

# What you see depends on what you hear

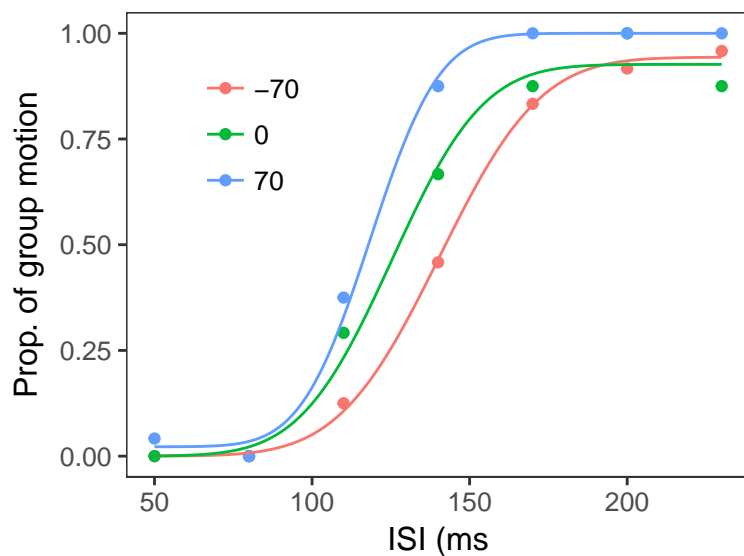
Temporal rate averaging and crossmodal integration

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## Experiment 1 - Regular auditory sequence and Visual Ternus apparent motion (TAM)

Estimate TAM transitional thresholds with quickpsy.

## Warning: package 'bindrcpp' was built under R version 3.4.4



- Mean PSEs

mIntv	mpse
-70	145.5821
0	131.3481
70	126.0138

- ANOVAs and posthoc analysis

```
##          numDF denDF  F-value p-value
## (Intercept)      1   40 845.8236 <.0001
## mIntv            2   40  12.1924 1e-04
##
```

	Effect	DFn	DFd	F	p	p<.05	ges
2	mIntv	2	40	12.19245	7.34e-05	*	0.1124435
	Effect	W	p	p<.05			
	2 mIntv	0.7224581	0.0455744	*			
	Effect	GGe	p[GG]	p[GG]<.05	HFe	p[HF]	p[HF]<.05
2	mIntv	0.7827532	0.0003247	*	0.8374419	0.0002231	*

```

## Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: lme.formula(fixed = thre ~ mIntv, data = exp1$thresholds, random = ~1 |
##      sub)
##
## Linear Hypotheses:
##           Estimate Std. Error z value Pr(>|z|)
## 0 - -70 == 0    -14.234      4.097  -3.474  0.00154 **
## 70 - -70 == 0    -19.568      4.097  -4.776 5.36e-06 ***
## 70 - 0 == 0      -5.334      4.097  -1.302  0.57878
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- bonferroni method)

• Mean JNDs and statistical summary:

## # A tibble: 3 x 3
##   mIntv msig    se
##   <fct> <dbl> <dbl>
## 1 -70    34.9  3.09
## 2 0      30.5  3.38
## 3 70     28.4  2.87

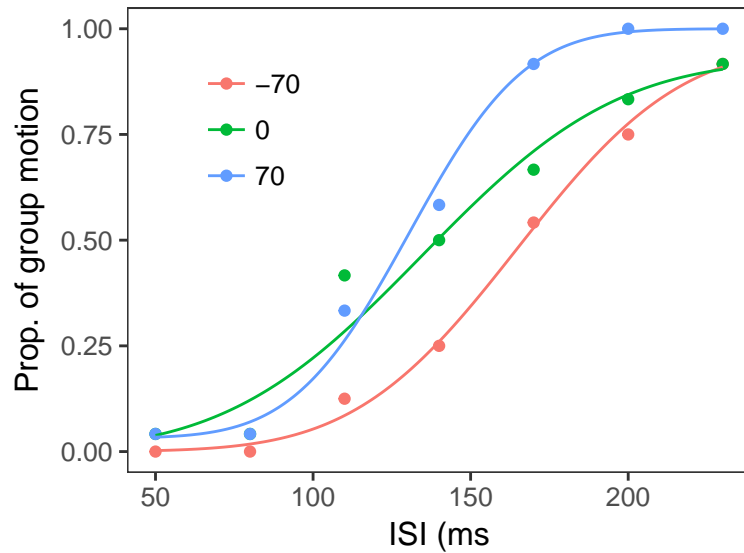
##           numDF denDF   F-value p-value
## (Intercept)     1    40 173.83689 <.0001
## mIntv           2    40  1.77938  0.1818

##
## Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: lme.formula(fixed = par ~ mIntv, data = exp1$par %>% filter(parn ==
##      "p2"), random = ~1 | sub)
##
## Linear Hypotheses:
##           Estimate Std. Error z value Pr(>|z|)
## 0 - -70 == 0     -4.405      3.520  -1.251  0.632
## 70 - -70 == 0     -6.505      3.520  -1.848  0.194
## 70 - 0 == 0      -2.101      3.520  -0.597  1.000
## (Adjusted p values reported -- bonferroni method)

