Supplementary Material Appendix 3

# R Output

> #dprime, music as categorical variable

> DISdprime.cat <- lmer(DISdprime ~ LanguageBackground \* MusicBackground +(1|Subject) +(1|Tones))

> summary(DISdprime.cat)

Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']

Formula: DISdprime ~ LanguageBackground \* MusicBackground + (1 | Subject) + (1 | Tones)

REML criterion at convergence: 366.5

Scaled residuals:

 Min 1Q Median 3Q Max

-2.48658 -0.61023 0.01007 0.63419 2.61791

Random effects:

 Groups Name Variance Std.Dev.

 Subject (Intercept) 0.1888 0.4345

 Tones (Intercept) 0.2508 0.5008

 Residual 0.2907 0.5392

Number of obs: 186, groups: Subject, 31; Tones, 6

Fixed effects:

 Estimate Std. Error df t value Pr(>|t|)

(Intercept) 3.0356 0.8524 29.7529 3.561 0.00126 \*\*

LanguageBackground -0.9442 0.5462 27.0000 -1.729 0.09526 .

MusicBackground -1.2718 0.5462 27.0000 -2.329 0.02761 \*

LanguageBackground:MusicBackground 0.7930 0.3541 27.0000 2.239 0.03358 \*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:

 (Intr) LnggBc MscBck

LnggBckgrnd -0.917

MuscBckgrnd -0.917 0.886

LnggBckg:MB 0.876 -0.946 -0.946

> mixed(DISdprime ~ MusicBackground\*LanguageBackground + (1|Subject) +(1|Tones), data = lmmdata, method = "LRT")

Numerical variables NOT centered on 0: MusicBackground, LanguageBackground

If in interactions, interpretation of lower order (e.g., main) effects difficult.

REML argument to lmer() set to FALSE for method = 'PB' or 'LRT'

Fitting 4 (g)lmer() models:

[....]

Mixed Model Anova Table (Type 3 tests, LRT-method)

Model: DISdprime ~ MusicBackground \* LanguageBackground + (1 | Subject) +

Model: (1 | Tones)

Data: lmmdata

Df full model: 7

 Effect df Chisq p.value

1 MusicBackground 1 5.52 \* .019

2 LanguageBackground 1 3.17 + .075

3 MusicBackground:LanguageBackground 1 5.14 \* .023

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘+’ 0.1 ‘ ’ 1

> planlangxmusic = emmeans(DISdprime.cat, pairwise ~ LanguageBackground|MusicBackground, adjust = "tukey")

> planmusicxlang = emmeans(DISdprime.cat, pairwise ~ MusicBackground|LanguageBackground, adjust = "tukey")

> summary(planlangxmusic)

$emmeans

MusicBackground = 1:

 LanguageBackground emmean SE df lower.CL upper.CL

 1 1.61 0.256 10.8 1.048 2.18

 2 1.46 0.275 13.7 0.870 2.05

MusicBackground = 2:

 LanguageBackground emmean SE df lower.CL upper.CL

 1 1.13 0.275 13.7 0.542 1.73

 2 1.78 0.275 13.7 1.184 2.37

Degrees-of-freedom method: kenward-roger

Confidence level used: 0.95

$contrasts

MusicBackground = 1:

 contrast estimate SE df t.ratio p.value

 LanguageBackground1 - LanguageBackground2 0.151 0.24 27 0.630 0.5340

MusicBackground = 2:

 contrast estimate SE df t.ratio p.value

 LanguageBackground1 - LanguageBackground2 -0.642 0.26 27 -2.465 0.0204

Degrees-of-freedom method: kenward-roger

> summary(planmusicxlang)

$emmeans

LanguageBackground = 1:

 MusicBackground emmean SE df lower.CL upper.CL

 1 1.61 0.256 10.8 1.048 2.18

 2 1.13 0.275 13.7 0.542 1.73

LanguageBackground = 2:

 MusicBackground emmean SE df lower.CL upper.CL

 1 1.46 0.275 13.7 0.870 2.05

 2 1.78 0.275 13.7 1.184 2.37

Degrees-of-freedom method: kenward-roger

Confidence level used: 0.95

$contrasts

LanguageBackground = 1:

 contrast estimate SE df t.ratio p.value

 MusicBackground1 - MusicBackground2 0.479 0.24 27 1.995 0.0563

LanguageBackground = 2:

 contrast estimate SE df t.ratio p.value

 MusicBackground1 - MusicBackground2 -0.314 0.26 27 -1.207 0.2380

Degrees-of-freedom method: kenward-roger

> #dprime, music as continuous variable

> lmmdata$z\_YrMusic <- scale(lmmdata$MusicYears)

