

Emotion Inertia Analysis

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0.1 Descriptive statistics

```
feelings_initial <- load("feelings_initial.RData")
ls()
```

```
## [1] "dat"                "feelings_initial" "Iaro_wide"        "Ineg_wide"
## [5] "Ipos_wide"
```

```
summary(feelings_initial)
```

```
##      Length      Class      Mode
##      4 character character
```

```
str(dat)
```

```
## 'data.frame':    16380 obs. of  9 variables:
## $ subj      : Factor w/ 156 levels "f001","f002",...: 1 1 1 1 1 1 1 1 1 1 ...
## $ trial.num: int   1 2 3 4 5 6 7 8 9 10 ...
## $ trial.val: Factor w/ 3 levels "neg","neu","pos": 3 1 1 3 3 2 2 1 1 3 ...
## $ sex       : Factor w/ 3 levels "male","female",...: 2 2 2 2 2 2 2 2 2 2 ...
## $ age       : int   19 19 19 19 19 19 19 19 19 19 ...
## $ ethn      : Factor w/ 7 levels "Asian or Pacific Islander",...: 1 1 1 1 1 1 1 1 1 1 ...
## $ Ineg      : num   1 4 2 1 1 1 1 3 5 1 ...
## $ Ipos      : num   3.69 1 1 1 4 ...
## $ Iaro      : num   2.86 3 2 2 3 ...
```

```
library(dplyr)
```

```
##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##   filter, lag

## The following objects are masked from 'package:base':
##
##   intersect, setdiff, setequal, union
```

```
participant_info <- dat %>% distinct(subj, age, sex, ethn)
participant_info
```

```
##      subj age    sex                                ethn
## 1   f001  19 female                    Asian or Pacific Islander
## 2   f002  25 female                    Black/African American
```

## 3	f003	19 female	Asian or Pacific Islander
## 4	f004	19 female	Black/African American
## 5	f005	20 female	Latino/Hispanic
## 6	f006	21 female	White/Caucasian
## 7	f007	20 female	Other
## 8	f008	23 female	White/Caucasian
## 9	f009	19 female	Asian or Pacific Islander
## 10	f010	24 female	Latino/Hispanic
## 11	f011	26 female	White/Caucasian
## 12	f012	19 female	White/Caucasian
## 13	f013	24 female	Asian or Pacific Islander
## 14	f015	19 female	Other
## 15	f016	29 female	White/Caucasian
## 16	f019	26 female	Asian or Pacific Islander
## 17	f020	20 female	Black/African American
## 18	f021	18 female	White/Caucasian
## 19	f022	18 female	White/Caucasian
## 20	f023	20 female	White/Caucasian
## 21	f024	19 other	White/Caucasian
## 22	f025	22 female	White/Caucasian
## 23	f026	18 female	Asian or Pacific Islander
## 24	f027	18 female	Asian or Pacific Islander
## 25	f028	18 female	White/Caucasian
## 26	f029	18 female	White/Caucasian
## 27	f030	18 female	Other
## 28	f031	18 female	Asian or Pacific Islander
## 29	f032	23 female	White/Caucasian
## 30	f034	21 female	Asian or Pacific Islander
## 31	f035	21 female	White/Caucasian
## 32	f037	20 female	Latino/Hispanic
## 33	f038	19 female	White/Caucasian
## 34	f039	19 female	Asian or Pacific Islander
## 35	f040	19 female American Indian/Native	American or Alaskan Native
## 36	f041	18 female	Asian or Pacific Islander
## 37	f045	22 female	White/Caucasian
## 38	f046	18 female	Black/African American
## 39	f047	24 female	White/Caucasian
## 40	f048	24 female	White/Caucasian
## 41	f049	19 female	Asian or Pacific Islander
## 42	f052	19 female	Asian or Pacific Islander
## 43	f053	18 female	Other
## 44	f054	21 female	White/Caucasian
## 45	f055	18 female	Asian or Pacific Islander
## 46	f056	19 female	Asian or Pacific Islander
## 47	f057	30 female	White/Caucasian
## 48	f060	26 female	White/Caucasian
## 49	f063	19 female	White/Caucasian
## 50	f064	19 female	Asian or Pacific Islander

## 51	f066	27	female	White/Caucasian
## 52	f067	27	female	Asian or Pacific Islander
## 53	f069	19	female	Other
## 54	f070	18	female	White/Caucasian
## 55	f071	21	female	White/Caucasian
## 56	f072	23	female	White/Caucasian
## 57	f073	21	female	Black/African American
## 58	f074	27	female	Latino/Hispanic
## 59	f075	19	female	Asian or Pacific Islander
## 60	f076	21	female	White/Caucasian
## 61	f077	19	female	White/Caucasian
## 62	f078	22	female	Other
## 63	f080	21	female	White/Caucasian
## 64	f081	19	female	Latino/Hispanic
## 65	f082	18	female	White/Caucasian
## 66	f083	22	female	Asian or Pacific Islander
## 67	f085	19	female	Asian or Pacific Islander
## 68	f086	24	female	White/Caucasian
## 69	f088	24	female	White/Caucasian
## 70	f089	20	female	White/Caucasian
## 71	f090	19	female	White/Caucasian
## 72	f092	18	female	White/Caucasian
## 73	f093	19	female	White/Caucasian
## 74	f094	18	female	Black/African American
## 75	f096	18	female	Asian or Pacific Islander
## 76	f098	19	female	White/Caucasian
## 77	f102	19	female	Black/African American
## 78	f103	18	female	Latino/Hispanic
## 79	f104	19	female	White/Caucasian
## 80	f105	18	female	White/Caucasian
## 81	f910	20	female	Latino/Hispanic
## 82	f911	21	female	Asian or Pacific Islander
## 83	f912	22	female	White/Caucasian
## 84	f915	27	female	Latino/Hispanic
## 85	m002	27	male	White/Caucasian
## 86	m003	22	male	Latino/Hispanic
## 87	m004	19	male	Asian or Pacific Islander
## 88	m005	25	male	White/Caucasian
## 89	m006	23	male	White/Caucasian
## 90	m007	27	male	Black/African American
## 91	m008	19	male	Asian or Pacific Islander
## 92	m009	20	male	Latino/Hispanic
## 93	m010	21	male	American Indian/Native American or Alaskan Native
## 94	m011	20	male	White/Caucasian
## 95	m012	18	male	American Indian/Native American or Alaskan Native
## 96	m013	18	male	White/Caucasian
## 97	m015	20	male	Other
## 98	m016	25	male	Black/African American