```

## Experiment 2: With irregular auditory sequences

- A typical example from Experiment 2.



- Statistics and tests:

```
## # A tibble: 3 x 2
##   mIntv mpse
##   <fct> <dbl>
## 1 -70    149.
## 2 0      139.
## 3 70     135.

## $ANOVA
##   Effect DFn DFd      F      p p<.05      ges
## 2 mIntv   2  42 8.253778 0.0009479469 * 0.04090912
##
## $`Mauchly's Test for Sphericity`
##   Effect      W      p p<.05
## 2 mIntv 0.3797738 6.240934e-05 *
##
## $`Sphericity Corrections`
##   Effect      GGe      p[GG] p[GG]<.05      HFe      p[HF] p[HF]<.05
## 2 mIntv 0.6171978 0.005335022 * 0.6363757 0.004889236 *
##
##           numDF denDF  F-value p-value
## (Intercept)      1    42 547.0951 <.0001
## mIntv           2    42   8.2538 9e-04

##
## Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: lme.formula(fixed = thre ~ mIntv, data = exp2$thresholds, random = ~1 |
##   sub)
##
## Linear Hypotheses:
##           Estimate Std. Error z value Pr(>|z|)
## 0 - -70 == 0   -10.247      3.644  -2.812 0.014784 *
## 70 - -70 == 0   -14.380      3.644  -3.946 0.000239 ***
```

```
## 70 - 0 == 0      -4.133      3.644 -1.134 0.770254
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- bonferroni method)

## # A tibble: 3 x 3
##   mIntv msig    se
##   <fct> <dbl> <dbl>
## 1 -70    31.8  3.18
## 2  0     30.6  2.32
## 3  70     27.2  2.23

##           numDF denDF   F-value p-value
## (Intercept)      1    42 213.24299 <.0001
## mIntv           2    42   1.41712  0.2538

##
## Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: lme.formula(fixed = par ~ mIntv, data = exp2$par %>% filter(parn ==
## "p2"), random = ~1 | sub)
##
## Linear Hypotheses:
##           Estimate Std. Error z value Pr(>|z|)
## 0 - -70 == 0      -1.190      2.815  -0.423   1.000
## 70 - -70 == 0     -4.568      2.815  -1.623   0.314
## 70 - 0 == 0       -3.378      2.815  -1.200   0.690
## (Adjusted p values reported -- bonferroni method)
```

- Figure 2 with combination of Experiments 1 and 2, mean PSEs and typical psychometric curves.

### Experiment 3: Variance manipulation

- Plot mean results of PSEs as functions of variances and mean auditory intervals.

```
## $ANOVA
##      Effect DFn DFd      F      p p<.05      ges
## 2      var   1  15  5.2922997 0.0361893151 * 0.0043577583
## 3     mIntv   2  30 11.8064403 0.0001651132 * 0.0781513459
## 4 var:mIntv   2  30  0.3141222 0.7328030189 0.0008452636
##
## $`Mauchly's Test for Sphericity`
##      Effect      W      p p<.05
## 3     mIntv 0.4713005 0.005165177 *
## 4 var:mIntv 0.9190371 0.553772324
##
## $`Sphericity Corrections`
##      Effect      GGe      p[GG] p[GG]<.05      HFe      p[HF] p[HF]<.05
## 3     mIntv 0.6541508 0.001400474 * 0.691398 0.001110571 *
## 4 var:mIntv 0.9251011 0.716300027 1.049569 0.732803019
```