> DISdprime.con <- lmer(DISdprime ~ LanguageBackground \* z\_YrMusic +(1|Subject) +(1|Tones))

> summary(DISdprime.con)

Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']

Formula: DISdprime ~ LanguageBackground \* z\_YrMusic + (1 | Subject) + (1 | Tones)

REML criterion at convergence: 365.3

Scaled residuals:

 Min 1Q Median 3Q Max

-2.47127 -0.62433 0.03482 0.67675 2.59969

Random effects:

 Groups Name Variance Std.Dev.

 Subject (Intercept) 0.1594 0.3993

 Tones (Intercept) 0.2508 0.5008

 Residual 0.2907 0.5392

Number of obs: 186, groups: Subject, 31; Tones, 6

Fixed effects:

 Estimate Std. Error df t value Pr(>|t|)

(Intercept) 1.1886 0.3333 22.2840 3.566 0.00170 \*\*

LanguageBackground 0.1620 0.1745 27.0000 0.928 0.36146

z\_YrMusic 0.8181 0.2587 27.0000 3.162 0.00385 \*\*

LanguageBackground:z\_YrMusic -0.5735 0.1890 27.0000 -3.034 0.00529 \*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:

 (Intr) LnggBc z\_YrMs

LnggBckgrnd -0.746

z\_YrMusic -0.033 -0.058

LnggBck:\_YM -0.042 0.164 -0.943

> mixed(DISdprime ~ z\_YrMusic\*LanguageBackground + (1|Subject) +(1|Tones), data = lmmdata, method = "LRT")

Numerical variables NOT centered on 0: LanguageBackground

If in interactions, interpretation of lower order (e.g., main) effects difficult.

REML argument to lmer() set to FALSE for method = 'PB' or 'LRT'

Fitting 4 (g)lmer() models:

[....]

Mixed Model Anova Table (Type 3 tests, LRT-method)

Model: DISdprime ~ z\_YrMusic \* LanguageBackground + (1 | Subject) +

Model: (1 | Tones)

Data: lmmdata

Df full model: 7

 Effect df Chisq p.value

1 z\_YrMusic 1 9.50 \*\* .002

2 LanguageBackground 1 0.95 .330

3 z\_YrMusic:LanguageBackground 1 8.85 \*\* .003

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘+’ 0.1 ‘ ’ 1

> detach(lmmdata)

>

> #examining effect of years of musical training on dprime in each of the two tone language background groups

> lmmdata\_2tone <- lmmdata[which(lmmdata$LanguageBackground==2),]

> lmmdata\_1tone <- lmmdata[which(lmmdata$LanguageBackground==1),]

> lmmdata\_2tone$z\_YrMusic <- scale(lmmdata\_2tone$MusicYears)

> lmmdata\_1tone$z\_YrMusic <- scale(lmmdata\_1tone$MusicYears)

> attach(lmmdata\_1tone)

> DISdprime.1tone <- lmer(DISdprime ~ z\_YrMusic +(1|Subject) +(1|Tones))

> summary(DISdprime.1tone)

Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']

Formula: DISdprime ~ z\_YrMusic + (1 | Subject) + (1 | Tones)

REML criterion at convergence: 212.2

Scaled residuals:

 Min 1Q Median 3Q Max

-2.2679 -0.6543 -0.1020 0.5928 2.5731

Random effects:

 Groups Name Variance Std.Dev.

 Subject (Intercept) 0.1345 0.3667

 Tones (Intercept) 0.2040 0.4516

 Residual 0.3271 0.5719

Number of obs: 102, groups: Subject, 17; Tones, 6

Fixed effects:

 Estimate Std. Error df t value Pr(>|t|)

(Intercept) 1.4154 0.2124 7.1363 6.664 0.000264 \*\*\*

z\_YrMusic 0.2665 0.1060 15.0000 2.515 0.023780 \*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:

 (Intr)

z\_YrMusic 0.000

> detach(lmmdata\_1tone)

> attach(lmmdata\_2tone)

> DISdprime.2tone <- lmer(DISdprime ~ z\_YrMusic +(1|Subject) +(1|Tones))

> summary(DISdprime.2tone)

Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']

Formula: DISdprime ~ z\_YrMusic + (1 | Subject) + (1 | Tones)

REML criterion at convergence: 165.1

Scaled residuals:

 Min 1Q Median 3Q Max

-1.9112 -0.6757 0.1650 0.6956 1.9666

Random effects:

 Groups Name Variance Std.Dev.

