

Data analyses for PLoS One paper Vasishth et al 2013

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Date of compilation: November 27, 2013

Note: This compilation needs to be cleaned up a bit. I (SV) will do this soon. But the basic analyses should be reproducible.

1 Gibson and Wu's data

	subj	item	type	pos	correct	rt
1	1	13	obj-ext	0	-	3301
2	1	13	obj-ext	1	-	7013
3	1	13	obj-ext	2	-	3941
4	1	13	obj-ext	3	-	1615
5	1	13	obj-ext	4	-	437
6	1	13	obj-ext	5	-	510

[1] 37

	item
subj	1 2 3 4 5 6 7 8 9 10 11 13 14 15 16
1	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
2	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
3	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
4	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
5	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
6	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
7	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
8	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
9	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
11	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
12	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
14	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
15	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
16	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
17	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
18	15 15 17 17 12 12 12 13 16 14 13 13 13 11 13

```

19 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
20 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
21 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
22 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
23 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
24 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
26 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
27 15 0 17 0 0 0 0 13 16 0 0 13 0 11 13
28 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
29 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
30 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
31 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
32 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
33 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
34 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
35 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
36 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
37 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
38 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
39 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13
40 15 15 17 17 12 12 12 13 16 14 13 13 13 11 13

```

[1] 37

Next we do some pre-processing to get ready for analysis:

[1] 547 8

[1] 547 8

```

      subj-ext
obj-ext      0
subj-ext     1

> hnoun$cond2<-factor(ifelse(hnoun$type=="obj-ext","object relative","subject relative"),lev
> tiff("boxplotsboxcox.tiff",res=300,width=17.35,#height=23.35,
+      height=17.35,
+      units="cm",compression="lzw",bg="white")
> par( mfrow=c(2,2) )
> boxplot(rt~cond2,hnoun,ylab="reading time (ms)")
> boxplot(log(rt)~cond2,hnoun,ylab="log reading time (log ms)")
> boxplot(-1000/rt~cond2,hnoun,ylab="negative reciprocal reading time (-1/s)")
> library(MASS)
> boxcox(rt~type*subj,data=hnoun)
> dev.off()

pdf
2

```

High resolution image:

```
> bitmap("fig1.tiff", height = 4, width = 4, units = 'in', type="tifflzw", res=300)
> par( mfrow=c(2,2) )
> boxplot(rt~cond2,hnoun,ylab="reading time (ms)")
> boxplot(log(rt)~cond2,hnoun,ylab="log reading time (log ms)")
> boxplot(-1000/rt~cond2,hnoun,ylab="negative reciprocal reading time (-1/s)")
> library(MASS)
> boxcox(rt~type*subj,data=hnoun)
> dev.off()
```

pdf
2

The Box-Cox transform suggests using the inverse for the head noun and the region after:

```
> cond<-factor(ifelse(critdata$type=="obj-ext","a","b"))
> critdata$cond<-cond
> ## all regions:
> bwplot(rt~cond|region,data=critdata,layout=c(5,1))
> par( mfrow=c(3,3) )
> library(MASS)
> #boxcox(rt~type*subj,data=critdata[critdata$region=="de1", ])
>
> boxcox(rt~type*subj,data=critdata[critdata$region=="de", ])
> boxcox(rt~cond*subj,data=critdata[critdata$region=="headnoun", ])
> boxcox(rt~type*subj,data=critdata[critdata$region=="headnoun1", ])
> ## transform:
> critdata$rrt <- -1000/critdata$rt
> means.rrt<-round(with(critdata,tapply(rrt,IND=list(region,type),mean)),digits=3)
> means.rt<-round(with(critdata,tapply(rt,IND=list(region,type),mean)),digits=0)
> library(xtable)
> xtable(cbind(means.rt,means.rrt))
```

% latex table generated in R 3.0.1 by xtable 1.7-1 package

% Wed Nov 27 17:22:21 2013

\begin{table}[ht]

\centering

\begin{tabular}{rrrrr}

\hline

& obj-ext & subj-ext & obj-ext & subj-ext \\\

\hline

VN/NV & 984.00 & 1050.00 & -1.20 & -1.18 \\\

de & 430.00 & 485.00 & -2.78 & -2.62 \\\

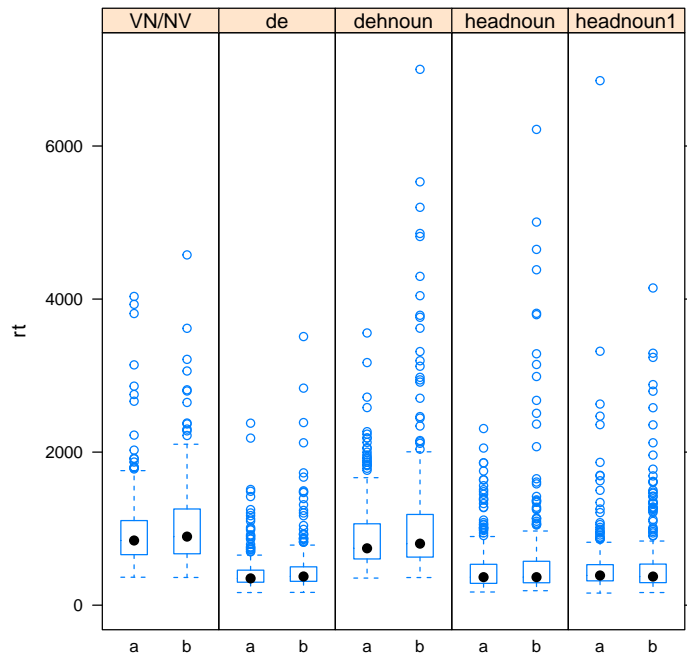
dehnoun & 917.00 & 1095.00 & -1.32 & -1.24 \\\

headnoun & 487.00 & 611.00 & -2.72 & -2.63 \\\

```

headnoun1 & 520.00 & 564.00 & -2.56 & -2.60 \\
\hline
\end{tabular}
\end{table}

```



```

> (gw.VN.rrt <- lmer(rrt~so+(1+so/subj)+(1+so/item),subset(critdata,region=="VN/NV")))

```

Linear mixed model fit by REML

Formula: $rrt \sim so + (1 + so \mid subj) + (1 + so \mid item)$

Data: subset(critdata, region == "VN/NV")

AIC BIC logLik deviance REMLdev

519 557 -250 492 501

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	0.10674	0.3267	
	so	0.01764	0.1328	-0.802
item	(Intercept)	0.01085	0.1042	
	so	0.00159	0.0398	-1.000
Residual		0.11421	0.3379	

Number of obs: 547, groups: subj, 37; item, 15

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	-1.1902	0.0618	-19.25
so	-0.0140	0.0378	-0.37

Correlation of Fixed Effects:

(Intr)
so -0.524

```
> qqPlot(residuals(gw.VN.rrt))
```

```
> (gw.de.rrt <- lmer(rrt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="de")))
```

Linear mixed model fit by REML

Formula: rrt ~ so + (1 + so | subj) + (1 + so | item)

Data: subset(critdata, region == "de")

AIC	BIC	logLik	deviance	REMLdev
1390	1429	-686	1366	1372

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	0.305395	0.5526	
	so	0.000856	0.0293	1.000
item	(Intercept)	0.033314	0.1825	
	so	0.014770	0.1215	-0.395
Residual		0.597042	0.7727	

Number of obs: 547, groups: subj, 37; item, 15

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	-2.6994	0.1076	-25.08
so	-0.1480	0.0735	-2.01

Correlation of Fixed Effects:

(Intr)
so -0.021

```
> qqPlot(residuals(gw.de.rrt))
```

```
> (gw.hnoun.rrt <- lmer(rrt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="headnoun")))
```

Linear mixed model fit by REML

Formula: rrt ~ so + (1 + so | subj) + (1 + so | item)

Data: subset(critdata, region == "headnoun")

AIC	BIC	logLik	deviance	REMLdev
1614	1652	-798	1591	1596

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	0.37121	0.609	
	so	0.05324	0.231	-0.506
item	(Intercept)	0.11004	0.332	

so	0.00922	0.096	1.000
Residual	0.89158	0.944	

Number of obs: 547, groups: subj, 37; item, 15

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	-2.6715	0.1379	-19.37
so	-0.0776	0.0929	-0.84

Correlation of Fixed Effects:

(Intr)
so 0.012

```
> qqPlot(residuals(gw.hnoun.rrt))
> (gw.dehnoun.rrt <- lmer(rrt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="dehnoun")))
```

Linear mixed model fit by REML

Formula: rrt ~ so + (1 + so | subj) + (1 + so | item)

Data: subset(critdata, region == "dehnoun")

AIC BIC logLik deviance REMLdev

703 742 -343 677 685

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	0.079518	0.2820	
	so	0.000255	0.0160	-1.000
item	(Intercept)	0.021133	0.1454	
	so	0.003068	0.0554	0.649
Residual		0.167788	0.4096	

Number of obs: 547, groups: subj, 37; item, 15

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	-1.2784	0.0622	-20.55
so	-0.0737	0.0380	-1.94

Correlation of Fixed Effects:

(Intr)
so 0.093

```
> qqPlot(residuals(gw.dehnoun.rrt))
> (gw.hnoun1.rrt <- lmer(rrt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="headnoun1")))
```

Linear mixed model fit by REML

Formula: rrt ~ so + (1 + so | subj) + (1 + so | item)

Data: subset(critdata, region == "headnoun1")

AIC BIC logLik deviance REMLdev

1557 1596 -770 1534 1539

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	0.24317	0.4931	
	so	0.02731	0.1653	-1.000
item	(Intercept)	0.15902	0.3988	
	so	0.00193	0.0439	-1.000
Residual		0.81868	0.9048	

Number of obs: 547, groups: subj, 37; item, 15

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	-2.5836	0.1367	-18.90
so	0.0423	0.0831	0.51

Correlation of Fixed Effects:

(Intr)
so -0.300

```
> qqPlot(residuals(gw.hnoun1.rrt))
> ## get coefs, SEs, t-values:
> gw.VN<-c(fixef(gw.VN.rrt)[2],
+          sqrt(vcov(gw.VN.rrt))[2,2],
+          fixef(gw.VN.rrt)[2]/sqrt(vcov(gw.VN.rrt))[2,2])
> gw.de<-c(fixef(gw.de.rrt)[2],
+          sqrt(vcov(gw.de.rrt))[2,2],
+          fixef(gw.de.rrt)[2]/sqrt(vcov(gw.de.rrt))[2,2])
> gw.hn<-c(fixef(gw.hnoun.rrt)[2],
+          sqrt(vcov(gw.hnoun.rrt))[2,2],
+          fixef(gw.hnoun.rrt)[2]/sqrt(vcov(gw.hnoun.rrt))[2,2])
> gw.hn1<-c(fixef(gw.hnoun1.rrt)[2],
+          sqrt(vcov(gw.hnoun1.rrt))[2,2],
+          fixef(gw.hnoun1.rrt)[2]/sqrt(vcov(gw.hnoun1.rrt))[2,2])
> gwresults<-rbind(gw.VN,gw.de,gw.hn,gw.hn1)
> rownames(gwresults)<-c("VN/NV","de","head noun","head noun+1")
> colnames(gwresults)<-c("coef","SE","t-value")
> xtable(round(gwresults,digits=2))
```

% latex table generated in R 3.0.1 by xtable 1.7-1 package

% Wed Nov 27 17:22:24 2013

\begin{table}[ht]

\centering

\begin{tabular}{rrrr}

\hline

& coef & SE & t-value \\\

\hline

VN/NV & -0.01 & 0.04 & -0.37 \\\

```

de & -0.15 & 0.07 & -2.01 \\
head noun & -0.08 & 0.09 & -0.84 \\
head noun+1 & 0.04 & 0.08 & 0.51 \\
\hline
\end{tabular}
\end{table}

```

We have predictions for the head noun and the word after that, but with reciprocal RT these are not borne out, cf the published paper's results based on raw RTs (also see below).

```
> (gw.hn.rt <- lmer(rt~so+(1+so/subj)+(1+so/item),subset(critdata,region=="headnoun")))
```

Linear mixed model fit by REML

Formula: $rt \sim so + (1 + so \mid subj) + (1 + so \mid item)$

Data: subset(critdata, region == "headnoun")

AIC BIC logLik deviance REMLdev

8498 8537 -4240 8500 8480

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	25729	160	
	so	37971	195	-1.000
item	(Intercept)	23836	154	
	so	20147	142	-1.000
Residual		295554	544	

Number of obs: 547, groups: subj, 37; item, 15

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	547.3	53.2	10.29
so	-119.7	67.5	-1.77

Correlation of Fixed Effects:

(Intr)
so -0.647

```
> (gw.hn.rrt <- lmer(-1000/rt~so+(1+so/subj)+(1+so/item),subset(critdata,region=="headnoun")))
```

Linear mixed model fit by REML

Formula: $-1000/rt \sim so + (1 + so \mid subj) + (1 + so \mid item)$

Data: subset(critdata, region == "headnoun")

AIC BIC logLik deviance REMLdev

1614 1652 -798 1591 1596

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	0.37121	0.609	
	so	0.05324	0.231	-0.506


```

item      (Intercept) 0.11004 0.332
          so          0.00922 0.096 1.000
Residual              0.89158 0.944
Number of obs: 547, groups: subj, 37; item, 15

```

Fixed effects:

```

          Estimate Std. Error t value
(Intercept) -2.6715    0.1379  -19.37
so           -0.0776    0.0929   -0.84

```

Correlation of Fixed Effects:

```

(Intr)
so 0.012

```

```

> (gw.hn.lrt <- lmer(log(rt)~so+(1+so|subj)+(1+so|item),subset(critdata,region=="headnoun")))

```

Linear mixed model fit by REML

Formula: log(rt) ~ so + (1 + so | subj) + (1 + so | item)

Data: subset(critdata, region == "headnoun")

AIC BIC logLik deviance REMLdev

```

929 968 -456    903    911

```

Random effects:

```

Groups   Name          Variance Std.Dev. Corr
subj     (Intercept) 5.99e-02 0.244815
          so          1.42e-02 0.119064 -1.000
item     (Intercept) 3.31e-02 0.182030
          so          1.97e-07 0.000444 1.000
Residual              2.65e-01 0.514326

```

Number of obs: 547, groups: subj, 37; item, 15

Fixed effects:

```

          Estimate Std. Error t value
(Intercept)  6.0618    0.0657   92.2
so           -0.0725    0.0483   -1.5

```

Correlation of Fixed Effects:

```

(Intr)
so -0.251

```

```

>

```

```

> #tiff("residuals.tiff",res=300,width=7.35,#height=23.35,

```

```

> #   height=17.35,

```

```

> #   units="cm",compression="lzw",bg="white")

```

```

> #

```

```

>

```

```

> bitmap("fig2.tiff", height = 4, width = 4, units = 'in', type="tifflzw", res=600)

```

```

> op<-par(mfrow=c(1,3),pty="s")
> par(cex.lab=1.3)
> qqPlot(residuals(gw.hn.rt),
+         ylab="raw reading time (ms)",
+         envelope=F)
> qqPlot(residuals(gw.hn.lrt),ylab="log reading times",envelope=F)
> qqPlot(residuals(gw.hn.rrt),ylab="negative reciprocal reading times",envelope=F)
> dev.off()

```

pdf
2

On this raw reading time scale, the differences in rt are about 178 ms at the head noun (OR advantage):

```

> means<-with(critdata,tapply(rt,IND=list(region,type),mean))

```

However, standard deviation is not similar:

```

> sds<-with(critdata,tapply(rt,IND=list(region,type),sd))

```

At the head noun, the ratio of variances is:

```

> round(sds[4,2]/sds[4,1],digits=1)

```

```

[1] 2.2

```

Note that Gibson and Wu fit raw reading times, and got significant effects (OR advantage). Here is an lmer fit analogous (but not identical) to what they did:

```

> ##head noun:
> (gw.hn <- lmer(rt~so+(1/item)+(1/subj),subset(critdata,region=="headnoun")))

```

Linear mixed model fit by REML

Formula: rt ~ so + (1 | item) + (1 | subj)

Data: subset(critdata, region == "headnoun")

AIC	BIC	logLik	deviance	REMLdev
8509	8531	-4250	8519	8499

Random effects:

Groups	Name	Variance	Std.Dev.
subj	(Intercept)	21738	147
item	(Intercept)	22396	150
Residual		314128	560

Number of obs: 547, groups: subj, 37; item, 15

Fixed effects:

Estimate	Std. Error	t value
----------	------------	---------

(Intercept)	548.4	51.6	10.64
so	-120.4	48.0	-2.51

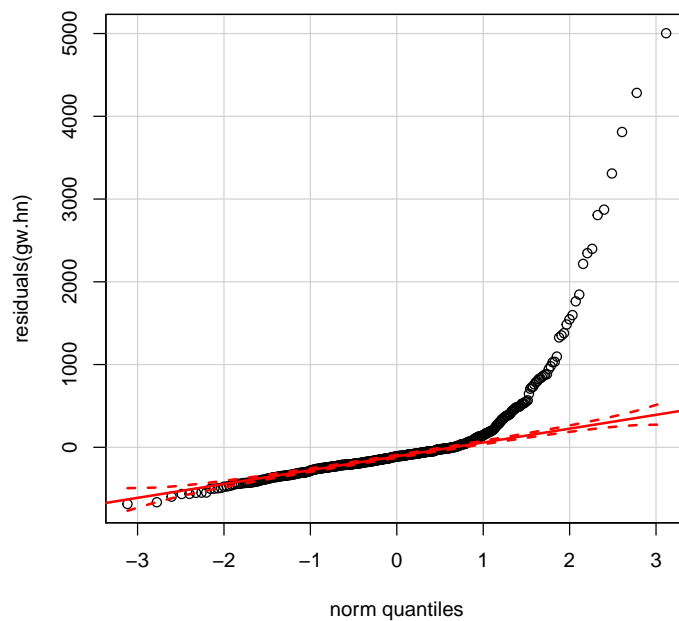
Correlation of Fixed Effects:

(Intr)	
so	-0.003

The model estimates that ORs are about 120 ms easier to process than SRs at the head noun.

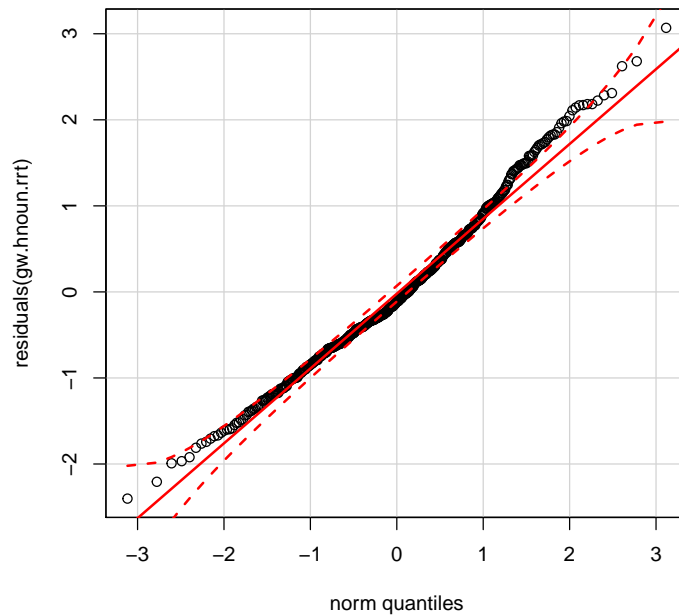
However, statistical significance here is a consequence of the normality assumption (of residuals) not being satisfied; I think that, more precisely, it's the equal variance assumption that's an issue (SR variance is much higher due to those extreme values).

```
> qqPlot(residuals(gw.hn))
```



Compare with the reciprocal rt's residuals:

```
> qqPlot(residuals(gw.hnoun.rrt))
```



Plotting for paper:

```
> se <- function(x)
+ {
+     y <- x[!is.na(x)] # remove the missing values
+     sqrt(var(as.vector(y))/length(y))
+ }
> #####Remove between subject variance for SE#####
> # (a) Aggregate to Subject x Condition means
>
> library(reshape)
> data.rs <- melt(critdata, id=c("type","region", "subj"), measure=c("rt"),na.rm=TRUE)
> data.id <- data.frame(cast(data.rs, subj + type + region ~ ., function(x) c(rt=mean(x), N=
> # (b) Remove between-subject variance
> ##
> (GM <- mean(tapply(data.id$rt, data.id$subj, mean)))

[1] 716.46

> data.id <- ddply(data.id, .(subj), transform, rt.w = rt - mean(rt) + GM)
> # (c) Compute condition means and error bars: +/- 2 SE of means after removal of between-
> temp<-melt(data.id, id.var=c("subj","type","region"), measure.var="rt.w")
> (M.id.w <- cast(temp,type+region ~ .,
+     function(x) c(M=mean(x), SE=sd(x)/sqrt(length(x)), N=length(x) ) ) )
```

	type	region	M	SE	N
1	obj-ext	VN/NV	988.55	27.768	37
2	obj-ext	de	434.78	18.680	37
3	obj-ext	dehnoun	924.96	20.746	37
4	obj-ext	headnoun	490.18	22.305	37
5	obj-ext	headnoun1	518.91	34.298	37
6	subj-ext	VN/NV	1058.08	36.187	37
7	subj-ext	de	482.02	23.896	37
8	subj-ext	dehnoun	1095.40	38.137	37
9	subj-ext	headnoun	613.38	31.490	37
10	subj-ext	headnoun1	558.29	27.286	37

No actual plotting needed here.

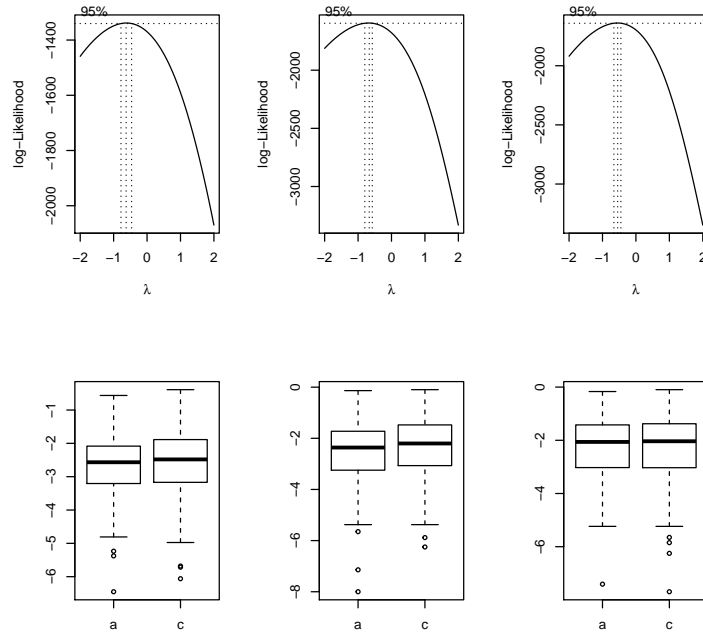
```
> ## to be used later:
> gwcritdata<-critdata
```

2 Experiment 1: Kuo study

```
> ## Design:
> #condition a: SRC      V | OBJ | DE | SBJ (head) | N1 | N2 | (N3)
> #condition c: ORC      SBJ | V | DE | OBJ (head) | N1 | N2 | (N3)
>
> critdata<-read.table("expt1critdata.txt",header=T)

a=subj rel, c=obj rel.

> par( mfrow=c(2,3) )
> boxcox(rt~condition*subj,data=critdata[critdata$region=="de", ])
> boxcox(rt~condition*subj,data=critdata[critdata$region=="headnoun", ])
> boxcox(rt~condition*subj,data=critdata[critdata$region=="headnoun1", ])
> ## transform:
> critdata$rrt <- -1000/critdata$rt
> critdata.orig<-critdata
> boxplot(rrt~condition,subset(critdata,region=="de"))
> boxplot(rrt~condition,subset(critdata,region=="headnoun"))
> boxplot(rrt~condition,subset(critdata,region=="headnoun1"))
> boxplot(rt~condition,subset(critdata,region=="de"))
> boxplot(rt~condition,subset(critdata,region=="headnoun"))
> boxplot(rt~condition,subset(critdata,region=="headnoun1"))
> ## critical regions:
> headnoun <- subset(critdata,region=="headnoun")
> headnoun1 <- subset(critdata,region=="headnoun1")
```



