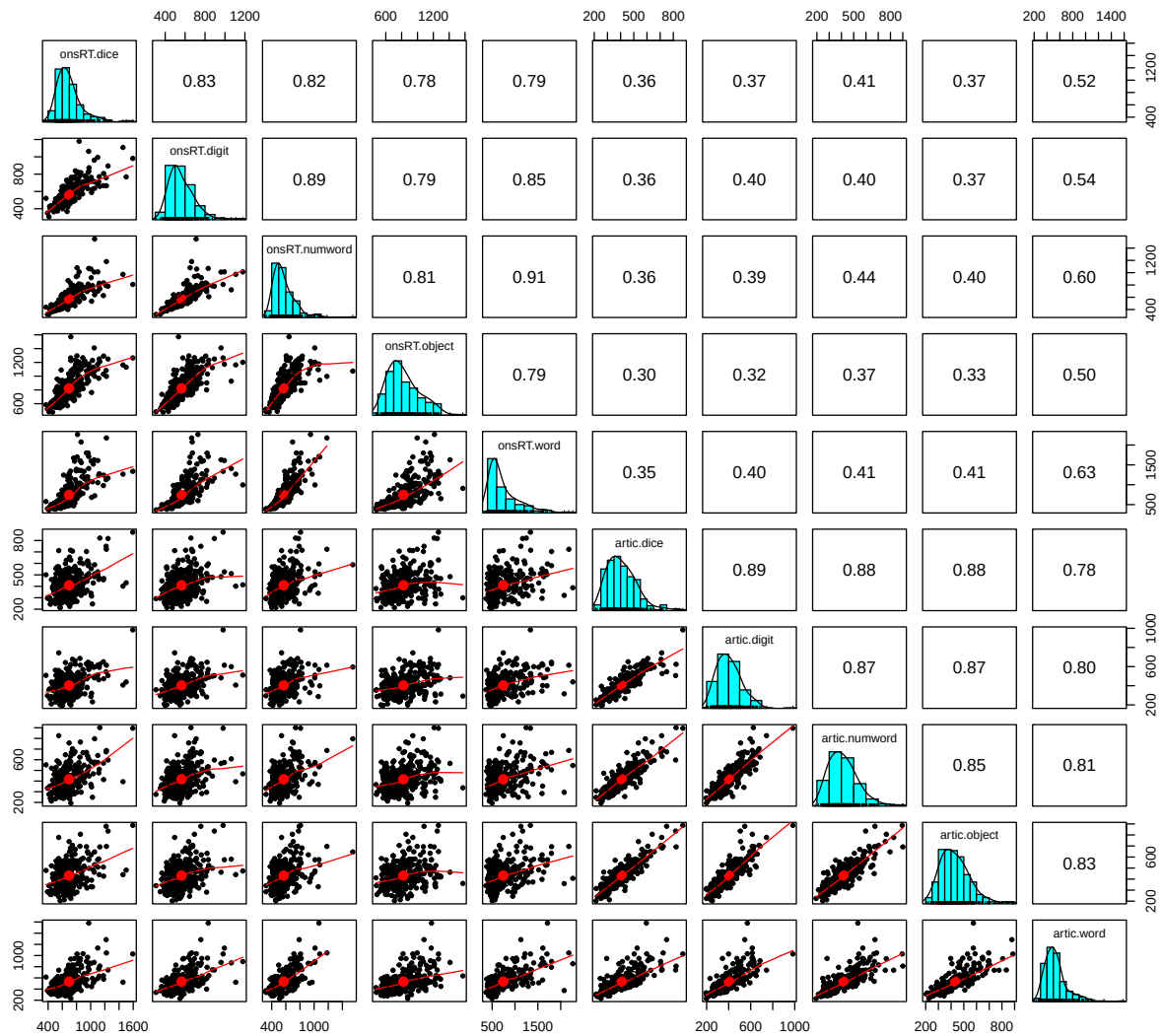
```
pairs.panels(discw[,c(accv,RTv)],cex.cor=0.75,method="spearman")
```



