

Supplementary Materials

Section A: Power Analysis

With respect to statistical power, using from comprehension results based on Wiseheart et al. (i.e. control = .95 and dyslexia = .84, SD= .14), and considering an alpha of .05 and power of .80, suggests a sample size of only 26. Conversely, if we calculate estimated power based on sample sizes of 50, we get estimated power of .98.

Section B: R Analysis

Internal Replication: The code and data (Rmd file and two csv files) for these analyses are available upon request. All of the following converged without a singularity warning. If singularity warnings did occur, we always removed “group” from items first, and then if that still gave a singularity error we removed “type” from subject. Analyses contained below begin with the relative noun region of interest (total reading time, first pass reading time, regressions, and regression path duration). The second set of analysis are the relative verb (total reading time, first pass reading time, regressions, and regression path duration).

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```
knitr::opts_chunk$set(echo = TRUE)

suppressPackageStartupMessages(library(lme4))
suppressPackageStartupMessages(library(lmerTest))

citation('lme4')$textVersion # so you have the LMER version number

## [1] "Douglas Bates, Martin Maechler, Ben Bolker, Steve Walker (2015). Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 67(1), 1-48. doi:10.18637/jss.v067.i01."

#Design is 2 x 2 (group x type)
#group is between subjects (dyslexia vs. control)
#type is within subject (subject vs. object)

#all DVs are linear, except regressions which are binomial.
```

#Noun ##Total DV

```
noun<-read.csv("~/Desktop/paul_noun.csv")
```

```

noun$group<-as.factor(noun$group)
noun$type<-as.factor(noun$type)
noun$subject<-as.factor(noun$subject)
noun1<-noun[noun$total!=".",]#remove "." trials

noun_model<-lmer(total ~ group*type+(1+type|subject) + (1+group|item), data=noun1,
REML=FALSE)

## boundary (singular) fit: see ?isSingular
## Warning: Model failed to converge with 1 negative eigenvalue: -2.1e+03
noun_modelrel<-lmer(total ~ group*type+(1+type|subject) + (1|item), data=noun1, REML=FALSE)
## boundary (singular) fit: see ?isSingular
noun_modelre2<-lmer(total ~ group*type+(1|subject) + (1|item), data=noun1, REML=FALSE)

summary(noun_modelre2)

## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
## method [lmerModLmerTest]
## Formula: total ~ group * type + (1 | subject) + (1 | item)
## Data: noun1
##
##      AIC      BIC   logLik deviance df.resid
## 31011.5 31050.7 -15498.8 30997.5      1993
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.6555 -0.5696 -0.1497  0.3359 11.8619
##
## Random effects:
## Groups Name Variance Std.Dev.
## subject (Intercept) 78786 280.7
## item (Intercept) 13086 114.4
## Residual 282075 531.1
## Number of obs: 2000, groups: subject, 100; item, 20
##
## Fixed effects:
##
## Estimate Std. Error df t value Pr(>|t|)
## (Intercept) 656.83 52.87 116.47 12.424 < 2e-16 ***
## groupdyslexia 162.49 65.44 132.46 2.483 0.0143 *
## type2 -133.99 33.63 1882.91 -3.984 7.05e-05 ***
## groupdyslexia:type2 76.91 47.63 1884.89 1.615 0.1065

```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##              (Intr) grpdys type2
## groupdyslex -0.619
## type2        -0.318  0.258
## grpdyslxt2   0.225 -0.364 -0.708
```