Reviewer asks for full dataset:

```
> ## load full dataset for PLoS One paper plot:
> critdata<-read.table("expt1fulldata.txt",header=T)
> critdata<-critdata[,c(1,3,4,8,11)]
> critdata<-subset(critdata,rcpos>0)
> summary(critdata)
```

subj	item	condition	rt	rcpos
Min. : 1.0	Min. : 1.00	a:1500	Min. : 125	Min. : 1
1st Qu.:15.8	1st Qu.: 5.75	c:1500	1st Qu.: 322	1st Qu.: 2
Median :30.5	Median :10.50		Median : 429	Median : 3
Mean :30.5	Mean :10.50		Mean : 578	Mean : 3
3rd Qu.:45.2	3rd Qu.:15.25		3rd Qu.: 586	3rd Qu.: 4
Max. :60.0	Max. :20.00		Max. :10260	Max. : 5

```
> region<-ifelse(critdata$rcpos==1,"V/N",
+               ifelse(critdata$rcpos==2,"N/V",
+               ifelse(critdata$rcpos==3,"de",
+               ifelse(critdata$rcpos==4,"head noun",
+               ifelse(critdata$rcpos==5,"head noun+1",NA))))))
> critdata$region<-region
> critdata$region<-factor(critdata$region,levels=c("V/N","N/V","de","head noun","head noun+1"))
> critdata$cond<-factor(ifelse(critdata$condition=="a",
```

```

+           "subject relative","object relative"),levels=c("subject relative","o
> library(reshape)
> data.rs <- melt(critdata, id=c("cond","region", "subj"), measure=c("rt"),na.rm=TRUE)
> data.id <- data.frame(cast(data.rs, subj + cond + region ~ ., function(x) c(rt=mean(x), N=
> # (b) Remove between-subject variance
> ##
> (GM <- mean(tapply(data.id$rt, data.id$subj, mean)))

[1] 577.63

> data.id <- ddply(data.id, .(subj), transform, rt.w = rt - mean(rt) + GM)
> # (c) Compute condition means and error bars: +/- 2 SE of means after removal of between-
> temp<-melt(data.id, id.var=c("subj","cond","region"), measure.var="rt.w")
> (M.id.w <- cast(temp,cond+region ~ .,
+           function(x) c(M=mean(x), SE=sd(x)/sqrt(length(x)), N=length(x) ) ) )

      cond      region      M      SE  N
1 subject relative    V/N 445.86 24.331 60
2 subject relative    N/V 531.86 19.321 60
3 subject relative      de 428.26 24.670 60
4 subject relative head noun 631.91 31.581 60
5 subject relative head noun+1 689.74 33.786 60
6 object relative    V/N 486.49 27.758 60
7 object relative    N/V 505.98 22.058 60
8 object relative      de 472.67 24.886 60
9 object relative head noun 797.69 61.873 60
10 object relative head noun+1 785.83 53.077 60

> byregion.plot<-function(data,
+           mytitle,k=1,
+           x.lab="region",
+           y.lab="reading time [msec]"){
+   ggplot(data,aes(x=region,y=M,
+           group=cond)) +
+     geom_point(shape=21,size=k*3) +
+     geom_line(aes(linetype=cond),size=k) +
+     geom_errorbar(aes(ymin=M-2*SE,
+           ymax=M+2*SE),
+           width=.1,size=k)+
+     xlab(x.lab)+
+     ylab(y.lab)+
+     labs(title=mytitle) +
+     theme_bw()
+ }
> ## plot:
> #tiff("expt1.tiff",res=300,width=17.35,
> #      height=15.35,
```

```

> #      units="cm",compression="lzw",bg
> #="white")
>
> bitmap("fig3.tiff", height = 4, width = 7, units = 'in', type="tiff", res=600)
> (plot.regions<-byregion.plot(M.id.w,
+                               mytitle="Experiment 1",k=.5,
+                               x.lab="region",y.lab="reading time [msec]"))
+ )
> dev.off()

```

pdf
2

By region analyses demanded by reviewer: we focus on de, head noun, head noun+1.

```

> critdata$so<-ifelse(critdata$condition=="a",-0.5,0.5)
> ## we stay with negative reciprocal for consistency:
> with(subset(critdata,region=="de"),boxcox(rt~condition*subj))
> with(subset(critdata,region=="head noun"),boxcox(rt~condition*subj))
> with(subset(critdata,region=="head noun+1"),boxcox(rt~condition*subj))
> critdata$rrt<- -1000/critdata$rt
> (kuo.de.rrt <- lmer(rrt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="de")))

```

Linear mixed model fit by REML

Formula: rrt ~ so + (1 + so | subj) + (1 + so | item)

Data: subset(critdata, region == "de")

AIC BIC logLik deviance REMLdev

1312 1351 -647 1287 1294

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	0.51432	0.7172	
	so	0.00803	0.0896	1.000
item	(Intercept)	0.00689	0.0830	
	so	0.01663	0.1290	-0.329
Residual		0.37501	0.6124	

Number of obs: 600, groups: subj, 60; item, 20

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	-2.6182	0.0977	-26.8
so	0.0823	0.0589	1.4

Correlation of Fixed Effects:

(Intr)
so 0.156


```

> qqPlot(residuals(gw.de.rrt))
> (kuo.hnoun.rrt <- lmer(rt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="head noun"))

Linear mixed model fit by REML
Formula: rt ~ so + (1 + so | subj) + (1 + so | item)
Data: subset(critdata, region == "head noun")
AIC   BIC logLik deviance REMLdev
9595 9634 -4788    9597    9577
Random effects:
Groups   Name             Variance Std.Dev. Corr
subj     (Intercept)  285654    534
         so           56099    237    1.000
item     (Intercept)  39946    200
         so           25857    161    1.000
Residual                    400997  633
Number of obs: 600, groups: subj, 60; item, 20

Fixed effects:
              Estimate Std. Error t value
(Intercept)    714.8      86.2    8.29
so             165.8      70.0    2.37

Correlation of Fixed Effects:
(Intr)
so 0.616

> hist(residuals(kuo.hnoun.rrt))
> qqPlot(residuals(kuo.hnoun.rrt))
> qqPlot(residuals(gw.hnoun.rrt))
> (kuo.hnoun1.rrt <- lmer(rrt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="head noun+1"))

Linear mixed model fit by REML
Formula: rrt ~ so + (1 + so | subj) + (1 + so | item)
Data: subset(critdata, region == "head noun+1")
AIC   BIC logLik deviance REMLdev
1633 1672 -807    1609    1615
Random effects:
Groups   Name             Variance Std.Dev. Corr
subj     (Intercept)  0.7943    0.891
         so           0.0117    0.108    1.000
item     (Intercept)  0.0424    0.206
         so           0.0100    0.100   -1.000
Residual                    0.6392  0.799
Number of obs: 600, groups: subj, 60; item, 20

Fixed effects:
              Estimate Std. Error t value

```

```
(Intercept)  -2.2292      0.1282  -17.40
so            0.0555      0.0704   0.79
```

Correlation of Fixed Effects:

```
(Intr)
so 0.064
```

```
> qqPlot(residuals(gw.hnoun1.rrt))
```

Tabulating results:

```
> ## get coefs, SEs, t-values:
> kuo.de<-c(fixef(kuo.de.rrt)[2],
+          sqrt(vcov(kuo.de.rrt))[2,2],
+          fixef(kuo.de.rrt)[2]/sqrt(vcov(kuo.de.rrt))[2,2])
> kuo.hnoun<-c(fixef(kuo.hnoun.rrt)[2],
+             sqrt(vcov(kuo.hnoun.rrt))[2,2],
+             fixef(kuo.hnoun.rrt)[2]/sqrt(vcov(kuo.hnoun.rrt))[2,2])
> kuo.hnoun1<-c(fixef(kuo.hnoun1.rrt)[2],
+              sqrt(vcov(kuo.hnoun1.rrt))[2,2],
+              fixef(kuo.hnoun1.rrt)[2]/sqrt(vcov(kuo.hnoun1.rrt))[2,2])
> kuoresults<-rbind(kuo.de,kuo.hnoun,kuo.hnoun1)
> rownames(kuoresults)<-c("de","head noun","head noun+1")
> colnames(kuoresults)<-c("coef. ","SE", "t-value")
> xtable(round(kuoresults,digits=2))
```

% latex table generated in R 3.0.1 by xtable 1.7-1 package

% Wed Nov 27 17:22:32 2013

```
\begin{table}[ht]
\centering
\begin{tabular}{rrrr}
\hline
& coef. & SE & t-value \\
\hline
de & 0.08 & 0.06 & 1.40 \\
head noun & 165.78 & 70.00 & 2.37 \\
head noun+1 & 0.06 & 0.07 & 0.79 \\
\hline
\end{tabular}
\end{table}
```