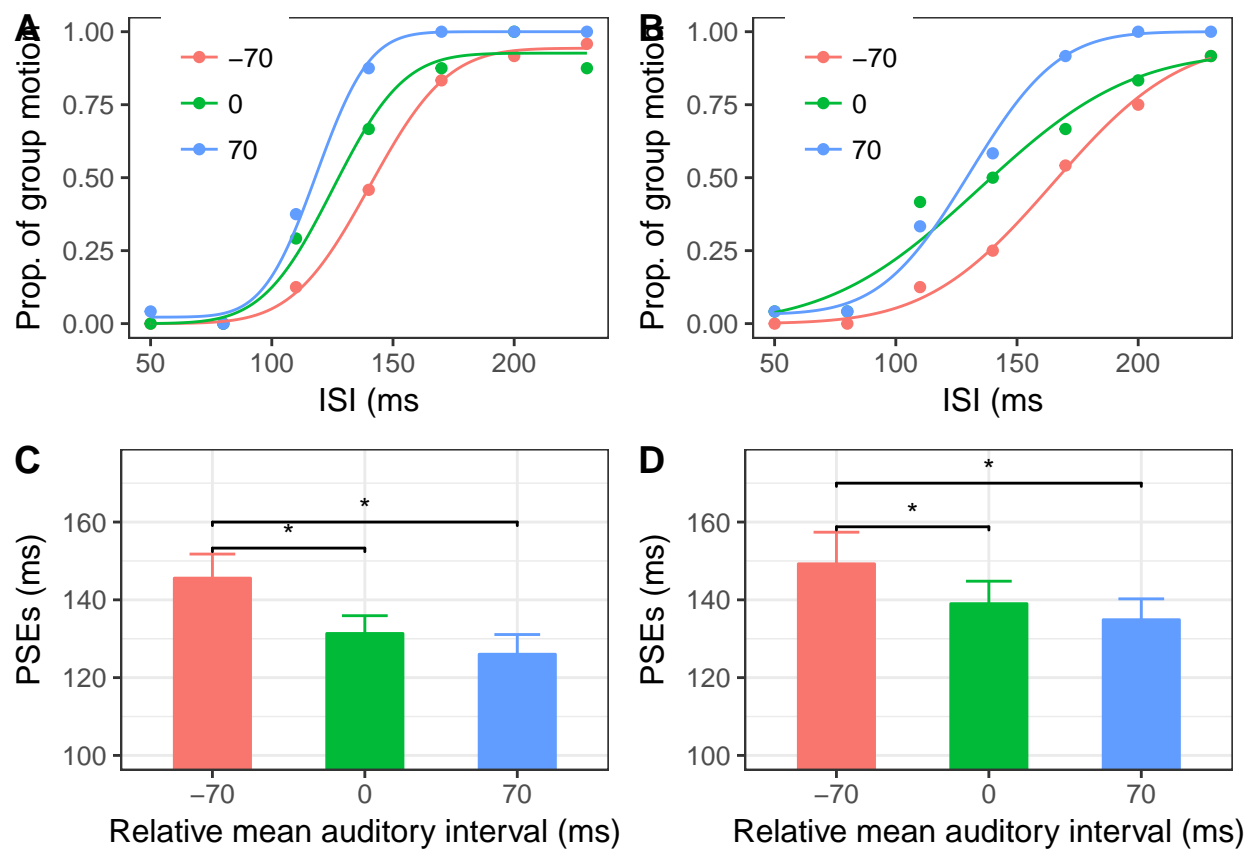
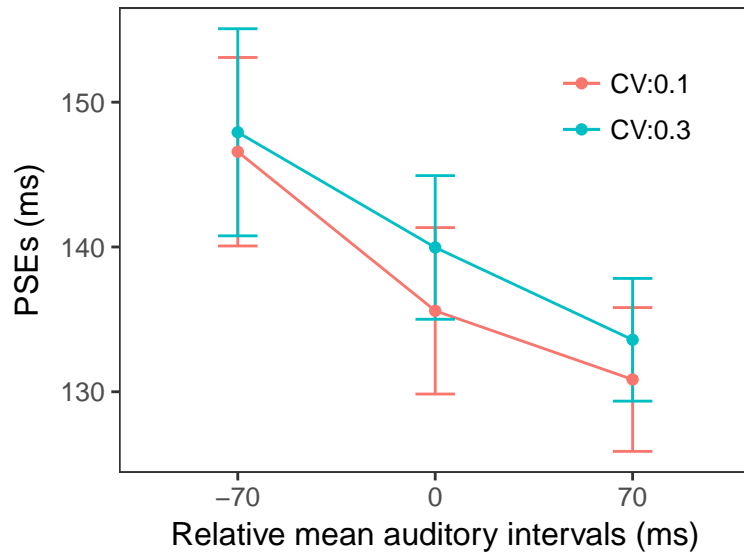