## 99	m019	21	male	Latino/Hispanic
## 100	m020	19	male	Latino/Hispanic
## 101	m021	19	male	White/Caucasian
## 102	m022	26	male	White/Caucasian
## 103	m023	22	male	White/Caucasian
## 104	m024	23	male	White/Caucasian
## 105	m025	18	male	White/Caucasian
## 106	m026	23	male	Latino/Hispanic
## 107	m027	26	male	Black/African American
## 108	m028	22	male	Black/African American
## 109	m029	19	male	White/Caucasian
## 110	m032	19	male	American Indian/Native American or Alaskan Native
## 111	m033	24	male	Latino/Hispanic
## 112	m035	19	male	White/Caucasian
## 113	m037	23	male	White/Caucasian
## 114	m040	26	male	White/Caucasian
## 115	m042	21	male	White/Caucasian
## 116	m043	23	male	Asian or Pacific Islander
## 117	m044	19	male	Asian or Pacific Islander
## 118	m045	26	male	Other
## 119	m047	24	male	White/Caucasian
## 120	m048	22	male	Decline to state
## 121	m049	25	male	White/Caucasian
## 122	m050	23	male	White/Caucasian
## 123	m051	19	male	Asian or Pacific Islander
## 124	m053	20	male	White/Caucasian
## 125	m055	19	male	Asian or Pacific Islander
## 126	m056	29	male	Latino/Hispanic
## 127	m057	18	male	White/Caucasian
## 128	m058	18	male	White/Caucasian
## 129	m059	19	male	Decline to state
## 130	m060	27	male	Latino/Hispanic
## 131	m061	18	male	Asian or Pacific Islander
## 132	m063	22	male	White/Caucasian
## 133	m064	18	male	White/Caucasian
## 134	m065	20	male	White/Caucasian
## 135	m066	19	male	White/Caucasian
## 136	m068	22	male	White/Caucasian
## 137	m069	18	male	White/Caucasian
## 138	m070	20	male	White/Caucasian
## 139	m071	19	male	Asian or Pacific Islander
## 140	m072	19	male	White/Caucasian
## 141	m073	23	male	Black/African American
## 142	m074	18	male	Asian or Pacific Islander
## 143	m075	18	male	White/Caucasian
## 144	m077	18	male	White/Caucasian
## 145	m078	18	male	Asian or Pacific Islander
## 146	m080	18	male	White/Caucasian

```
## 147 m083 19 male White/Caucasian
## 148 m084 18 male White/Caucasian
## 149 m085 18 male Black/African American
## 150 m086 18 male Asian or Pacific Islander
## 151 m087 19 male White/Caucasian
## 152 m088 18 male White/Caucasian
## 153 m089 19 male Black/African American
## 154 m090 20 male White/Caucasian
## 155 m091 23 male Asian or Pacific Islander
## 156 m907 24 male White/Caucasian
```

```
mean_age <- mean(participant_info$age, na.rm = TRUE)
cat("Mean age:", mean_age, "\n")
```

```
## Mean age: 20.82051
```

```
sd_age <- sd(participant_info$age, na.rm = TRUE)
cat("SD of age:", sd_age, "\n")
```

```
## SD of age: 2.936944
```

```
female_prop <- mean(participant_info$sex == "female", na.rm = TRUE)
cat("Proportion of female participants:", female_prop)
```

```
## Proportion of female participants: 0.5320513
```

```
summary(dat[, c("Ineg", "Ipos", "Iaro")])
```

```
##      Ineg      Ipos      Iaro
##  Min.   :1.000  Min.   :1.000  Min.   :1.000
## 1st Qu.:1.000  1st Qu.:1.000  1st Qu.:1.000
##  Median :2.000  Median :2.000  Median :3.000
##   Mean   :3.075   Mean   :3.066   Mean   :3.265
## 3rd Qu.:5.000  3rd Qu.:5.000  3rd Qu.:5.000
##   Max.   :9.000   Max.   :9.000   Max.   :9.000
```

- Mean score of Iaro is higher than the other two

```
# identify NAs
colSums(is.na(dat))
```

```
##      subj trial.num trial.val      sex      age      ethn      Ineg      Ipos
##         0         0         0         0         0         0         0         0
##      Iaro
##         0
```

There are no NAs in the dataset.

```
# identify outliers using z-score

# Calculate Z-scores for Ineg, Ipos, and Iaro
dat$z_Ineg <- scale(dat$Ineg)
dat$z_Ipos <- scale(dat$Ipos)
dat$z_Iaro <- scale(dat$Iaro)

# Identify outliers (Z-score > 3 or < -3)
outliers_Ineg <- dat[abs(dat$z_Ineg) > 3, ]
outliers_Ineg
```

```
## [1] subj      trial.num trial.val sex      age      ethn      Ineg
## [8] Ipos      Iaro      z_Ineg   z_Ipos   z_Iaro
## <0 rows> (or 0-length row.names)
```

```
outliers_Ipos <- dat[abs(dat$z_Ipos) > 3, ]
outliers_Ipos
```

```
## [1] subj      trial.num trial.val sex      age      ethn      Ineg
## [8] Ipos      Iaro      z_Ineg   z_Ipos   z_Iaro
## <0 rows> (or 0-length row.names)
```

```
outliers_Iaro <- dat[abs(dat$z_Iaro) > 3, ]
outliers_Iaro
```

```
## [1] subj      trial.num trial.val sex      age      ethn      Ineg
## [8] Ipos      Iaro      z_Ineg   z_Ipos   z_Iaro
## <0 rows> (or 0-length row.names)
```

There are no outliers.