##First DV

```
noun2<-noun[noun$first!=".",] #remove "." trials
noun2$first<-as.numeric(as.character(noun2$first)) #convert to numeric
noun_model_first<-lmer(first ~ group*type+(1+type|subject) + (1+group|item), data=noun2, REML=FALSE)
## boundary (singular) fit: see ?isSingular
noun_model_first2<-lmer(first ~ group*type+(1+type|subject) + (1|item), data=noun2, REML=FALSE)
## boundary (singular) fit: see ?isSingular
noun_model_first3<-lmer(first ~ group*type+(1|subject) + (1|item), data=noun2, REML=FALSE)
summary(noun_model_first3)
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
## method [lmerModLmerTest]
## Formula: first ~ group * type + (1 | subject) + (1 | item)
## Data: noun2
##
##          AIC          BIC    logLik deviance df.resid
## 24354.6    24393.4 -12170.3  24340.6      1872
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.1979 -0.5940 -0.2246  0.3361 11.8082
##
## Random effects:
## Groups   Name                Variance Std.Dev.
## subject  (Intercept)    2411.2     49.10
## item      (Intercept)     291.4     17.07
## Residual                    23166.6    152.21
## Number of obs: 1879, groups:  subject, 100; item, 20
##
```

```
## Fixed effects:
##
##           Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)    256.2049    10.6344  141.8904   24.092   <2e-16 ***
## groupdyslexia    -0.6669    14.0141  181.6654   -0.048    0.9621
## type2           25.3999    10.0087 1772.7123    2.538    0.0112 *
## groupdyslexia:type2  19.5568    14.0880 1774.5566    1.388    0.1653
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##           (Intr) grpdys type2
## groupdyslex -0.661
## type2       -0.473  0.359
## grpdyslxt2  0.336 -0.507 -0.711
```

##Regress DV

```
noun3<-noun[noun$regress!=".",]
str(noun3$regress)
## chr [1:1879] "1" "0" "1" "0" "0" "0" "0" "0" "1" "0" "0" "0" "0" "0" ...
noun3$regress<-as.numeric(as.character(noun3$regress))
noun_model_regress<-glmer(regress ~ group*type+(1+type|subject) + (1+group|item), d
ata=noun3, family="binomial")
## boundary (singular) fit: see ?isSingular
noun_model_regress_rel<-glmer(regress ~ group*type+(1+type|subject) + (1|item), dat
a=noun3, family="binomial")
summary(noun_model_regress_rel)
## Generalized linear mixed model fit by maximum likelihood (Laplace
## Approximation) [glmerMod]
## Family: binomial ( logit )
## Formula: regress ~ group * type + (1 + type | subject) + (1 | item)
## Data: noun3
##
##           AIC          BIC    logLik deviance df.resid
##    1982.5    2026.8   -983.3   1966.5     1871
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -0.8004 -0.5492 -0.4712 -0.3724  2.7045
##
## Random effects:
```

```
## Groups Name Variance Std.Dev. Corr
## subject (Intercept) 0.191397 0.43749
## type2 0.024986 0.15807 0.17
## item (Intercept) 0.002544 0.05044
## Number of obs: 1879, groups: subject, 100; item, 20
##
## Fixed effects:
## Estimate Std. Error z value Pr(>|z|)
## (Intercept) -1.24326 0.13147 -9.457 <2e-16 ***
## groupdyslexia 0.22301 0.17715 1.259 0.2081
## type2 -0.39755 0.17707 -2.245 0.0248 *
## groupdyslexia:type2 0.04047 0.23033 0.176 0.8605
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
## (Intr) grpdys type2
## groupdyslex -0.708
## type2 -0.558 0.392
## grpdyslxt2 0.407 -0.566 -0.712
```