Figure 1: Typical examples and mean PSEs from Exp. 1 and 2



- Statistical tests:

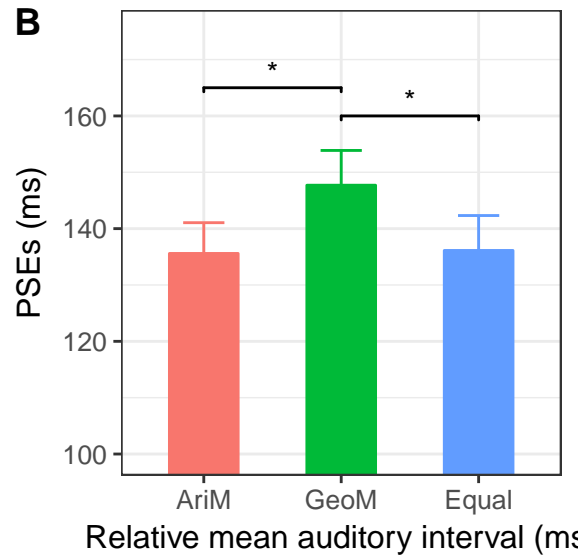
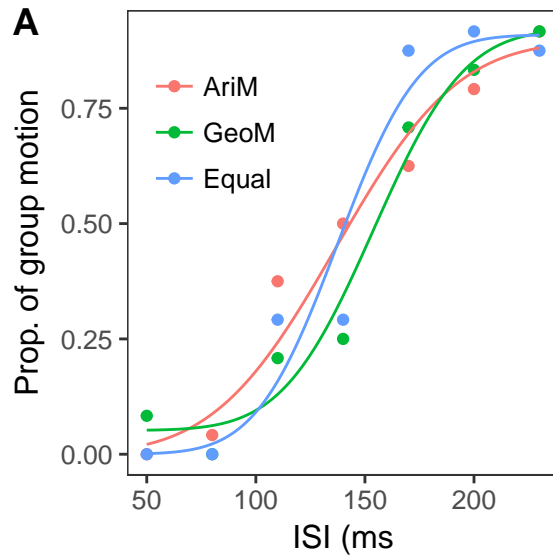
```
##          numDF denDF  F-value p-value
## (Intercept)      1    75 760.9257 <.0001
## mIntv           2    75  19.8063 <.0001
## var             1    75   2.0451 0.1568
## mIntv:var        2    75   0.1976 0.8211

## Warning in mcp2matrix(model, linfct = linfct): covariate interactions found
## -- default contrast might be inappropriate

##
## Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: lme.formula(fixed = thre ~ mIntv * var, data = exp3$thresholds,
##       random = ~1 | sub)
##
## Linear Hypotheses:
##           Estimate Std. Error z value Pr(>|z|)
## 0 - -70 == 0  -10.989      3.415  -3.217 0.00388 **
## 70 - -70 == 0  -15.731      3.415  -4.606 1.23e-05 ***
## 70 - 0 == 0    -4.743      3.415  -1.389 0.49490
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- bonferroni method)
```