0.2 Linear Mixed Effects Model: emotional responses by trial type & demographics

- Each participant has multiple trials, so the trials within a participant are likely correlated
- Data is nested
- Each participant may have their own baseline level of emotional responses
- fixed effects (trial.val, sex, age, ethn) explain the variation between individuals
- random effects (1|subj) explain the correlation of repeated measures within individuals

0.2.1 How different trial types & demographics affect negative emotional response (Ineg)?

```
library(lme4)
```

```
## Loading required package: Matrix
```

```
# Mixed-effects model for predicting Ineg
```

```
model_ineg <- lmer(Ineg ~ trial.val + sex + age + ethn + (1|subj), data = dat)
summary(model_ineg)
```

```
## Linear mixed model fit by REML ['lmerMod']
```

```
## Formula: Ineg ~ trial.val + sex + age + ethn + (1 | subj)
```

```
## Data: dat
```

```
##
```

```
## REML criterion at convergence: 58969.5
```

```
##
```

```
## Scaled residuals:
```

```
##      Min       1Q   Median       3Q      Max
## -3.9915 -0.5714 -0.0487  0.5031  5.6660
```

```
##
```

```
## Random effects:
```

```
## Groups   Name      Variance Std.Dev.
```

```
## subj     (Intercept) 0.5259   0.7252
```

```
## Residual                2.0745   1.4403
```

```
## Number of obs: 16380, groups: subj, 156
```

```
##
```

```
## Fixed effects:
```

```
##
```

```
## (Intercept)                Estimate Std. Error
```

```
## trial.valneu                -4.076439   0.034381
```

```
## trial.valpos                -4.086175   0.024311
```

```
## sexfemale                   0.317543   0.121858
```

```
## sexother                    -0.031652   0.747300
```

```
## age                         0.001809   0.021086
```

```
## ethnBlack/African American -0.060943   0.237892
```

```
## ethnLatino/Hispanic         -0.317652   0.232008
```

```
## ethnOther                   0.138570   0.290750
```

```
## ethnWhite/Caucasian         0.070420   0.155354
```

```
## ethnAmerican Indian/Native American or Alaskan Native -0.692261   0.393608
```

```
## ethnDecline to state        -0.275510   0.543413
```

```
##
```

```
## t value
```

```
## (Intercept)                11.759
```

```
## trial.valneu               -118.566
```

```
## trial.valpos               -168.079
```

```
## sexfemale                   2.606
```



```

## sexother -0.042
## age 0.086
## ethnBlack/African American -0.256
## ethnLatino/Hispanic -1.369
## ethnOther 0.477
## ethnWhite/Caucasian 0.453
## ethnAmerican Indian/Native American or Alaskan Native -1.759
## ethnDecline to state -0.507
##
## Correlation of Fixed Effects:
##          (Intr) trl.vln trl.vlp sexfml sexthr age etB/AA ethL/H ethnOt
## trial.valne -0.019
## trial.valps -0.027 0.354
## sexfemale -0.197 0.000 0.000
## sexother -0.070 0.000 0.000 0.084
## age -0.941 0.000 0.000 0.021 0.059
## ethnBlck/AA -0.026 0.000 0.000 0.072 -0.002 -0.149
## ethnLtn/Hsp 0.065 0.000 0.000 0.072 -0.008 -0.250 0.334
## ethnOther -0.081 0.000 0.000 -0.044 -0.006 -0.038 0.234 0.244
## ethnWht/Ccs -0.091 0.000 0.000 0.107 -0.062 -0.171 0.468 0.496 0.357
## ethAI/NAoAN -0.141 0.000 0.000 0.123 0.012 0.029 0.176 0.178 0.134
## ethnDclntst -0.067 0.000 0.000 0.144 0.010 -0.027 0.139 0.145 0.096
##          ethW/C eIAoAN
## trial.valne
## trial.valps
## sexfemale
## sexother
## age
## ethnBlck/AA
## ethnLtn/Hsp
## ethnOther
## ethnWht/Ccs
## ethAI/NAoAN 0.271
## ethnDclntst 0.211 0.092

```

- Random effects: each participant has a different baseline emotional response
 - (1|subj): represents the random effect
 - * each participant (subj) has a different baseline deviation (intercept).
 - * This accounts for the correlation between multiple trial results from the same participant
- REML score (residual maximum likelihood estimate): assess the model fit
- Fixed Effects:
 - Intercept: Negative trial
 - trial.valneu (Neutral trial): Estimate = -4.08, t = -118.57, a very significant negative value.

- * Compared to the baseline (negative trial), **the neutral trial significantly decreases negative emotions (Ineg)**
- trial.valpos (Positive trial): Estimate = -4.09, t = -168.08, also significant.
 - * **the positive trial also significantly decreases negative emotions** compared to the negative trial
- sexfemale: Estimate = 0.317543, t = 2.606.
 - * **Females have significantly higher negative emotional responses (Ineg)** compared to males
- The effects of age and ethnicity are small and not significant

0.2.2 How different trial types & demographics affect positive emotional response (Ipos)?

```
# Mixed-effects model for predicting Ipos
model_ipos <- lmer(Ipos ~ trial.val + sex + age + ethn + (1|subj), data = dat)
summary(model_ipos)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: Ipos ~ trial.val + sex + age + ethn + (1 | subj)
## Data: dat
##
## REML criterion at convergence: 60034.7
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -3.8302 -0.5834 -0.0294  0.5335  5.4659
##
## Random effects:
## Groups Name Variance Std.Dev.
## subj (Intercept) 0.5687 0.7541
## Residual 2.2138 1.4879
## Number of obs: 16380, groups: subj, 156
##
## Fixed effects:
##
## Estimate Std. Error
## (Intercept) 0.71768 0.46141
## trial.valneu 0.33658 0.03552
## trial.valpos 4.03432 0.02511
## sexfemale 0.20020 0.12669
## sexother -1.13135 0.77693
## age 0.02213 0.02192
## ethnBlack/African American 0.08731 0.24732
## ethnLatino/Hispanic -0.33718 0.24121
## ethnOther -0.01740 0.30228
## ethnWhite/Caucasian 0.13375 0.16151
```

```

## ethnAmerican Indian/Native American or Alaskan Native -0.93997    0.40921
## ethnDecline to state -0.33289    0.56496
## t value
## (Intercept) 1.555
## trial.valneu 9.477
## trial.valpos 160.642
## sexfemale 1.580
## sexother -1.456
## age 1.010
## ethnBlack/African American 0.353
## ethnLatino/Hispanic -1.398
## ethnOther -0.058
## ethnWhite/Caucasian 0.828
## ethnAmerican Indian/Native American or Alaskan Native -2.297
## ethnDecline to state -0.589
##
## Correlation of Fixed Effects:
## (Intr) trl.vln trl.vlp sexfml sexthr age etB/AA ethL/H ethnOt
## trial.valne -0.019
## trial.valps -0.027 0.354
## sexfemale -0.197 0.000 0.000
## sexother -0.070 0.000 0.000 0.084
## age -0.941 0.000 0.000 0.021 0.059
## ethnBlck/AA -0.026 0.000 0.000 0.072 -0.002 -0.149
## ethnLtn/Hsp 0.065 0.000 0.000 0.072 -0.008 -0.250 0.334
## ethnOther -0.081 0.000 0.000 -0.044 -0.006 -0.038 0.234 0.244
## ethnWht/Ccs -0.091 0.000 0.000 0.107 -0.062 -0.171 0.468 0.496 0.357
## ethAI/NAoAN -0.141 0.000 0.000 0.123 0.012 0.029 0.176 0.178 0.134
## ethnDclntst -0.067 0.000 0.000 0.144 0.010 -0.027 0.139 0.145 0.096
## ethW/C eIAoAN
## trial.valne
## trial.valps
## sexfemale
## sexother
## age
## ethnBlck/AA
## ethnLtn/Hsp
## ethnOther
## ethnWht/Ccs
## ethAI/NAoAN 0.271
## ethnDclntst 0.211 0.092