##regpath DV

```
noun4<-noun[noun$regpath!=".",]
str(noun4$regpath)
## chr [1:1879] "1562" "165" "1768" "412" "163" "300" "1127" "704" "1355" ...
noun4$regpath<-as.numeric(as.character(noun4$regpath))

noun_mode_regpa<-lmer(regpath ~ group*type+(1+type|subject) + (1+group|item), data=
noun4, REML=FALSE)

## boundary (singular) fit: see ?isSingular
## Warning: Model failed to converge with 1 negative eigenvalue: -1.6e-01
noun_mode_regpa_re1<-lmer(regpath ~ group*type+(1+type|subject) + (1|item), data=no
un4, REML=FALSE)

## boundary (singular) fit: see ?isSingular
noun_mode_regpa_re2<-lmer(regpath ~ group*type+(1|subject) + (1|item), data=noun4,
REML=FALSE)

summary(noun_mode_regpa_re2)

## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
## method [lmerModLmerTest]
## Formula: regpath ~ group * type + (1 | subject) + (1 | item)
```

```
##      Data: noun4
##
##      AIC      BIC    logLik deviance df.resid
## 29647.3 29686.0 -14816.6 29633.3      1872
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -1.9890 -0.4764 -0.2689  0.0856 11.2639
##
## Random effects:
##  Groups      Name      Variance Std.Dev.
##  subject  (Intercept)  39874    199.69
##  item      (Intercept)   1478     38.44
##  Residual                389537   624.13
## Number of obs: 1879, groups:  subject, 100; item, 20
##
## Fixed effects:
##
##              Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)      473.23      41.43   156.91  11.423 < 2e-16 ***
## groupdyslexia     195.45      57.22   183.92   3.416 0.000783 ***
## type2             -26.99      41.02  1775.47  -0.658 0.510709
## groupdyslexia:type2 -47.66      57.72  1778.63  -0.826 0.409069
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##              (Intr) grpdys type2
## groupdyslex -0.693
## type2       -0.497  0.360
## grpdyslxt2  0.354 -0.509 -0.711
```

#Verb

```
verb<-read.csv("~/Desktop/paul_verb.csv")
verb$group<-as.factor(verb$group)
verb$type<-as.factor(verb$type)
verb$subject<-as.factor(verb$subject)
```

##Total DV

```
verb1<-verb[verb$total!=".",]#remove "." trials
```

```

verb_model<-lmer(total ~ group*type+(1+type|subject) + (1+group|item), data=verb1,
REML=FALSE)

## boundary (singular) fit: see ?isSingular

verb_modelrel<-lmer(total ~ group*type+(1+type|subject) + (1|item), data=verb1, REM
L=FALSE)

summary(verb_modelrel)

## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
## method [lmerModLmerTest]
## Formula: total ~ group * type + (1 + type | subject) + (1 | item)
## Data: verb1
##
##      AIC      BIC   logLik deviance df.resid
## 31819.3 31869.7 -15900.6 31801.3      1991
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.6227 -0.5658 -0.1549  0.3738 11.3391
##
## Random effects:
## Groups   Name                Variance Std.Dev. Corr
## subject  (Intercept) 121869    349.1
##          type2      19534    139.8   -0.43
## item     (Intercept) 32215     179.5
## Residual                417345    646.0
## Number of obs: 2000, groups: subject, 100; item, 20
##
## Fixed effects:
##              Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)      867.25      69.89   86.61  12.409 < 2e-16 ***
## groupdyslexia     267.61     80.93   99.91   3.307 0.001312 **
## type2            -163.49     45.45   99.35  -3.597 0.000504 ***
## groupdyslexia:type2  44.26     64.36   99.43   0.688 0.493277
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##              (Intr) grpdys type2
## groupdyslex -0.579

```

```
## type2          -0.396  0.343
## grpdyslx:t2    0.280 -0.484 -0.708
```