## Experiment 4: Geometric vs. Arithmetic mean

- Estimate thresholds and show a typical example.
- Figure 4



- Statistical tests

```
# plot means and ANOVA analysis
exp4$thresholds %>% group_by( mIntv) %>% summarise(mpse = mean(thre), se = sd(thre)/sqrt(nlevels(sub))-
exp4$thresholds %>% ezANOVA(data = ., dv = thre, wid = sub, within = .( mIntv))
```

```
## $ANOVA
##   Effect DFn DFd      F      p p<.05      ges
## 2 mIntv   2  22 8.80723 0.001549738 * 0.08038994
##
## $`Mauchly's Test for Sphericity`
##   Effect      W      p p<.05
## 2 mIntv 0.8116804 0.3523102
##
## $`Sphericity Corrections`
##   Effect      GGe      p[GG] p[GG]<.05      HFe      p[HF] p[HF]<.05
## 2 mIntv 0.8415244 0.003006332 * 0.9765312 0.001708956 *
```

```
# posthoc analysis
lme_exp4 = lme(thre ~ mIntv, data = exp4$thresholds, random = ~1|sub)
anova(lme_exp4)
```

```
##           numDF denDF F-value p-value
## (Intercept)      1    22 675.7265 <.0001
## mIntv            2    22  8.8072 0.0015
```

```
summary(glht(lme_exp4, linfct = mcp(mIntv = 'Tukey')), test = adjusted(type = 'bonferroni'))
```

```
##
## Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: lme.formula(fixed = thre ~ mIntv, data = exp4$thresholds, random = ~1 |
## sub)
##
## Linear Hypotheses:
```

```
##               Estimate Std. Error z value Pr(>|z|)
## GeoM - AriM == 0   12.1096     3.2613   3.713 0.000614 ***
## Equal - AriM == 0    0.5295     3.2613   0.162 1.000000
## Equal - GeoM == 0 -11.5801     3.2613  -3.551 0.001152 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- bonferroni method)
```

## Bayesian modeling of audiovisual integration

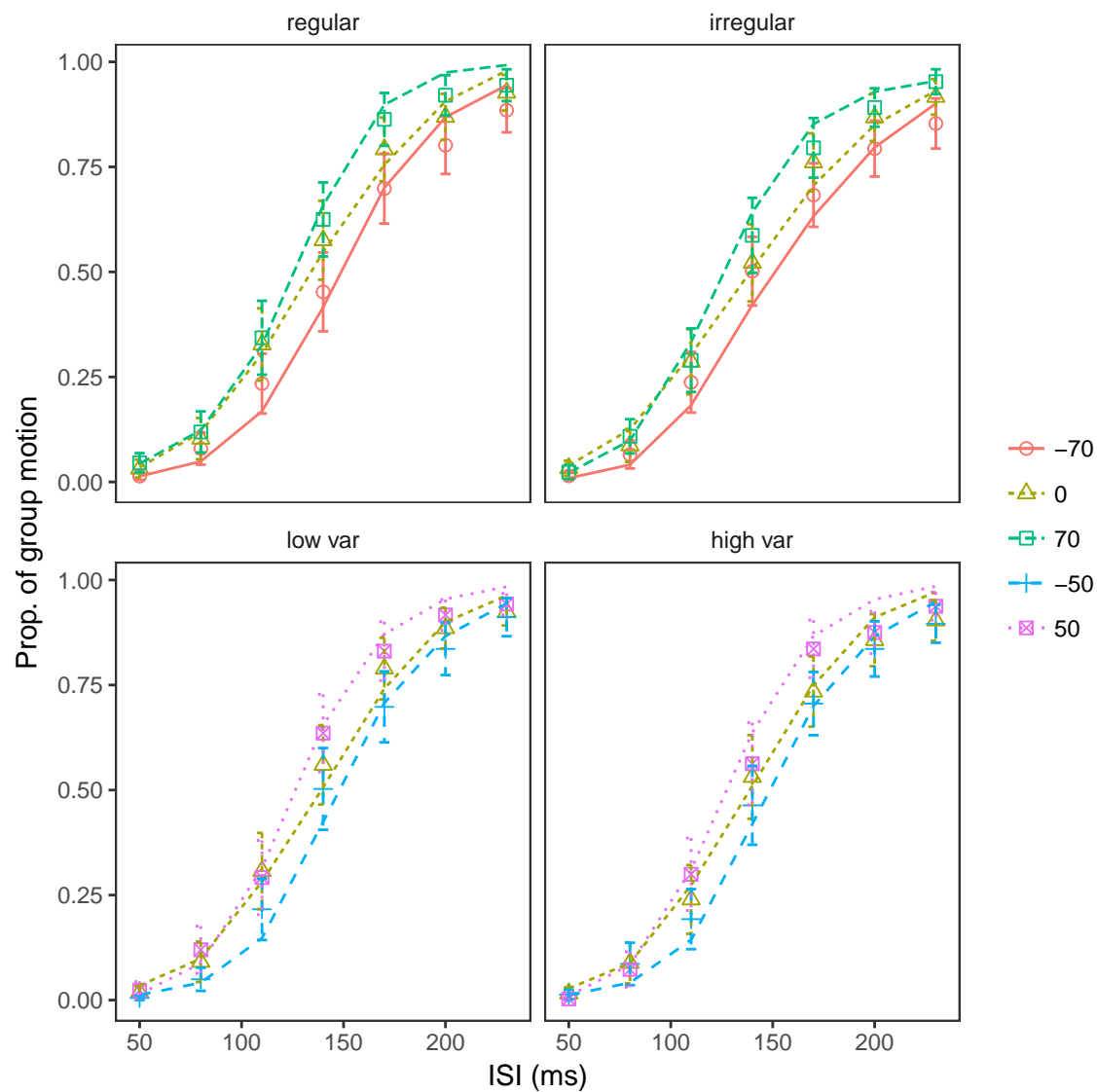
The detailed model is described in the main text of the paper (see also some comments in `ana_functions.R`).