3 Experiment 2: Qiang Li

```
> expt2.allregions<-read.table("expt2allregions.txt",header=T)
> head(expt2.allregions)
```

```

      subj item condition   rt rcpos
58 1.dat   22          b  995     1
59 1.dat   22          b  904     2
60 1.dat   22          b  859     3
61 1.dat   22          b 2150     4
62 1.dat   22          b 1491     5
95 1.dat   18          b   950     1

> region<-factor(ifelse(expt2.allregions$rcpos==1,"V/N",
+   ifelse(expt2.allregions$rcpos==2,"N/V",
+   ifelse(expt2.allregions$rcpos==3,"de",
+   ifelse(expt2.allregions$rcpos==4,"head noun",ifelse(expt2.allregions$rcpos==5,"head noun+1",""))
> region<-factor(region,levels=c("V/N","N/V","de","head noun","head noun+1"))
> unique(region)

[1] V/N      N/V      de      head noun  head noun+1
Levels: V/N N/V de head noun head noun+1

> expt2.allregions$region<-region

Plotting:

> critdata<-subset(expt2.allregions,condition%in%c("a","b"))
> critdata$condition<-factor(critdata$condition)
> RCType<-factor(ifelse(critdata$condition=="a","subject relative","object relative"),levels=c("subject relative","object relative"))
> critdata$RCType<-RCType
> library(reshape)
> data.rs <- melt(critdata, id=c("region","RCType","subj"), measure=c("rt"),na.rm=TRUE)
> data.id <- data.frame(cast(data.rs, subj + RCType + region ~ ., function(x) c(rt=mean(x), SE=sd(x)/sqrt(length(x)), N=length(x)))))
> # (b) Remove between-subject variance
> ##
> (GM <- mean(tapply(data.id$rt, data.id$subj, mean)))

[1] 631.91

> data.id <- ddply(data.id, .(subj), transform, rt.w = rt - mean(rt) + GM)
> # (c) Compute condition means and error bars: +/- 2 SE of means after removal of between-subject variance
> temp<-melt(data.id, id.var=c("subj","RCType","region"), measure.var="rt.w")
> (M.id.w <- cast(temp,RCType+region ~ .,
+   function(x) c(M=mean(x), SE=sd(x)/sqrt(length(x)), N=length(x)) ) ) )

      RCType      region      M      SE  N
1 subject relative    V/N 575.89 23.216 61
2 subject relative    N/V 583.89 19.754 61
3 subject relative      de 471.93 17.337 61
4 subject relative head noun 608.15 20.878 61
5 subject relative head noun+1 791.38 37.315 61

```

```

6   object relative          V/N 537.37 18.805 61
7   object relative          N/V 628.26 22.209 61
8   object relative          de 492.00 15.557 61
9   object relative  head noun 691.13 35.912 61
10  object relative head noun+1 939.14 50.793 61

> #tiff("expt2.tiff",res=300,width=17.35,
> #      height=15.35,
> #      units="cm",compression="lzw",bg
> #="white")
>
> bitmap("fig4.tiff", height = 4, width = 7, units = 'in', type="tifflzw", res=600)
> byregion.plot<-function(data,
+                           mytitle,k=.5,
+                           x.lab="region",
+                           y.lab="reading time [msec]"){
+   ggplot(data,aes(x=region,y=M,
+                   group=RCType)) +
+     geom_point(shape=21,size=k*3) +
+     geom_line(aes(linetype=RCType),size=k) +
+     geom_errorbar(aes(ymin=M-2*SE,
+                       ymax=M+2*SE),
+                   width=.1,size=k)+
+     xlab(x.lab)+
+     ylab(y.lab)+
+     labs(title=mytitle) +
+     theme_bw()
+ }
> (plot.regions<-byregion.plot(M.id.w,
+                               mytitle="Experiment 2",k=.5,
+                               x.lab="region",y.lab="reading time [msec]"))
> )
> dev.off()

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2

> # condition a: Subj-modifying SRC
> # condition b: Subj-modifying ORC
> # condition c: Obj-modifying SRC
> # condition d: Obj-modifying ORC
> ## We focus on a,b for consistency with the
> ## earlier studies
>
> #a=subj rel, c=obj rel.
>
> critdata<-read.table("expt2critdata.txt",header=T)

```

```

> par( mfrow=c(2,3) )
> boxcox(rt~condition*subj,data=critdata[critdata$region=="de", ])
> boxcox(rt~condition*subj,data=critdata[critdata$region=="headnoun", ])
> boxcox(rt~condition*subj,data=critdata[critdata$region=="headnoun1", ])
> critdata$rrt <- -1000/critdata$rt
> headnoun <- subset(critdata,region=="headnoun")
> headnoun1 <- subset(critdata,region=="headnoun1")
> library(MASS)
> with(headnoun,boxcox(rt~condition*subj))

```

lmer models:

```

> with(critdata,tapply(rt,IND=list(region,condition),mean))

```

	a	b
de	471.93	492.00
headnoun	608.15	691.13
headnoun1	791.38	939.14

```

> (m1<-lmer(rt~condition+(1|subj)+(1/item),headnoun))

```

Linear mixed model fit by REML

Formula: rt ~ condition + (1 | subj) + (1 | item)

Data: headnoun

AIC BIC logLik deviance REMLdev

11402 11425 -5696 11410 11392

Random effects:

Groups	Name	Variance	Std.Dev.
subj	(Intercept)	47520	218.0
item	(Intercept)	9142	95.6
Residual		310403	557.1

Number of obs: 732, groups: subj, 61; item, 24

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	608.4	44.8	13.6
conditionb	82.6	41.2	2.0

Correlation of Fixed Effects:

(Intr)

conditionb -0.460

```

> qqPlot(residuals(m1))

```

```

> (m2<-lmer(rrt~so+(1+so|subj)+(1/item),headnoun))

```

Linear mixed model fit by REML

Formula: rrt ~ so + (1 + so | subj) + (1 | item)

```

Data: headnoun
AIC   BIC logLik deviance REMLdev
1796 1829   -891    1775    1782
Random effects:
Groups   Name             Variance Std.Dev. Corr
subj     (Intercept)  0.25544   0.5054
          so           0.00447   0.0669   1.000
item     (Intercept)  0.02590   0.1609
Residual                0.55183   0.7429
Number of obs: 732, groups: subj, 61; item, 24

Fixed effects:
              Estimate Std. Error t value
(Intercept)  -2.1357     0.0776  -27.52
so            0.0683     0.0556    1.23

Correlation of Fixed Effects:
(Intr)
so 0.128

> qqPlot(residuals(m2))
> (m3<-lmer(rrt~so+(1+so|subj)+(1|item),headnoun1))

Linear mixed model fit by REML
Formula: rrt ~ so + (1 + so | subj) + (1 | item)
Data: headnoun1
AIC   BIC logLik deviance REMLdev
1653 1685   -819    1632    1639
Random effects:
Groups   Name             Variance Std.Dev. Corr
subj     (Intercept)  0.19563   0.4423
          so           0.00352   0.0593   0.186
item     (Intercept)  0.10922   0.3305
Residual                0.43595   0.6603
Number of obs: 732, groups: subj, 61; item, 24

Fixed effects:
              Estimate Std. Error t value
(Intercept)  -1.7562     0.0914  -19.22
so            0.2287     0.0494    4.63

Correlation of Fixed Effects:
(Intr)
so 0.018

> qqPlot(residuals(m3))
>

```

By region analyses as demanded by reviewer:

```
> (qiang.de.rrt<-lmer(rrt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="de")))
```

Linear mixed model fit by REML

Formula: rrt ~ so + (1 + so | subj) + (1 + so | item)

Data: subset(critdata, region == "de")

AIC	BIC	logLik	deviance	REMLdev
1515	1557	-749	1490	1497

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	0.16003	0.4000	
	so	0.00296	0.0544	1.000
item	(Intercept)	0.01606	0.1267	
	so	0.02329	0.1526	-0.858
Residual		0.37337	0.6110	

Number of obs: 732, groups: subj, 61; item, 24

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	-2.3909	0.0617	-38.8
so	0.0745	0.0553	1.3

Correlation of Fixed Effects:

(Intr)
so -0.098

```
> qqPlot(residuals(qiang.de.rrt))
```

```
> (qiang.hnoun.rrt<-lmer(rrt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="headnoun")))
```