```

- Intercept (negative trial): estimate = 0.72, t-value = 1.56. The effect of negative trial on positive emotions (Ipos) is small.
- trial.valneu: estimate = 0.34, t-value = 9.48. Compared to valneg, the neutral trial significantly increases positive emotions (Ipos).
- trial.valpos: estimate = 4.03, t-value = 160.64. Compared to valneg, the positive trial largely increases positive emotions (Ipos), and the effect is extremely significant.

- `sexfemale`: estimate = 0.20, $t = 1.58$. Females tend to have slightly higher positive emotional responses than males.
- `ethnAmerican Indian/Native American or Alaskan Native`: estimate = -0.94, $t = -2.30$. This ethnicity tends to have **significantly lower positive emotional responses** compared to the reference group (Asian or Pacific Islander).
- `trial.valneu` and `trial.valpos` have a correlation of 0.354, showing that the effects of neutral and positive trials are somewhat related.

0.2.3 How different trial types & demographics affect arousal emotional response (Iaro)?

```
# Mixed-effects model for predicting Iaro
model_aro <- lmer(Iaro ~ trial.val + sex + age + ethn + (1|subj), data = dat)
summary(model_aro)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: Iaro ~ trial.val + sex + age + ethn + (1 | subj)
## Data: dat
##
## REML criterion at convergence: 59841.3
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -4.4843 -0.6288 -0.1072  0.5760  4.8022
##
## Random effects:
## Groups Name Variance Std.Dev.
## subj (Intercept) 1.593 1.262
## Residual 2.168 1.472
## Number of obs: 16380, groups: subj, 156
##
## Fixed effects:
##
## (Intercept) 2.92802 0.76311
## trial.valneu -2.25913 0.03515
## trial.valpos -0.30058 0.02485
## sexfemale 0.22642 0.20959
## sexother -1.53358 1.28529
## age 0.02904 0.03627
## ethnBlack/African American 0.22313 0.40915
## ethnLatino/Hispanic 0.12385 0.39903
## ethnOther 0.52839 0.50007
## ethnWhite/Caucasian 0.06932 0.26720
## ethnAmerican Indian/Native American or Alaskan Native -0.85245 0.67697
## ethnDecline to state 0.07313 0.93462
##
## t value
```

```

## (Intercept) 3.837
## trial.valneu -64.279
## trial.valpos -12.095
## sexfemale 1.080
## sexother -1.193
## age 0.801
## ethnBlack/African American 0.545
## ethnLatino/Hispanic 0.310
## ethnOther 1.057
## ethnWhite/Caucasian 0.259
## ethnAmerican Indian/Native American or Alaskan Native -1.259
## ethnDecline to state 0.078
##
## Correlation of Fixed Effects:
##          (Intr) trl.vln trl.vlp sexfml sexthr age      etB/AA ethL/H ethnOt
## trial.valne -0.012
## trial.valps -0.016  0.354
## sexfemale -0.197  0.000  0.000
## sexother -0.070  0.000  0.000  0.084
## age -0.942  0.000  0.000  0.021  0.059
## ethnBlck/AA -0.026  0.000  0.000  0.072 -0.002 -0.149
## ethnLtn/Hsp  0.065  0.000  0.000  0.072 -0.008 -0.250  0.334
## ethnOther -0.081  0.000  0.000 -0.044 -0.006 -0.038  0.234  0.244
## ethnWht/Ccs -0.091  0.000  0.000  0.107 -0.062 -0.171  0.468  0.496  0.357
## ethAI/NAoAN -0.141  0.000  0.000  0.123  0.012  0.029  0.176  0.178  0.134
## ethnDclntst -0.067  0.000  0.000  0.144  0.010 -0.027  0.139  0.145  0.096
##          ethW/C eIAoAN
## trial.valne
## trial.valps
## sexfemale
## sexother
## age
## ethnBlck/AA
## ethnLtn/Hsp
## ethnOther
## ethnWht/Ccs
## ethAI/NAoAN  0.271
## ethnDclntst  0.211  0.092

```

- Intercept (negative trial): estimate = 2.93, t-value = 3.84. The effect of negative trial on arousal (Iaro) is moderate.
- trial.valneu: estimate -2.26, t-value = -64.28. Compared to valneg, the **neutral trial significantly decreases arousal (Iaro)**, which can be expected.
- trial.valpos: estimate = -0.30, t-value = -12.10. Compared to valneg, the **positive trial also significantly decreases arousal (Iaro)**, but the effect is small.
- Other fixed effects are not significant.

0.3 Autoregressive Modeling

0.3.1 Assign 12 inertia scores for each participant

Assign 1 overall inertia score for pos, neg, and aro for each participant:

```
library(dplyr)
library(purrr)
library(broom)

# Create a function to return inertia (lag-1 beta value)
get_inertia <- function(x) {
  # Create lagged data
  lag_x <- dplyr::lag(x)
  df <- data.frame(current = x, lagged = lag_x)
  df <- na.omit(df)

  # Linear regression: current ~ lagged
  model <- lm(current ~ lagged, data = df)
  coef(model)["lagged"]
}

# find inertia scores for the 3 emotions for each participant
overall_inertia <- dat %>%
  group_by(subj) %>%
  summarise(
    pos_inertia = get_inertia(Ipos),
    neg_inertia = get_inertia(Ineg),
    aro_inertia = get_inertia(Iaro)
  )
overall_inertia
```

```
## # A tibble: 156 x 4
##   subj pos_inertia neg_inertia aro_inertia
##   <fct>      <dbl>      <dbl>      <dbl>
## 1 f001    -0.0956    -0.149    -0.139
## 2 f002     0.0187     0.0682     0.0974
## 3 f003    -0.0855    -0.143     0.0149
## 4 f004     0.0648    -0.0705     0.0150
## 5 f005    -0.0433    -0.0918    -0.0962
## 6 f006    -0.0750     0.160     0.175
## 7 f007     0.0834     0.0245     0.190
## 8 f008    -0.0125    -0.0254     0.00949
## 9 f009     0.0162     0.0865    -0.136
## 10 f010     0.164     0.110     0.0143
## # i 146 more rows
```