##First DV

```
verb2<-verb[verb$first!=".",] #remove "." trials
verb2$first<-as.numeric(as.character(verb2$first)) #convert to numeric

verb_model_first<-lmer(first ~ group*type+(1+type|subject) + (1+group|item), data=verb2, REML=FALSE)

## boundary (singular) fit: see ?isSingular

verb_model_first2<-lmer(first ~ group*type+(1+type|subject) + (1|item), data=verb2, REML=FALSE)

summary(verb_model_first2)

## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
## method [lmerModLmerTest]
## Formula: first ~ group * type + (1 + type | subject) + (1 | item)
## Data: verb2
##
##          AIC          BIC    logLik deviance df.resid
## 26239.8 26290.0 -13110.9 26221.8      1938
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.1989 -0.6087 -0.2334  0.3874  6.6555
##
## Random effects:
##   Groups   Name                Variance Std.Dev. Corr
##  subject  (Intercept)         4700     68.56
##           type2              1689     41.10  -0.70
##   item     (Intercept)         1295     35.98
##  Residual                38479     196.16
## Number of obs: 1947, groups: subject, 100; item, 20
##
## Fixed effects:
##
##              Estimate Std. Error    df t value Pr(>|t|)
## (Intercept)      320.31      15.43  86.53  20.763  <2e-16 ***
## groupdyslexia       54.46      18.59 100.40   2.930   0.0042 **
## type2             -27.85      13.90 100.66  -2.003   0.0478 *
## groupdyslexia:type2 -20.87      19.63  99.94  -1.063   0.2905
## ---
```



```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##              (Intr) grpdys type2
## groupdyslex -0.605
## type2        -0.555  0.461
## grpdyslxt2   0.393 -0.649 -0.709
```

##Regress DV

```
verb3<-verb[verb$regress!=".",]
str(verb3$regress)
##  chr [1:1947] "0" "1" "0" "0" "0" "0" "0" "0" "0" "0" "1" "1" "0" "0" "0" ...
verb3$regress<-as.numeric(as.character(verb3$regress))
verb_model_regress<-glmer(regress ~ group*type+(1+type|subject) + (1+group|item), d
ata=verb3, family="binomial")
## boundary (singular) fit: see ?isSingular
verb_model_regress_rel<-glmer(regress ~ group*type+(1+type|subject) + (1|item), dat
a=verb3, family="binomial")
summary(verb_model_regress_rel)
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##   Family: binomial   ( logit )
## Formula: regress ~ group * type + (1 + type | subject) + (1 | item)
##   Data: verb3
##
##           AIC          BIC    logLik deviance df.resid
##    2277.0    2321.6  -1130.5   2261.0     1939
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -0.8924 -0.6272 -0.5347  1.2634  2.1984
##
## Random effects:
##   Groups Name             Variance Std.Dev. Corr
##   subject (Intercept) 0.261410 0.51128
##           type2        0.009979 0.09989  -1.00
##   item      (Intercept) 0.006755 0.08219
## Number of obs: 1947, groups:  subject, 100; item, 20
##
## Fixed effects:
```

```
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)    -1.20674    0.13524  -8.923   <2e-16 ***
## groupdyslexia    0.19755    0.18159   1.088    0.277
## type2           0.09746    0.15653   0.623    0.534
## groupdyslexia:type2 0.12066    0.20924   0.577    0.564
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##              (Intr) grpdys type2
## groupdyslex -0.707
## type2       -0.645  0.459
## grpdyslxl:t2  0.461 -0.642 -0.720
```

##regpath DV

```
verb4<-verb[verb$regpath!=".",]
str(verb4$regpath)
## chr [1:1947] "169" "1122" "217" "189" "221" "169" "356" "146" "386" "146" ...
verb4$regpath<-as.numeric(as.character(verb4$regpath))

verb_mode_regpa<-lmer(regpath ~ group*type+(1+type|subject) + (1+group|item), data=
verb4, REML=FALSE)

## boundary (singular) fit: see ?isSingular

verb_mode_regpa_rel<-lmer(regpath ~ group*type+(1+type|subject) + (1|item), data=ve
rb4, REML=FALSE)

summary(verb_mode_regpa_rel)
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
## method [lmerModLmerTest]
## Formula: regpath ~ group * type + (1 + type | subject) + (1 | item)
## Data: verb4
##
##      AIC      BIC   logLik deviance df.resid
## 30556.6 30606.7 -15269.3 30538.6      1938
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.1504 -0.5511 -0.2788  0.2671  7.4969
##
## Random effects:
```

```
## Groups      Name      Variance Std.Dev. Corr
## subject    (Intercept)  68919   262.52
##           type2        13897   117.88  -0.83
## item       (Intercept)   6482    80.51
## Residual                349776  591.42
## Number of obs: 1947, groups:  subject, 100; item, 20
##
## Fixed effects:
##
##              Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)      598.05      49.22 103.22  12.150  <2e-16 ***
## groupdyslexia    164.22      64.72 100.38   2.538   0.0127 *
## type2           -91.98      41.55 102.21  -2.214   0.0291 *
## groupdyslexia:type2  24.84      58.68 101.50   0.423   0.6729
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##              (Intr) grpdys type2
## groupdyslex -0.659
## type2       -0.602  0.459
## grpdyslxt2  0.427 -0.646 -0.709
```