4.5 Intercorrelations among silent and spoken intervals

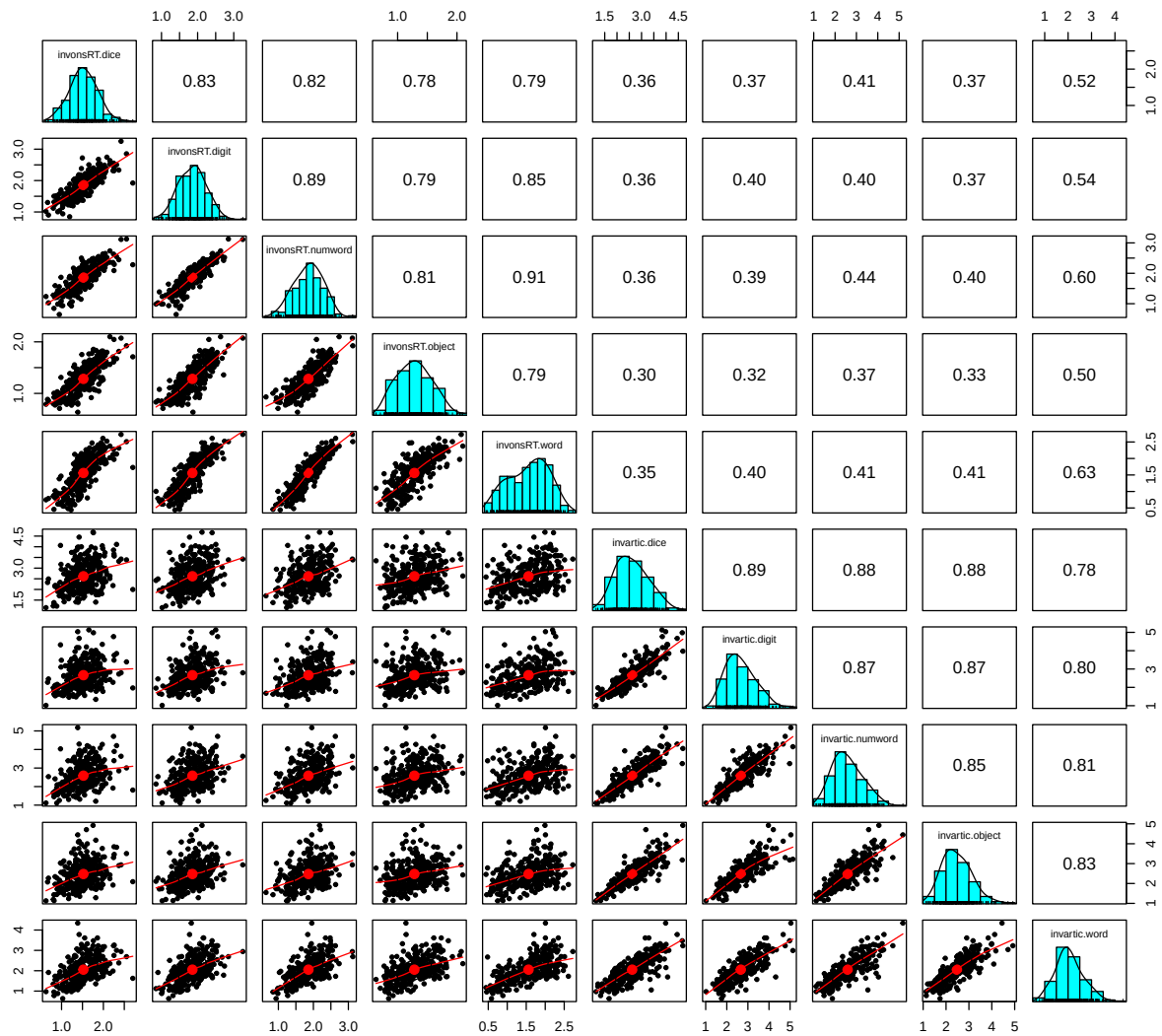
The following panels display the bivariate distributions (and associated nonparametric correlation coefficients) of onset latency and articulation duration per discrete task (across grades).

```
pairs.panels(discw[,c(onsv,artv)],cex.cor=0.75,method="spearman")
```