For each of the 3 emotional reactions (pos, neg, aro), assign 1 inertia score for each of the 3 trial type (pos, neg, neu)

```
library(tidyr)

##
## Attaching package: 'tidyr'

## The following objects are masked from 'package:Matrix':
##
##     expand, pack, unpack

# For each subj x trial.val x emotion
inertia_long <- dat %>%
  group_by(subj, trial.val) %>%
  summarise(
    pos_inertia = get_inertia(Ipos),
    neg_inertia = get_inertia(Ineg),
    aro_inertia = get_inertia(Iaro),
    .groups = "drop"
  )

# Reshape into wide format: 1 row per participant, 9 inertia scores
inertia_wide <- inertia_long %>%
  pivot_wider(
    names_from = trial.val,
    values_from = c(pos_inertia, neg_inertia, aro_inertia),
    names_glue = "{.value}_{trial.val}"
  )

inertia_wide

## # A tibble: 156 x 10
##   subj pos_inertia_neg pos_inertia_neu pos_inertia_pos neg_inertia_neg
##   <fct>          <dbl>          <dbl>          <dbl>          <dbl>
## 1 f001         -0.0233             NA             0.0214         -0.203
## 2 f002         -0.0233         -0.115         -0.00418         0.376
## 3 f003          0.131         -0.0939         -0.127         -0.106
## 4 f004         -0.0732         -0.0111          0.196          0.0689
## 5 f005          0.223         -0.0769          0.0571          0.107
## 6 f006         -0.0883         -0.161          0.239          0.416
## 7 f007         -0.0233         -0.0888          0.0636          0.191
## 8 f008          0.0422         -0.247          0.0363         -0.174
## 9 f009         -0.0560          0.0590          0.0652          0.0603
## 10 f010         -0.0233          0.0577          0.199          0.220
## # i 146 more rows
## # i 5 more variables: neg_inertia_neu <dbl>, neg_inertia_pos <dbl>,
## #   aro_inertia_neg <dbl>, aro_inertia_neu <dbl>, aro_inertia_pos <dbl>
```

```
# Find the reason of NAs
```

```
# Whether there's not enough data for each subj × trial.val group?
```

```
dat %>%  
  group_by(subj, trial.val) %>%  
  summarise(n = n()) %>%  
  filter(n < 5)
```

```
## 'summarise()' has grouped output by 'subj'. You can override using the  
## '.groups' argument.
```

```
## # A tibble: 0 x 3  
## # Groups:   subj [0]  
## # i 3 variables: subj <fct>, trial.val <fct>, n <int>
```

```
# Whether some emotion ratings for certain trial type are always the same?
```

```
dat %>%  
  group_by(subj, trial.val) %>%  
  summarise(  
    Ineg_var = var(Ineg),  
    Ipos_var = var(Ipos),  
    Iaro_var = var(Iaro)  
  ) %>%  
  filter(Ineg_var == 0 | Ipos_var == 0 | Iaro_var == 0)
```

```
## 'summarise()' has grouped output by 'subj'. You can override using the  
## '.groups' argument.
```

```
## # A tibble: 106 x 5  
## # Groups:   subj [80]  
##   subj trial.val Ineg_var Ipos_var Iaro_var  
##   <fct> <fct>      <dbl>   <dbl>   <dbl>  
## 1 f001 neu         0      0.267  0.352  
## 2 f001 pos         0      1.61   1.08  
## 3 f002 neu         0      1.26   1.35  
## 4 f002 pos         0      1.51   1.14  
## 5 f005 neu         0      0.267  0.0667  
## 6 f007 neu         0      0.0663  0  
## 7 f007 pos         0      0.786  0.382  
## 8 f013 neu         0      0.0659  0  
## 9 f019 neu      0.124    4.92   0  
## 10 f020 neu         0      2.52   1.55  
## # i 96 more rows
```