 Subject (Intercept) 0.1884 0.4340

 Tones (Intercept) 0.2953 0.5434

 Residual 0.2591 0.5090

Number of obs: 84, groups: Subject, 14; Tones, 6

Fixed effects:

 Estimate Std. Error df t value Pr(>|t|)

(Intercept) 1.6184 0.2564 7.5853 6.312 0.000287 \*\*\*

z\_YrMusic -0.2533 0.1294 11.9999 -1.958 0.073856 .

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:

 (Intr)

z\_YrMusic 0.000

> detach(lmmdata\_2tone)

> #imitation accuracy, music as categorical variable

> IMacc.cat <- lmer(IMacc ~ LanguageBackground \* MusicBackground +(1|Subject) +(1|Tones), data = lmmdata)

> summary(IMacc.cat)

Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']

Formula: IMacc ~ LanguageBackground \* MusicBackground + (1 | Subject) + (1 | Tones)

 Data: lmmdata

REML criterion at convergence: 1692

Scaled residuals:

 Min 1Q Median 3Q Max

-2.6777 -0.7594 0.1159 0.7433 2.0227

Random effects:

 Groups Name Variance Std.Dev.

 Subject (Intercept) 4.278 2.068

 Tones (Intercept) 327.807 18.105

 Residual 536.773 23.168

Number of obs: 186, groups: Subject, 31; Tones, 6

Fixed effects:

 Estimate Std. Error df t value Pr(>|t|)

(Intercept) 50.5952 18.0317 31.3502 2.806 0.00855 \*\*

LanguageBackground 8.0357 10.8556 26.9978 0.740 0.46555

MusicBackground -0.2976 10.8556 26.9978 -0.027 0.97833

LanguageBackground:MusicBackground -2.0833 7.0391 26.9978 -0.296 0.76952

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:

 (Intr) LnggBc MscBck

LnggBckgrnd -0.862

MuscBckgrnd -0.862 0.886

LnggBckg:MB 0.823 -0.946 -0.946

> mixed(IMacc ~ MusicBackground\*LanguageBackground + (1|Subject) +(1|Tones), data = lmmdata, method = "LRT")

Numerical variables NOT centered on 0: MusicBackground, LanguageBackground

If in interactions, interpretation of lower order (e.g., main) effects difficult.

REML argument to lmer() set to FALSE for method = 'PB' or 'LRT'

Fitting 4 (g)lmer() models:

[boundary (singular) fit: see help('isSingular')

.boundary (singular) fit: see help('isSingular')

.boundary (singular) fit: see help('isSingular')

.boundary (singular) fit: see help('isSingular')

.]

Mixed Model Anova Table (Type 3 tests, LRT-method)

Model: IMacc ~ MusicBackground \* LanguageBackground + (1 | Subject) +

Model: (1 | Tones)

Data: lmmdata

Df full model: 7

 Effect df Chisq p.value

1 MusicBackground 1 0.00 .978

2 LanguageBackground 1 0.58 .447

3 MusicBackground:LanguageBackground 1 0.09 .761

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘+’ 0.1 ‘ ’ 1

Warning messages:

1: lme4 reported (at least) the following warnings for 'full':

 \* boundary (singular) fit: see help('isSingular')

2: lme4 reported (at least) the following warnings for 'MusicBackground':

 \* boundary (singular) fit: see help('isSingular')

3: lme4 reported (at least) the following warnings for 'LanguageBackground':

 \* boundary (singular) fit: see help('isSingular')

4: lme4 reported (at least) the following warnings for 'MusicBackground:LanguageBackground':

 \* boundary (singular) fit: see help('isSingular')

> #original model resulted in singular fit, Subject-intercept was removed.

> mixed(IMacc ~ MusicBackground\*LanguageBackground + (1|Tones), data = lmmdata, method = "LRT")

Numerical variables NOT centered on 0: MusicBackground, LanguageBackground

If in interactions, interpretation of lower order (e.g., main) effects difficult.