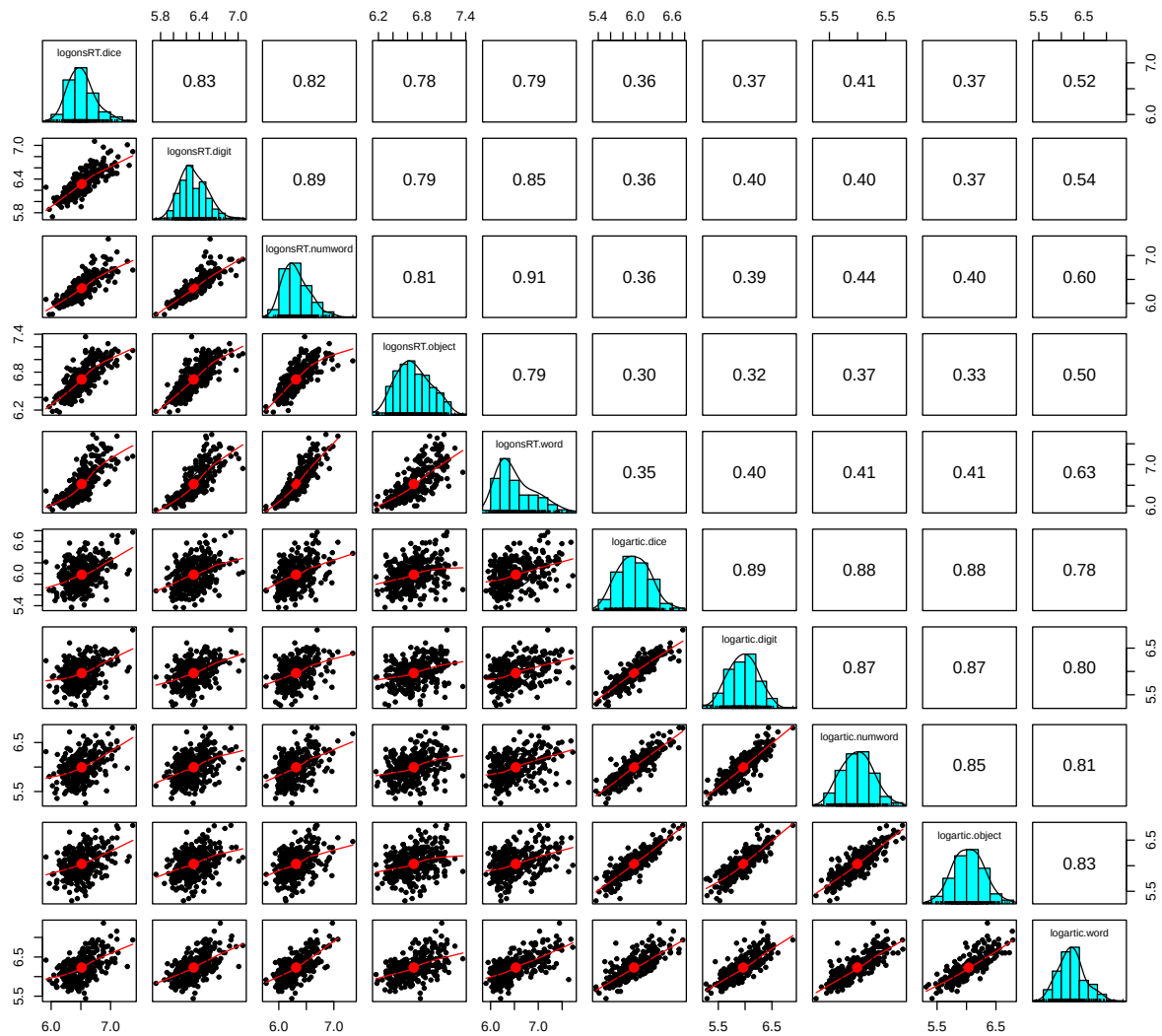
Note that the distributions are much improved after inverse transformation.

```
ionsv <- names(discw)[substr(names(discw),1,9)=="invonsRT."]
iartv <- names(discw)[substr(names(discw),1,9)=="invartic."]
pairs.panels(discw[,c(ionsv,iartv)],cex.cor=0.75,method="spearman")
```



Logarithmic transformation leads to acceptable distributions also, especially for articulation times.