- The reason of NAs is not due to insufficient data for each $\text{subj} \times \text{trial.val}$ group
- NAs are also not likely to be caused by zero-variance of some emotion inertia ratings, since NAs from `inertia_wide` are more than the number of $\text{Var} = 0$.

```
# Merge all inertia scores (by subj)
inertia_all <- overall_inertia %>%
  left_join(inertia_wide, by = "subj")
inertia_all
```

```
## # A tibble: 156 x 13
##   subj pos_inertia neg_inertia aro_inertia pos_inertia_neg pos_inertia_neu
##   <fct>      <dbl>      <dbl>      <dbl>      <dbl>      <dbl>
## 1 f001    -0.0956    -0.149    -0.139    -0.0233      NA
## 2 f002     0.0187     0.0682     0.0974    -0.0233    -0.115
## 3 f003    -0.0855    -0.143     0.0149     0.131    -0.0939
## 4 f004     0.0648    -0.0705     0.0150    -0.0732    -0.0111
## 5 f005    -0.0433    -0.0918    -0.0962     0.223    -0.0769
## 6 f006    -0.0750     0.160     0.175    -0.0883    -0.161
## 7 f007     0.0834     0.0245     0.190    -0.0233    -0.0888
## 8 f008    -0.0125    -0.0254     0.00949    0.0422    -0.247
## 9 f009     0.0162     0.0865    -0.136    -0.0560     0.0590
## 10 f010     0.164     0.110     0.0143    -0.0233     0.0577
## # i 146 more rows
## # i 7 more variables: pos_inertia_pos <dbl>, neg_inertia_neg <dbl>,
## #   neg_inertia_neu <dbl>, neg_inertia_pos <dbl>, aro_inertia_neg <dbl>,
## #   aro_inertia_neu <dbl>, aro_inertia_pos <dbl>
```

```
library(ggplot2)
library(dplyr)
library(tidyr)
library(e1071) # for skewness
library(psych) # for describe()
```

```
##
## Attaching package: 'psych'
```

```
## The following objects are masked from 'package:ggplot2':
##
##   %+%, alpha
```

```
# Convert to inertia_long format
inertia_long <- inertia_all %>%
  pivot_longer(-subj, names_to = "inertia_type", values_to = "inertia")

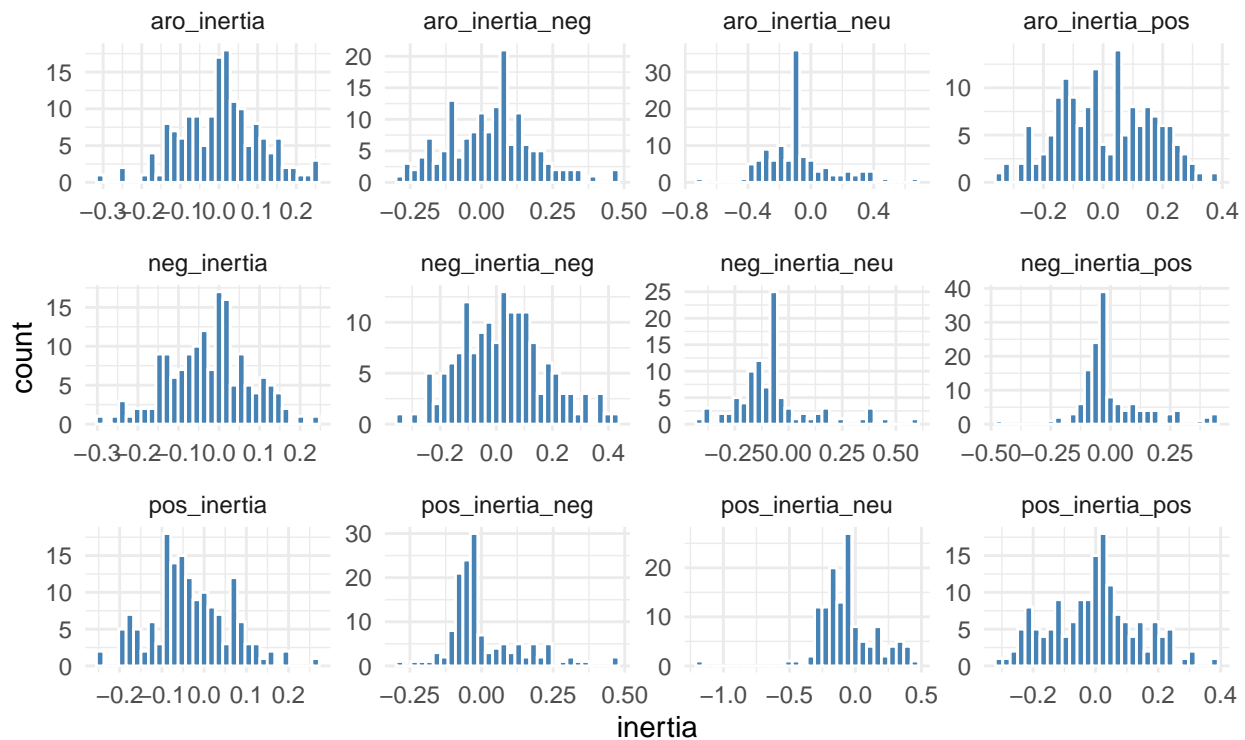
# Distribution & Skewness
inertia_long %>%
```

```
group_by(inertia_type) %>%
mutate(
  skew = skewness(inertia, na.rm = TRUE),
  normality_p = shapiro.test(inertia)$p.value
) %>%
ggplot(aes(x = inertia)) +
geom_histogram(bins = 30, fill = "steelblue", color = "white") +
facet_wrap(~ inertia_type, scales = "free") +
theme_minimal() +
labs(title = "Histogram of Inertia Scores across Participants",
      subtitle = "Check for skewness & normality visually")
```

```
## Warning: Removed 159 rows containing non-finite outside the scale range
## ('stat_bin()').
```

Histogram of Inertia Scores across Participants

Check for skewness & normality visually



```
# describe_stats for all 3 + 9 = 12 types of inertia
describe_stats <- inertia_long %>%
group_by(inertia_type) %>%
summarise(
  n = sum(!is.na(inertia)),
  sd = sd(inertia, na.rm = TRUE),
```

```

    Q1 = quantile(inertia, 0.25, na.rm = TRUE),
    Q3 = quantile(inertia, 0.75, na.rm = TRUE),
    skewness = skewness(inertia, na.rm = TRUE),
    normality_p = shapiro.test(inertia)$p.value
  )
describe_stats

```

```

## # A tibble: 12 x 7
##   inertia_type      n    sd    Q1    Q3 skewness normality_p
##   <chr>      <int> <dbl> <dbl> <dbl> <dbl>      <dbl>
## 1 aro_inertia    156 0.103 -0.0630 0.0666 -0.0809  6.10e- 1
## 2 aro_inertia_neg 156 0.150 -0.0772 0.124  0.230  1.39e- 1
## 3 aro_inertia_neu 117 0.208 -0.182 -0.00947 0.715  3.86e- 5
## 4 aro_inertia_pos 154 0.157 -0.117 0.134  0.0368 1.11e- 1
## 5 neg_inertia    156 0.0998 -0.0890 0.0316 -0.120  8.17e- 1
## 6 neg_inertia_neg 156 0.151 -0.0928 0.117  0.253  4.16e- 1
## 7 neg_inertia_neu  95 0.177 -0.166 -0.0635 1.30  1.30e- 7
## 8 neg_inertia_pos 141 0.139 -0.0694 0.0458 1.08  6.69e-10
## 9 pos_inertia    156 0.0927 -0.0889 0.0276 0.290  2.67e- 1
## 10 pos_inertia_neg 140 0.129 -0.0691 0.0479 1.27  2.32e- 9
## 11 pos_inertia_neu 130 0.216 -0.167 0.0242 -0.399  8.44e- 8
## 12 pos_inertia_pos 156 0.141 -0.119 0.0684 0.0816 1.17e- 1

```

Inertia scores that are not normal:

- neg_inertia_pos: normality_p = 6.689087e-10; skewness = 1.07982750
 - Under positive stimuli, negative emotion inertia is right-skewed: a few individuals have unusually persistent negative emotions
- pos_inertia_neg: normality_p = 2.318693e-09; skewness = 1.27067898
 - Under negative stimuli, positive emotion inertia is strongly right-skewed: most people have low inertia in positive feelings, with a few showing strong inertia
- pos_inertia_neu: normality_p = 8.436415e-08; skewness = -0.39896752
 - For neutral stimuli, positive emotion inertia is slightly left-skewed
- neg_inertia_neu: normality_p = 1.296106e-07; skewness = 1.29575508
 - For neutral stimuli, negative emotion inertia is strongly right-skewed
- aro_inertia_neu: normality_p = 3.859573e-05; skewness = 0.71497318
 - For neutral stimuli, arousal inertia is right-skewed