- Comparison among partial and full models:

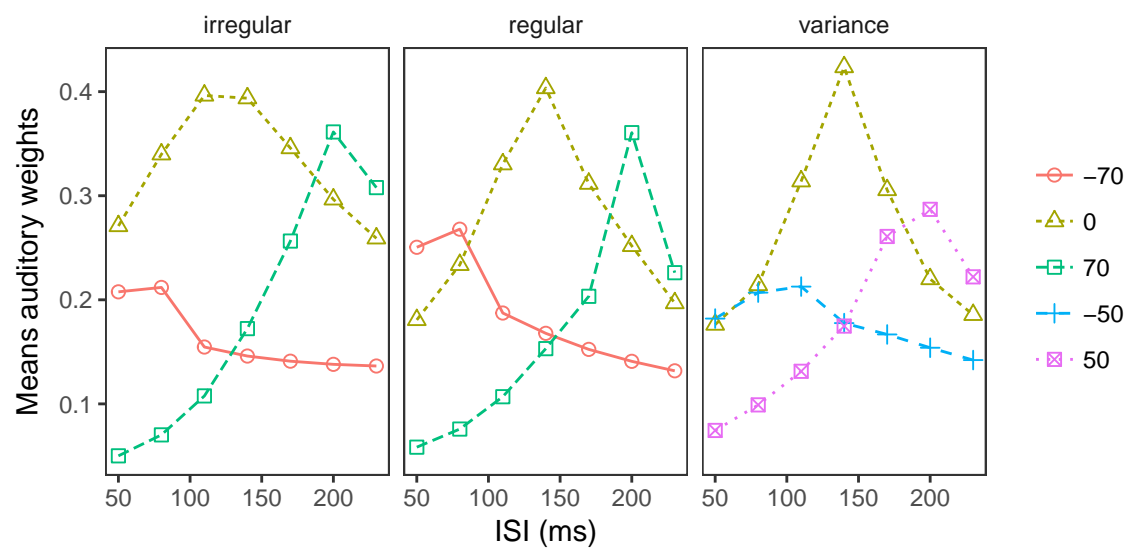
Exp.	BIC P.I.	R2 P.I.	BIC F.I.	R2 F.I.	BIC Diff.
irregular	-1858.71	0.86	-1391.84	0.63	466.87
regular	-1932.10	0.91	-1771.83	0.88	160.26
variance	-2894.25	0.91	-2877.68	0.91	16.57

- Predicted average responses versus empirical results.





- Plot mean weights



- Show predicted vs. behavioral results.

```
##
## Call:
## lm(formula = ppse ~ pse - 1, data = .)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -54.562  -7.385  -0.607   8.581  85.273
##
## Coefficients:
##      Estimate Std. Error t value Pr(>|t|)
## pse 1.007837   0.008801   114.5  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 18.62 on 227 degrees of freedom
## Multiple R-squared:  0.983, Adjusted R-squared:  0.9829
## F-statistic: 1.311e+04 on 1 and 227 DF,  p-value: < 2.2e-16
```