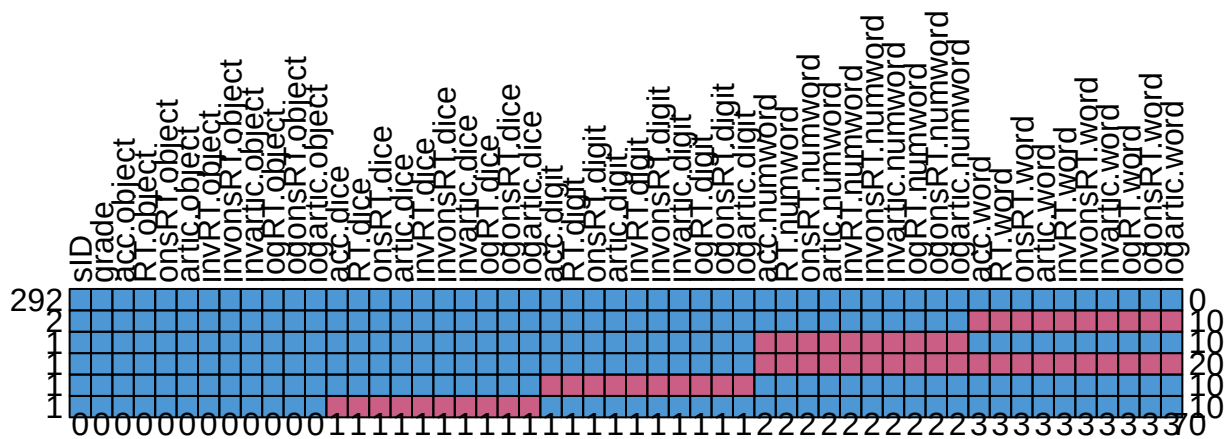
```
lonsv <- names(discw)[substr(names(discw),1,9)=="logonsRT."]
lartv <- names(discw)[substr(names(discw),1,9)=="logartic."]
pairs.panels(discw[,c(lonsv,lartv)],cex.cor=0.75,method="spearman")
```



4.6 Missing data report

The few points removed due to low accuracy are the only missing data here.

```
md.pattern(discw,rotate.names=T)
```



##	SID	grade	acc.object	RT.object	onsRT.object	artic.object	invRT.object	invsRT.object	
##	292	1	1	1	1	1	1	1	
##	2	1	1	1	1	1	1	1	
##	1	1	1	1	1	1	1	1	
##	1	1	1	1	1	1	1	1	
##	1	1	1	1	1	1	1	1	
##	1	1	1	1	1	1	1	1	
##		0	0	0	0	0	0	0	
##			invartic.object	logRT.object	logonsRT.object	logartic.object	acc.dice	RT.dice	onsRT.dice
##	292		1	1	1	1	1	1	1
##	2		1	1	1	1	1	1	1
##	1		1	1	1	1	1	1	1
##	1		1	1	1	1	1	1	1
##	1		1	1	1	1	1	1	1
##	1		1	1	1	1	0	0	0
##			0	0	0	0	1	1	1
##			artic.dice	invRT.dice	invsRT.dice	invartic.dice	logRT.dice	logonsRT.dice	logartic.dice
##	292		1	1	1	1	1	1	1
##	2		1	1	1	1	1	1	1
##	1		1	1	1	1	1	1	1
##	1		1	1	1	1	1	1	1
##	1		1	1	1	1	1	1	1
##	1		0	0	0	0	0	0	0
##			1	1	1	1	1	1	1
##			acc.digit	RT.digit	onsRT.digit	artic.digit	invRT.digit	invsRT.digit	invartic.digit
##	292		1	1	1	1	1	1	1

```

## 2      1      1      1      1      1      1      1
## 1      1      1      1      1      1      1      1
## 1      1      1      1      1      1      1      1
## 1      0      0      0      0      0      0      0
## 1      1      1      1      1      1      1      1
##      1      1      1      1      1      1      1
##      logRT.digit logonsRT.digit logartic.digit acc.numword RT.numword onsRT.numword artic.numword
## 292      1      1      1      1      1      1      1
## 2      1      1      1      1      1      1      1
## 1      1      1      1      0      0      0      0
## 1      1      1      1      0      0      0      0
## 1      0      0      0      1      1      1      1
## 1      1      1      1      1      1      1      1
##      1      1      1      2      2      2      2
##      invRT.numword invonsRT.numword invartic.numword logRT.numword logonsRT.numword logartic.numword
## 292      1      1      1      1      1      1      1
## 2      1      1      1      1      1      1      1
## 1      0      0      0      0      0      0      0
## 1      0      0      0      0      0      0      0
## 1      1      1      1      1      1      1      1
## 1      1      1      1      1      1      1      1
##      2      2      2      2      2      2      2
##      acc.word RT.word onsRT.word artic.word invRT.word invonsRT.word invartic.word logRT.word
## 292      1      1      1      1      1      1      1
## 2      0      0      0      0      0      0      0
## 1      1      1      1      1      1      1      1
## 1      0      0      0      0      0      0      0
## 1      1      1      1      1      1      1      1
## 1      1      1      1      1      1      1      1
##      3      3      3      3      3      3      3
##      logonsRT.word logartic.word
## 292      1      1 0
## 2      0      0 10
## 1      1      1 10
## 1      0      0 20
## 1      1      1 10
## 1      1      1 10
##      3      3 70