0.3.2 Normalize the skewed inertia types

```

# Transform the skewed inertia types to normal
library(bestNormalize)

skewed_vars <- c(
  "neg_inertia_pos", "pos_inertia_neg", "pos_inertia_neu",
  "neg_inertia_neu", "aro_inertia_neu"
)

inertia_long_normalized <- inertia_long %>%
  group_by(inertia_type) %>%
  mutate(
    inertia_trans = if_else(
      inertia_type %in% skewed_vars,
      orderNorm(inertia)$x.t, # transform only these
      inertia # leave others unchanged
    )
  )

```

```

## Warning: There were 6 warnings in 'mutate()'.
## The first warning was:
## i In argument: 'inertia_trans = if_else(...)'
## i In group 3: 'inertia_type = "aro_inertia_neu"'.
## Caused by warning in 'orderNorm()':
## ! Ties in data, Normal distribution not guaranteed
## i Run 'dplyr::last_dplyr_warnings()' to see the 5 remaining warnings.

```

```
inertia_long_normalized
```

```

## # A tibble: 1,872 x 4
## # Groups:   inertia_type [12]
##   subj  inertia_type    inertia inertia_trans
##   <fct> <chr>          <dbl>      <dbl>
## 1 f001 pos_inertia    -0.0956   -0.0956
## 2 f001 neg_inertia    -0.149    -0.149
## 3 f001 aro_inertia   -0.139    -0.139
## 4 f001 pos_inertia_neg -0.0233    0.244
## 5 f001 pos_inertia_neu NA         NA
## 6 f001 pos_inertia_pos 0.0214    0.0214
## 7 f001 neg_inertia_neg -0.203    -0.203
## 8 f001 neg_inertia_neu NA         NA
## 9 f001 neg_inertia_pos NA         NA
## 10 f001 aro_inertia_neg -0.187    -0.187
## # i 1,862 more rows

```

0.3.3 Compare means and sd of the 12 inertia types

```
# Find mean value of each of the 12 inertia types

inertia_means <- inertia_long_normalized %>%
  group_by(inertia_type) %>%
  summarise(
    mean_inertia = mean(inertia_trans, na.rm = TRUE),
    sd_inertia = sd(inertia_trans, na.rm = TRUE),
    n = sum(!is.na(inertia_trans))
  ) %>%
  arrange(desc(abs(mean_inertia)))

inertia_means
```

```
## # A tibble: 12 x 4
##   inertia_type      mean_inertia sd_inertia      n
##   <chr>              <dbl>      <dbl> <int>
## 1 pos_inertia      -0.0324      0.0927   156
## 2 aro_inertia_neg   0.0308      0.150    156
## 3 neg_inertia       -0.0244      0.0998   156
## 4 neg_inertia_neg   0.0242      0.151    156
## 5 aro_inertia_pos   0.00693     0.157    154
## 6 pos_inertia_pos  -0.00589     0.141    156
## 7 aro_inertia       0.00482     0.103    156
## 8 neg_inertia_neu  -0.0000523   0.998     95
## 9 aro_inertia_neu  -0.0000440   0.998    117
## 10 pos_inertia_neg -0.0000328   0.999    140
## 11 neg_inertia_pos -0.00000932  0.999    141
## 12 pos_inertia_neu  0.000000373  0.999    130
```

- aro_inertia_neu: Extremely high SD (0.998) — arousal inertia under neutral stimuli varies greatly across individuals
- neg_inertia_pos: Negative near-zero mean ($-9.32\text{e-}06$) but very high variance ($\text{sd} = 0.999$);
 - Negative emotion is likely to bounce back after positive stimuli
 - Huge individual differences
- pos_inertia_neg: Negative near-zero mean ($-3.28\text{e-}05$) but very high variance ($\text{sd} = 0.999$);
 - Positive emotion is likely to bounce back after negative stimuli
 - Huge individual differences
- aro_inertia_neg (mean = 0.031) vs. aro_inertia_pos (mean = 0.007)
 - participants show slightly greater arousal persistence following negative stimuli ($M = 0.0308$) compared to positive stimuli

– but the difference is non-significant (p-value = 0.1727)

```
# check significance for aro_inertia_neg vs. aro_inertia_pos
t.test(inertia_trans ~ inertia_type,
       data = filter(inertia_long_normalized, inertia_type %in% c("aro_inertia_neg", "aro_inertia_pos")))

##
## Welch Two Sample t-test
##
## data: inertia_trans by inertia_type
## t = 1.3669, df = 306.81, p-value = 0.1727
## alternative hypothesis: true difference in means between group aro_inertia_neg and group aro_inertia_pos
## 95 percent confidence interval:
## -0.01049249 0.05823600
## sample estimates:
## mean in group aro_inertia_neg mean in group aro_inertia_pos
## 0.030804571 0.006932816
```

- neg_inertia (mean = -0.024) vs. pos_inertia (mean = -0.032):

```
t.test(inertia_trans ~ inertia_type,
       data = filter(inertia_long_normalized, inertia_type %in% c("neg_inertia", "pos_inertia")))

##
## Welch Two Sample t-test
##
## data: inertia_trans by inertia_type
## t = 0.73868, df = 308.32, p-value = 0.4607
## alternative hypothesis: true difference in means between group neg_inertia and group pos_inertia
## 95 percent confidence interval:
## -0.01340656 0.02952216
## sample estimates:
## mean in group neg_inertia mean in group pos_inertia
## -0.02436017 -0.03241797
```

- Negative emotions appeared to decay slightly more slowly ($M = -0.024$) than positive ones ($M = -0.032$), but the difference is not significant (p-value = 0.461)
- on average, both emotional valences exhibited similarly rapid decay, and individual variability may overshadow any consistent group-level differences
- neg_inertia_pos (mean = $-9.32e-06$) vs. pos_inertia_neg ($-3.28e-05$):

```
t.test(inertia_trans ~ inertia_type,
       data = filter(inertia_long_normalized, inertia_type %in% c("neg_inertia_pos", "pos_inertia_neg")))
##
```

```
##
## Welch Two Sample t-test
##
## data: inertia_trans by inertia_type
## t = 0.00019662, df = 278.99, p-value = 0.9998
## alternative hypothesis: true difference in means between group neg_inertia_pos and group pos_inertia_neg
## 95 percent confidence interval:
## -0.2345872 0.2346341
## sample estimates:
## mean in group neg_inertia_pos mean in group pos_inertia_neg
## -9.318999e-06 -3.275277e-05
```