Section C: Item Analyses

Table A

Mixed ANCOVA item analysis for eye movement measures for the relative verb

	First Pass RT	Total RT	Regressions Out	Regression Path
2 x 2 (Type x Group)				
Type	$F(1,19) = 13.67, p < .01$	$F(1,19) = 12.82, p < .01$	N.S.	$F(1,19) = 5.24, p < .05$
Group	$F(1,19) = 16.52, p < .01$	$F(1,19) = 48.97, p < .001$	$F(1,19) = 7.81, p < .05$	$F(1,19) = 50.03, p < .001$
Type x Group	N.S.	N.S.	N.S.	N.S.
ANCOVA – with Verbal IQ				
Type	$F(1,18) = 14.68, p < .01$	$F(1,18) = 25.96, p < .001$	N.S.	$F(1,18) = 7.36, p < .05$
Group	$F(1,18) = 11.90, p < .01$	$F(1,18) = 37.22, p < .001$	$F(1,18) = 6.05, p < .05$	$F(1,18) = 39.02, p < .001$
Verbal IQ	N.S.	N.S.	N.S.	N.S.
Type x Group	N.S.	N.S.	N.S.	N.S.
Type x Verbal IQ	N.S.	$F(1,18) = 8.91, p < .01$	N.S.	N.S.
ANCOVA – with WM				
Type	N.S.	$F(1,18) = 5.17, p < .05$	N.S.	N.S.
Group	N.S.	$F(1,18) = 6.49, p < .05$	N.S.	N.S.
Working Memory	N.S.	N.S.	N.S.	N.S.
Type x Group	N.S.	N.S.	N.S.	N.S.
Type x Working Memory	N.S.	N.S.	N.S.	N.S.

Table B

Mixed ANCOVA item analysis for eye movement measures for the relative noun

	First Pass RT	Total RT	Regressions Out	Regression Path
2 x 2 (Type x Group)				
Type	$F(1,19) = 21.44, p < .001$	$F(1,19) = 17.31, p < .01$	$F(1,19) = 9.16, p < .01$	N.S.
Group	N.S.	$F(1,19) = 39.50, p < .001$	$F(1,19) = 5.37, p < .05$	$F(1,19) = 27.28, p < .001$
Type x Group	N.S.	N.S.	N.S.	N.S.
ANCOVA – with Verbal IQ				
Type	$F(1,18) = 19.22, p < .001$	$F(1,18) = 18.02, p < .001$	$F(1,18) = 5.39, p < .05$	N.S.
Group	N.S.	$F(1,18) = 33.11, p < .001$	N.S.	$F(1,18) = 19.56, p < .001$
Verbal IQ	N.S.	N.S.	N.S.	N.S.
Type x Group	N.S.	N.S.	N.S.	N.S.
Type x Verbal IQ	N.S.	N.S.	N.S.	N.S.
ANCOVA – with WM				
Type	$F(1,18) = 5.21, p < .05$	$F(1,18) = 7.23, p < .05$	N.S.	N.S.
Group	N.S.	$F(1,18) = 8.03, p < .05$	N.S.	N.S.
Working Memory	N.S.	N.S.	N.S.	N.S.
Type x Group	N.S.	N.S.	N.S.	N.S.
Type x Working Memory	N.S.	N.S.	N.S.	N.S.