Linear mixed model fit by REML

Formula: rrt ~ so + (1 + so | subj) + (1 + so | item)

Data: subset(critdata, region == "headnoun")

AIC	BIC	logLik	deviance	REMLdev
1800	1842	-891	1775	1782

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	0.25497	0.5049	
	so	0.00451	0.0671	1.000
item	(Intercept)	0.02593	0.1610	
	so	0.00104	0.0323	-1.000
Residual		0.55161	0.7427	

Number of obs: 732, groups: subj, 61; item, 24

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	-2.1356	0.0775	-27.54

```
so          0.0683    0.0560    1.22
```

Correlation of Fixed Effects:

```
(Intr)
so 0.078
```

```
> qqPlot(residuals(qiang.hnoun.rrt))
```

```
> (qiang.hnoun1.rrt<-lmer(rrt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="headnoun1"))
```

Linear mixed model fit by REML

Formula: rrt ~ so + (1 + so | subj) + (1 + so | item)

Data: subset(critdata, region == "headnoun1")

AIC BIC logLik deviance REMLdev

```
1655 1697 -819    1630    1637
```

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	0.195813	0.4425	
	so	0.000123	0.0111	1.000
item	(Intercept)	0.109744	0.3313	
	so	0.020655	0.1437	0.214
Residual		0.431732	0.6571	

Number of obs: 732, groups: subj, 61; item, 24

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	-1.7564	0.0915	-19.19
so	0.2286	0.0568	4.03

Correlation of Fixed Effects:

```
(Intr)
so 0.097
```

```
> qqPlot(residuals(qiang.hnoun1.rrt))
```

```
> #bwplot(rrt~cond,subset(critdata,region=="headnoun1" & rrt>-4))
```

```
>
```

```
> ## assemble table:
```

```
> qiang.de<-c(fixef(qiang.de.rrt)[2],
```

```
+ sqrt(vcov(qiang.de.rrt))[2,2],
```

```
+ fixef(qiang.de.rrt)[2]/sqrt(vcov(qiang.de.rrt))[2,2])
```

```
> qiang.hnoun<-c(fixef(qiang.hnoun.rrt)[2],
```

```
+ sqrt(vcov(qiang.hnoun.rrt))[2,2],
```

```
+ fixef(qiang.hnoun.rrt)[2]/sqrt(vcov(qiang.hnoun.rrt))[2,2])
```

```
> qiang.hnoun1<-c(fixef(qiang.hnoun1.rrt)[2],
```

```
+ sqrt(vcov(qiang.hnoun1.rrt))[2,2],
```

```
+ fixef(qiang.hnoun1.rrt)[2]/sqrt(vcov(qiang.hnoun1.rrt))[2,2])
```

```
> qiangresults<-rbind(qiang.de,qiang.hnoun,qiang.hnoun1)
```

```
> rownames(qiangresults)<-c("de","head noun","head noun+1")
```



```

> colnames(qiangresults)<-c("coef.", "SE", "t-value")
> xtable(qiangresults)

% latex table generated in R 3.0.1 by xtable 1.7-1 package
% Wed Nov 27 17:22:37 2013
\begin{table}[ht]
\centering
\begin{tabular}{rrrr}
\hline
& coef. & SE & t-value \\
\hline
de & 0.07 & 0.06 & 1.35 \\
head noun & 0.07 & 0.06 & 1.22 \\
head noun+1 & 0.23 & 0.06 & 4.03 \\
\hline
\end{tabular}
\end{table}

> #####Remove between subject variance for SE#####
> # (a) Aggregate to Subject x Condition means
>
> data.rs <- melt(critdata, id=c("condition", "region", "subj"), measure=c("rt"), na.rm=TRUE)
> data.id <- data.frame(cast(data.rs, subj + condition + region ~ ., function(x) c(rt=mean(x)
> # (b) Remove between-subject variance
> ##
> (GM <- mean(tapply(data.id$rt, data.id$subj, mean)))

[1] 665.62

> data.id <- ddply(data.id, .(subj), transform, rt.w = rt - mean(rt) + GM)
> # (c) Compute condition means and error bars: +/- 2 SE of means after removal of between-
> temp<-melt(data.id, id.var=c("subj", "condition", "region"), measure.var="rt.w")
> (M.id.w <- cast(temp, condition+region ~ .,
+               function(x) c(M=mean(x), SE=sd(x)/sqrt(length(x)), N=length(x) ) ) )

  condition    region      M      SE  N
1         a         de 471.93 23.335 61
2         a headnoun 608.15 19.881 61
3         a headnoun1 791.38 34.033 61
4         b         de 492.00 20.754 61
5         b headnoun 691.13 33.132 61
6         b headnoun1 939.14 46.386 61

```

4 Experiment 3: Gibson and Wu replication

Now we look at our “exact” replication of Gibson and Wu:

```

> gwrerun<-read.table("gwrerun.txt",header=F)
> colnames(gwrerun) <- c("machine","subj","item","condition","pos","word","correct","rt")
> gwrerun$subj<-paste(gwrerun$machine,gwrerun$subj,sep="")
> questions.gwrerun <- subset(gwrerun,correct%in%c(0,1))
> with(questions.gwrerun,tapply(as.integer(as.character(correct)),condition,mean))

obj-ext subj-ext
0.87667 0.89333

> lmer(I(-1/rt)~ condition+(1/|subj|)+(1/|item|),questions.gwrerun)

Linear mixed model fit by REML
Formula: I(-1/rt) ~ condition + (1 | subj) + (1 | item)
Data: questions.gwrerun
AIC BIC logLik deviance REMLdev
-7223 -7201 3616 -7269 -7233
Random effects:
Groups Name Variance Std.Dev.
subj (Intercept) 7.60e-08 2.76e-04
item (Intercept) 5.81e-09 7.62e-05
Residual 2.85e-07 5.34e-04
Number of obs: 600, groups: subj, 40; item, 15

Fixed effects:
Estimate Std. Error t value
(Intercept) -3.60e-04 5.69e-05 -6.33
conditionsbj-ext -4.17e-05 4.37e-05 -0.95

Correlation of Fixed Effects:
(Intr)
cndtnsbj-xt -0.384

> with(questions.gwrerun,tapply(rt,condition,mean))

obj-ext subj-ext
3951.9 4005.6

> questions.lmer.gwrerun<- lmer(correct~condition+(1/|item|)+(1/|item|),questions.gwrerun,family

Plotting:

> ## isolate relevant columns:
> gwdata<-gwrerun[,c(2,3,4,5,8)]
> #xtabs(~subj+condition,gwdata)
>
> region<-factor(ifelse(gwdata$pos==5,"V/N",
+ ifelse(gwdata$pos==6,"N/V",

```

```

+         ifelse(gwdata$pos==7,"de",
+         ifelse(gwdata$pos==8,"head noun",
+         ifelse(gwdata$pos==9,"head noun+1",-1))))),
+         levels=c("V/N","N/V","de","head noun","head noun+1"))
> gwdata$region<-region
> gwdata<-subset(gwdata,region!="-1")
> gwdata$region<-factor(gwdata$region)
> critdata<-gwdata
> critdata$subj<-factor(critdata$subj)
> with(subset(critdata,region=="de"),boxcox(rt~condition*subj))
> with(subset(critdata,region=="head noun"),boxcox(rt~condition*subj))
> with(subset(critdata,region=="head noun+1"),boxcox(rt~condition*subj))
> critdata$rrt<- -1000/critdata$rt
> critdata$cond <- factor(ifelse(critdata$cond=="subj-ext","subject relative","object relative"))
> ## rt plot
> data.rs <- melt(critdata, id=c("cond","region", "subj"), measure=c("rt"),na.rm=TRUE)
> data.id <- data.frame(cast(data.rs, subj + cond + region ~ ., function(x) c(rt=mean(x), N=length(x))
> # (b) Remove between-subject variance
> ##
> (GM <- mean(tapply(data.id$rt, data.id$subj, mean)))

[1] 492.31

> data.id <- ddply(data.id, .(subj), transform, rt.w = rt - mean(rt) + GM)
> # (c) Compute condition means and error bars: +/- 2 SE of means after removal of between-subject variance
> temp<-melt(data.id, id.var=c("subj","cond","region"), measure.var="rt.w")
> (M.id.w <- cast(temp,cond+region ~ .,
+         function(x) c(M=mean(x), SE=sd(x)/sqrt(length(x)), N=length(x) ) ) )

      cond      region      M      SE  N
1 subject relative    V/N 496.43 21.150 40
2 subject relative    N/V 563.19 26.806 40
3 subject relative      de 479.97 25.724 40
4 subject relative head noun 557.81 44.064 40
5 subject relative head noun+1 534.22 21.598 40
6 object relative    V/N 516.72 25.454 40
7 object relative    N/V 458.01 12.378 40
8 object relative      de 384.93 13.454 40
9 object relative head noun 442.30 16.056 40
10 object relative head noun+1 489.50 31.283 40

> byregion.plot<-function(data,
+         mytitle,k=1,
+         x.lab="region",
+         y.lab="reading time [msec]"){
+   ggplot(data,aes(x=region,y=M,
+         group=cond)) +