```

```

write.table(discw,file="discrete_wide.txt")
write.table(merge(dsdw,merge(discw,artpaw,by=c("sID","grade")),by=c("sID","grade")),file="read_discrete_wide.txt")

```

5 Session information

```

date()

## [1] "Fri Feb  9 12:14:42 2024"

sessionInfo()

## R version 4.3.1 (2023-06-16 ucrt)
## Platform: x86_64-w64-mingw32/x64 (64-bit)
## Running under: Windows 10 x64 (build 19045)
##

```

```

## Matrix products: default
##
##
## locale:
## [1] LC_COLLATE=Norwegian Bokmål_Norway.utf8 LC_CTYPE=Norwegian Bokmål_Norway.utf8
## [3] LC_MONETARY=Norwegian Bokmål_Norway.utf8 LC_NUMERIC=C
## [5] LC_TIME=Norwegian Bokmål_Norway.utf8
##
## time zone: Europe/Berlin
## tzcode source: internal
##
## attached base packages:
## [1] stats      graphics  grDevices  utils      datasets  methods   base
##
## other attached packages:
## [1] lattice_0.21-8 mice_3.16.0    reshape2_1.4.4 psych_2.3.3
##
## loaded via a namespace (and not attached):
## [1] utf8_1.2.3      generics_0.1.3  tidyr_1.3.0     shape_1.4.6     stringi_1.7.12
## [6] lme4_1.1-33     digest_0.6.31   magrittr_2.0.3  mitml_0.4-5     evaluate_0.21
## [11] grid_4.3.1      iterators_1.0.14 fastmap_1.1.1    foreach_1.5.2   jomo_2.7-6
## [16] plyr_1.8.8      glmnet_4.1-7    Matrix_1.5-4.1  nnet_7.3-19     backports_1.4.1
## [21] survival_3.5-5  purrr_1.0.1     fansi_1.0.4     codetools_0.2-19 mnormt_2.1.1
## [26] cli_3.6.1       rlang_1.1.1     splines_4.3.1   yaml_2.3.7      pan_1.6
## [31] tools_4.3.1     parallel_4.3.1  nloptr_2.0.3    minqa_1.2.5     dplyr_1.1.2
## [36] boot_1.3-28.1   broom_1.0.5     rpart_4.1.19    vctrs_0.6.3     R6_2.5.1
## [41] lifecycle_1.0.3 stringr_1.5.0    MASS_7.3-60     pkgconfig_2.0.3 pillar_1.9.0
## [46] glue_1.6.2      Rcpp_1.0.10     highr_0.10      xfun_0.39       tibble_3.2.1
## [51] tidyselect_1.2.0 rstudioapi_0.14 knitr_1.43      htmltools_0.5.5 nlme_3.1-162
## [56] rmarkdown_2.22  compiler_4.3.1

```