REML argument to lmer() set to FALSE for method = 'PB' or 'LRT'

Fitting 4 (g)lmer() models:

[....]

Mixed Model Anova Table (Type 3 tests, LRT-method)

Model: IMacc ~ MusicBackground \* LanguageBackground + (1 | Tones)

Data: lmmdata

Df full model: 6

 Effect df Chisq p.value

1 MusicBackground 1 0.00 .978

2 LanguageBackground 1 0.58 .447

3 MusicBackground:LanguageBackground 1 0.09 .761

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘+’ 0.1 ‘ ’ 1

> #imitation accuracy, music as continuous variable

> IMacc.con <- lmer(IMacc ~ LanguageBackground \* z\_YrMusic +(1|Subject) +(1|Tones), data = lmmdata)

> summary(IMacc.con)

Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']

Formula: IMacc ~ LanguageBackground \* z\_YrMusic + (1 | Subject) + (1 | Tones)

 Data: lmmdata

REML criterion at convergence: 1694.1

Scaled residuals:

 Min 1Q Median 3Q Max

-2.6363 -0.7253 0.1630 0.7380 1.9749

Random effects:

 Groups Name Variance Std.Dev.

 Subject (Intercept) 3.163 1.778

 Tones (Intercept) 327.779 18.105

 Residual 536.769 23.168

Number of obs: 186, groups: Subject, 31; Tones, 6

Fixed effects:

 Estimate Std. Error df t value Pr(>|t|)

(Intercept) 48.8198 9.2474 10.4935 5.279 0.000305 \*\*\*

LanguageBackground 5.8675 3.6825 27.0164 1.593 0.122722

z\_YrMusic 2.5773 5.4617 27.0164 0.472 0.640800

LanguageBackground:z\_YrMusic -0.3813 3.9901 27.0164 -0.096 0.924575

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:

 (Intr) LnggBc z\_YrMs

LnggBckgrnd -0.568

z\_YrMusic -0.025 -0.058

LnggBck:\_YM -0.032 0.164 -0.943

> mixed(IMacc ~ z\_YrMusic\*LanguageBackground + (1|Subject) +(1|Tones), data = lmmdata, method = "LRT")

Numerical variables NOT centered on 0: LanguageBackground

If in interactions, interpretation of lower order (e.g., main) effects difficult.

REML argument to lmer() set to FALSE for method = 'PB' or 'LRT'

Fitting 4 (g)lmer() models:

[boundary (singular) fit: see help('isSingular')

.boundary (singular) fit: see help('isSingular')

..boundary (singular) fit: see help('isSingular')

.]

Mixed Model Anova Table (Type 3 tests, LRT-method)

Model: IMacc ~ z\_YrMusic \* LanguageBackground + (1 | Subject) + (1 |

Model: Tones)

Data: lmmdata

Df full model: 7

 Effect df Chisq p.value

1 z\_YrMusic 1 0.23 .629

2 LanguageBackground 1 2.64 .104

3 z\_YrMusic:LanguageBackground 1 0.01 .922

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘+’ 0.1 ‘ ’ 1

Warning messages:

1: lme4 reported (at least) the following warnings for 'full':

 \* boundary (singular) fit: see help('isSingular')

2: lme4 reported (at least) the following warnings for 'z\_YrMusic':

 \* boundary (singular) fit: see help('isSingular')

3: lme4 reported (at least) the following warnings for 'z\_YrMusic:LanguageBackground':

 \* boundary (singular) fit: see help('isSingular')

> #original model resulted in singular fit, Subject-intercept was removed.

> mixed(IMacc ~ z\_YrMusic\*LanguageBackground + (1|Tones), data = lmmdata, method = "LRT")

Numerical variables NOT centered on 0: LanguageBackground

If in interactions, interpretation of lower order (e.g., main) effects difficult.

REML argument to lmer() set to FALSE for method = 'PB' or 'LRT'

Fitting 4 (g)lmer() models:

[....]

Mixed Model Anova Table (Type 3 tests, LRT-method)

Model: IMacc ~ z\_YrMusic \* LanguageBackground + (1 | Tones)

Data: lmmdata

Df full model: 6

 Effect df Chisq p.value

1 z\_YrMusic 1 0.23 .629

2 LanguageBackground 1 2.64 .104

3 z\_YrMusic:LanguageBackground 1 0.01 .922

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘+’ 0.1 ‘ ’ 1