```

```

+     geom_point(shape=21,size=k*3) +
+     geom_line(aes(linetype=cond),size=k) +
+     geom_errorbar(aes(ymin=M-2*SE,
+                       ymax=M+2*SE),
+                   width=.1,size=k)+
+     xlab(x.lab)+
+     ylab(y.lab)+
+     labs(title=mytitle) +
+     theme_bw()
+ }
> ## plot:
> #tiff("expt3.tiff",res=300,width=17.35,
> #     height=15.35,
> #     units="cm",compression="lzw",bg
> #="white")
>
> bitmap("fig5.tiff", height = 4, width = 7, units = 'in', type="tiff", res=600)
> (plot.regions<-byregion.plot(M.id.w,
+                               mytitle="Experiment 3",k=0.5,
+                               x.lab="region",y.lab="reading time [msec]")
+ )
> dev.off()

```

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2

The reviewer demands a fuller analysis:

```

> so<-ifelse(critdata$condition=="subj-ext",-0.5,0.5)
> critdata$so<-so
> ## a surprising OR advantage, cannot be attributed to
> ## storage cost:
> (gwrerun.de.rrt <- lmer(rrt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="de")))

```

Linear mixed model fit by REML

Formula: $rrt \sim so + (1 + so | subj) + (1 + so | item)$

Data: subset(critdata, region == "de")

AIC BIC logLik deviance REMLdev

1437 1477 -710 1413 1419

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	2.05e-01	0.452961	
	so	6.12e-07	0.000783	-0.999
item	(Intercept)	1.57e-02	0.125241	
	so	2.63e-02	0.162087	-0.193
Residual		5.38e-01	0.733793	

Number of obs: 596, groups: subj, 40; item, 15

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	-2.7373	0.0841	-32.5
so	-0.2214	0.0734	-3.0

Correlation of Fixed Effects:

(Intr)
so -0.041

```
> qqPlot(residuals(gwrrerun.de.rrt))
> bwplot(rrt~cond,subset(critdata,region=="de"))
> row<-which(subset(critdata,region=="de")$rrt< -5.5)
> ## item 1 is unusual but doesn't affect result:
> subset(critdata,region=="de")[row,]
```

	subj	item	condition	pos	rt	region	rrt	cond	so
8218	2m9	1	obj-ext	7	167	de	-5.988	object	relative 0.5

```
> (gwrrerun.hnoun.rrt <- lmer(rrt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="head noun"))
```

Linear mixed model fit by REML

Formula: rrt ~ so + (1 + so | subj) + (1 + so | item)

Data: subset(critdata, region == "head noun")

AIC BIC logLik deviance REMLdev

1572 1611 -777 1548 1554

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	0.3686	0.607	
	so	0.0714	0.267	0.267
item	(Intercept)	0.0681	0.261	
	so	0.0680	0.261	-0.481
Residual		0.6305	0.794	

Number of obs: 595, groups: subj, 40; item, 15

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	-2.738	0.122	-22.49
so	-0.149	0.103	-1.44

Correlation of Fixed Effects:

(Intr)
so -0.087

```
> qqPlot(residuals(gwrrerun.hnoun.rrt))
> row<-which(subset(critdata,region=="head noun")$rrt< -5.5)
> ## item 3 in the object extracted condition is unusual:
> subset(critdata,region=="head noun")[row,]
```

```

      subj item condition pos rt region rrt cond so
1733 1m17 3 obj-ext 8 172 head noun -5.814 object relative 0.5

> (gwrerun.hnoun1.rrt <- lmer(rrt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="head n

Linear mixed model fit by REML
Formula: rrt ~ so + (1 + so | subj) + (1 + so | item)
Data: subset(critdata, region == "head noun+1")
AIC BIC logLik deviance REMLdev
1635 1675 -809 1612 1617
Random effects:
Groups Name Variance Std.Dev. Corr
subj (Intercept) 0.3116 0.558
so 0.0607 0.246 -0.186
item (Intercept) 0.1523 0.390
so 0.0416 0.204 -0.146
Residual 0.7094 0.842
Number of obs: 595, groups: subj, 40; item, 15

Fixed effects:
Estimate Std. Error t value
(Intercept) -2.6547 0.1383 -19.19
so -0.0562 0.0954 -0.59

Correlation of Fixed Effects:
(Intr)
so -0.106

> qqPlot(residuals(gwrerun.hnoun1.rrt))
> ## one data point is unusual on ORs, but does not affect result:
> bwplot(rrt~cond,subset(critdata,region=="head noun+1" & rrt> -6))
> ## get coefs, SEs, t-values:
> gwrerun.de<-c(fixef(gwrerun.de.rrt)[2],
+ sqrt(vcov(gwrerun.de.rrt))[2,2],
+ fixef(gwrerun.de.rrt)[2]/sqrt(vcov(gwrerun.de.rrt))[2,2])
> gwrerun.hnoun<-c(fixef(gwrerun.hnoun.rrt)[2],
+ sqrt(vcov(gwrerun.hnoun.rrt))[2,2],
+ fixef(gwrerun.hnoun.rrt)[2]/sqrt(vcov(gwrerun.hnoun.rrt))[2,2])
> gwrerun.hnoun1<-c(fixef(gwrerun.hnoun1.rrt)[2],
+ sqrt(vcov(gwrerun.hnoun1.rrt))[2,2],
+ fixef(gwrerun.hnoun1.rrt)[2]/sqrt(vcov(gwrerun.hnoun1.rrt))[2,2])
> gwrerunresults<-rbind(gwrerun.de,gwrerun.hnoun,gwrerun.hnoun1)
> rownames(gwrerunresults)<-c("de","head noun","head noun+1")
> colnames(gwrerunresults)<-c("coef. ","SE","t-value")
> xtable(gwrerunresults)

% latex table generated in R 3.0.1 by xtable 1.7-1 package
% Wed Nov 27 17:22:42 2013

```

```

\begin{table}[ht]
\centering
\begin{tabular}{rrrrr}
\hline
& coef. & SE & t-value & \\
\hline
de & -0.22 & 0.07 & -3.02 & \\
head noun & -0.15 & 0.10 & -1.44 & \\
head noun+1 & -0.06 & 0.10 & -0.59 & \\
\hline
\end{tabular}
\end{table}

```

Combined analysis:

```

> ## rerun:
> gwrerun<-critdata
> ## original data:
> gwcritdata<-gwcritdata[,c(1,2,3,4,7)]
> gwrerun<-gwrerun[,1:5]
> head(gwrerun)

```

	subj	item	condition	pos	rt
6	1m1	15	obj-ext	5	566
7	1m1	15	obj-ext	6	1041
8	1m1	15	obj-ext	7	733
9	1m1	15	obj-ext	8	832
10	1m1	15	obj-ext	9	1859
17	1m1	8	subj-ext	5	515

```

> head(gwcritdata)

```

	subj	item	type	pos	rt
7	1	13	obj-ext	6	1140
20	1	6	subj-ext	6	1197
32	1	5	obj-ext	6	756
44	1	9	obj-ext	6	643
60	1	14	subj-ext	6	860
73	1	4	subj-ext	6	868

```

> colnames(gwcritdata)[3]<-"condition"
> gwcritdata$expt<-factor("gw")
> gwrerun$expt<-factor("gwrerun")
> gwall<-rbind(gwcritdata,gwrerun)
> head(gwall)

```

	subj	item	condition	pos	rt	expt
7	1	13	obj-ext	6	1140	gw

```

20  1    6  subj-ext    6 1197  gw
32  1    5  obj-ext    6  756  gw
44  1    9  obj-ext    6  643  gw
60  1   14  subj-ext    6  860  gw
73  1    4  subj-ext    6  868  gw

> length(unique(gwall$subj))

[1] 77

> #xtabs(~subj+condition,gwall)

> critdata<-gwall
> region<-factor(ifelse(critdata$pos==5,"V/N",
+                       ifelse(critdata$pos==6,"N/V",
+                               ifelse(critdata$pos==7,"de",
+                                       ifelse(critdata$pos==8,"head noun",
+                                               ifelse(critdata$pos==9,"head noun+1",-1))))),
+                 levels=c("V/N","N/V","de","head noun","head noun+1"))
> critdata$region<-region
> critdata<-subset(critdata,region!="-1")
> critdata$region<-factor(critdata$region)
> critdata$subj<-factor(critdata$subj)
> with(subset(critdata,region=="de"),boxcox(rt~condition*subj))
> with(subset(critdata,region=="head noun"),boxcox(rt~condition*subj))
> with(subset(critdata,region=="head noun+1"),boxcox(rt~condition*subj))
> ## for consistency, we use negative reciprocal:
> critdata$rtrt<- -1000/critdata$rt
> critdata$type <- factor(ifelse(critdata$condition=="subj-ext","subject relative","object r
> data.rs <- melt(critdata, id=c("type","region", "subj"), measure=c("rt"),na.rm=TRUE)
> data.id <- data.frame(cast(data.rs, subj + type + region ~ ., function(x) c(rt=mean(x), N=
> # (b) Remove between-subject variance
> ##
> (GM <- mean(tapply(data.id$rt, data.id$subj, mean)))

[1] 592.26

> data.id <- ddply(data.id, .(subj), transform, rt.w = rt - mean(rt) + GM)
> # (c) Compute condition means and error bars: +/- 2 SE of means after removal of between-
> temp<-melt(data.id, id.var=c("subj","type","region"), measure.var="rt.w")
> (M.id.w <- cast(temp,type+region ~ .,
+                 function(x) c(M=mean(x), SE=sd(x)/sqrt(length(x)), N=length(x) ) ) )

      type      region      M      SE  N
1 subject relative    V/N 596.39 21.150 40
2 subject relative    N/V 801.00 27.791 77
3 subject relative     de 480.96 20.660 77

```



```

4 subject relative head noun 700.32 28.832 77
5 subject relative head noun+1 545.79 19.726 77
6 object relative V/N 616.67 25.454 40
7 object relative N/V 712.95 23.618 77
8 object relative de 408.89 14.039 77
9 object relative head noun 569.77 12.369 77
10 object relative head noun+1 503.63 24.681 77

> byregion.plot<-function(data,
+                           mytitle,k=1,
+                           x.lab="region",
+                           y.lab="reading time [msec]"){
+   ggplot(data,aes(x=region,y=M,
+                   group=type)) +
+     geom_point(shape=21,size=k*3) +
+     geom_line(aes(linetype=type),size=k) +
+     geom_errorbar(aes(ymin=M-2*SE,
+                       ymax=M+2*SE),
+                  width=.1,size=k)+
+     xlab(x.lab)+
+     ylab(y.lab)+
+     labs(title=mytitle) +
+     theme_bw()
+ }
> tiff("expt3a.tiff",res=300,width=17.35,
+      height=15.35,
+      units="cm",compression="lzw",bg="white")
> bitmap("fig6.tiff", height = 4, width = 7, units = 'in', type="tiff", res=600)
> ## plot:
> (plot.regions<-byregion.plot(M.id.w,
+                               mytitle="Combined data (Gibson and Wu expt. \n and replication)",k=0.5,
+                               x.lab="region",y.lab="reading time [msec]"))
> dev.off()

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2

> critdata$so<-ifelse(critdata$condition=="subj-ext",-0.5,0.5)
> (gwall.de.rrt <- lmer(rrt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="de"))))

Linear mixed model fit by REML
Formula: rrt ~ so + (1 + so | subj) + (1 + so | item)
Data: subset(critdata, region == "de")
AIC BIC logLik deviance REMLdev
2805 2851 -1394 2780 2787
Random effects:

```

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	0.249869	0.4999	
	so	0.000884	0.0297	1.000
item	(Intercept)	0.021385	0.1462	
	so	0.014101	0.1187	-0.085
Residual		0.570503	0.7553	

Number of obs: 1143, groups: subj, 77; item, 15

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	-2.7191	0.0719	-37.8
so	-0.1875	0.0544	-3.4

Correlation of Fixed Effects:

(Intr)
so 0.024

```
> qqPlot(residuals(gwall.de.rrt))
> (gwall.hnoun.rrt <- lmer(rrt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="head noun"))
```

Linear mixed model fit by REML

Formula: rrt ~ so + (1 + so | subj) + (1 + so | item)

Data: subset(critdata, region == "head noun")

	AIC	BIC	logLik	deviance	REMLdev
	4907	4956	-2445	4882	4889

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	0.414650	0.6439	
	so	0.000128	0.0113	1.000
item	(Intercept)	0.056017	0.2367	
	so	0.000640	0.0253	1.000
Residual		0.932860	0.9658	

Number of obs: 1689, groups: subj, 77; item, 15

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	-2.3579	0.0987	-23.90
so	-0.1023	0.0476	-2.15

Correlation of Fixed Effects:

(Intr)
so 0.105

```
> qqPlot(residuals(gwall.hnoun.rrt))
> (gwall.hnoun1.rrt <- lmer(rrt~so+(1+so|subj)+(1+so|item),subset(critdata,region=="head noun"))
```

Linear mixed model fit by REML

Formula: rrt ~ so + (1 + so | subj) + (1 + so | item)

```
Data: subset(critdata, region == "head noun+1")
```

```
AIC BIC logLik deviance REMLdev
3154 3200 -1568 3130 3136
```

```
Random effects:
```

Groups	Name	Variance	Std.Dev.	Corr
subj	(Intercept)	0.273658	0.5231	
	so	0.009658	0.0983	-0.978
item	(Intercept)	0.157608	0.3970	
	so	0.000138	0.0117	-1.000
Residual		0.775088	0.8804	

```
Number of obs: 1142, groups: subj, 77; item, 15
```

```
Fixed effects:
```

	Estimate	Std. Error	t value
(Intercept)	-2.61994	0.12143	-21.58
so	-0.00867	0.05352	-0.16

```
Correlation of Fixed Effects:
```

```
(Intr)
so -0.149
```

```
> qqPlot(residuals(gwall.hnoun1.rrt))
> ## sign of fit above changes if we remove the data points that have rrt> -6, but result d
> ##not change:
> bwplot(rrt~condition,subset(critdata,region=="head noun+1" & rrt> -6))
> ## get coefs, SEs, t-values:
>
> gwall.de<-c(fixef(gwall.de.rrt)[2],
+ sqrt(vcov(gwall.de.rrt))[2,2],
+ fixef(gwall.de.rrt)[2]/sqrt(vcov(gwall.de.rrt))[2,2])
> gwall.hn<-c(fixef(gwall.hnoun.rrt)[2],
+ sqrt(vcov(gwall.hnoun.rrt))[2,2],
+ fixef(gwall.hnoun.rrt)[2]/sqrt(vcov(gwall.hnoun.rrt))[2,2])
> gwall.hn1<-c(fixef(gwall.hnoun1.rrt)[2],
+ sqrt(vcov(gwall.hnoun1.rrt))[2,2],
+ fixef(gwall.hnoun1.rrt)[2]/sqrt(vcov(gwall.hnoun1.rrt))[2,2])
> gwallresults<-rbind(gwall.de,gwall.hn,gwall.hn1)
> rownames(gwallresults)<-c("de","head noun","head noun+1")
> colnames(gwallresults)<-c("coef","SE","t-value")
> xtable(round(gwallresults,digits=2))
```

```
% latex table generated in R 3.0.1 by xtable 1.7-1 package
```

```
% Wed Nov 27 17:22:48 2013
```

```
\begin{table}[ht]
```

```
\centering
```

```
\begin{tabular}{rrrrr}
```

```

\hline
& coef & SE & t-value \\
\hline
de & -0.19 & 0.05 & -3.45 \\
head noun & -0.10 & 0.05 & -2.15 \\
head noun+1 & -0.01 & 0.05 & -0.16 \\
\hline
\end{tabular}
\end{table}

```