- Interpretation: Emotions tend to reset quickly when the stimulus is the opposite, potentially due to contrast effects or attentional shifts, meaning that people are likely to be affected by opposite stimuli
- no statistically significant difference ($p = 0.9998$)

```
# Overall there's no statistically significant difference between the 12 inertia types
anova_result <- aov(inertia_trans ~ inertia_type, data = inertia_long_normalized)
summary(anova_result)
```

```
##              Df Sum Sq Mean Sq F value Pr(>F)
## inertia_type  11    0.5  0.0466   0.125    1
## Residuals    1701  634.8  0.3732
## 159 observations deleted due to missingness
```

0.3.4 Compare 12 emotional inertia types by demographics

```
# Pivot transformed inertia data to wide format

inertia_wide_trans <- inertia_long_normalized %>%
  select(subj, inertia_type, inertia_trans) %>%
  tidyr::pivot_wider(
    names_from = inertia_type,
    values_from = inertia_trans
  )

# Extract demographic info from your original dat

demo_info <- dat %>%
  select(subj, sex, age, ethn) %>%
  distinct()

# Merge the transformed inertia data with demographics
inertia_full <- inertia_wide_trans %>%
```

```
left_join(demo_info, by = "subj")
inertia_full
```

```
## # A tibble: 156 x 16
##   subj pos_inertia neg_inertia aro_inertia pos_inertia_neg pos_inertia_neu
##   <fct>      <dbl>      <dbl>      <dbl>      <dbl>      <dbl>
## 1 f001    -0.0956    -0.149    -0.139         0.244        NA
## 2 f002     0.0187     0.0682     0.0974         0.244    -0.184
## 3 f003    -0.0855    -0.143     0.0149         0.935    -0.145
## 4 f004     0.0648    -0.0705     0.0150        -0.779     0.535
## 5 f005    -0.0433    -0.0918    -0.0962         1.49     0.0579
## 6 f006    -0.0750     0.160     0.175        -1.08    -0.581
## 7 f007     0.0834     0.0245     0.190         0.244    -0.0869
## 8 f008    -0.0125    -0.0254     0.00949        0.641    -1.10
## 9 f009     0.0162     0.0865    -0.136        -0.434     0.724
## 10 f010     0.164     0.110     0.0143         0.244     0.699
## # i 146 more rows
## # i 10 more variables: pos_inertia_pos <dbl>, neg_inertia_neg <dbl>,
## #   neg_inertia_neu <dbl>, neg_inertia_pos <dbl>, aro_inertia_neg <dbl>,
## #   aro_inertia_neu <dbl>, aro_inertia_pos <dbl>, sex <fct>, age <int>,
## #   ethn <fct>
```

```
# Inertia types by Sex (mean)

# By sex
inertia_full %>%
  group_by(sex) %>%
  summarise(across(starts_with("pos_") | starts_with("neg_") | starts_with("aro_"),
    ~mean(.x, na.rm = TRUE)))
```

0.3.4.1 By Sex

```
## # A tibble: 3 x 13
##   sex pos_inertia pos_inertia_neg pos_inertia_neu pos_inertia_pos neg_inertia
##   <fct>      <dbl>      <dbl>      <dbl>      <dbl>      <dbl>
## 1 male    -0.0206         0.126    -0.0479    -0.000842   -0.0241
## 2 female  -0.0432    -0.0984     0.0620    -0.0106    -0.0245
## 3 other    0.0144    -0.881    -1.51     0.0190    -0.0339
## # i 7 more variables: neg_inertia_neg <dbl>, neg_inertia_neu <dbl>,
## #   neg_inertia_pos <dbl>, aro_inertia <dbl>, aro_inertia_neg <dbl>,
## #   aro_inertia_neu <dbl>, aro_inertia_pos <dbl>
```

- On average, males showed slightly higher positive emotion inertia ($M = -0.021$) than females ($M = -0.043$)

- pos_inertia_neg: male(0.1255) vs. female(-0.0984)
 - On average, Females lose positive emotions quickly in response to negative stimuli
- neg_inertia_pos: male (-0.0489) vs. female(0.0297)
 - On average, Females retain negative emotions more than males even under positive stimuli -> showing difficulty to let go of negativity
- This may partly explain why females are more likely to get depression

```
library(dplyr)
library(tidyr)
library(purrr)

# Transform into long_format
inertia_sex_long <- inertia_full %>%
  filter(!is.na(sex)) %>%
  pivot_longer(
    cols = starts_with("pos_") | starts_with("neg_") | starts_with("aro_"),
    names_to = "inertia_type",
    values_to = "inertia_value"
  )

# Check for normality using Shapiro test
normality_test <- inertia_sex_long %>%
  group_by(inertia_type, sex) %>%
  filter(n() >= 3) %>% # Keep groups with sample size >= 3
  summarise(
    n = n(),
    shapiro_p = shapiro.test(inertia_value)$p.value,
    skewness = e1071::skewness(inertia_value, na.rm = TRUE),
    .groups = "drop"
  ) %>%
  mutate(normal = ifelse(shapiro_p >= 0.05, "Yes", "No"))

normality_test
```

```
## # A tibble: 24 x 6
##   inertia_type    sex      n shapiro_p skewness normal
##   <chr>          <fct> <int>    <dbl>    <dbl> <chr>
## 1 aro_inertia    male    72     0.520   -0.226 Yes
## 2 aro_inertia    female  83     0.637   -0.0532 Yes
## 3 aro_inertia_neg male    72     0.287    0.182 Yes
## 4 aro_inertia_neg female  83     0.583    0.278 Yes
## 5 aro_inertia_neu male    72     0.971    0.0313 Yes
## 6 aro_inertia_neu female  83     0.941   -0.0292 Yes
## 7 aro_inertia_pos male    72     0.216   -0.0686 Yes
```

```
## 8 aro_inertia_pos female      83      0.489    0.0951 Yes
## 9 neg_inertia      male       72      0.819    0.0121 Yes
## 10 neg_inertia     female     83      0.645   -0.198   Yes
## # i 14 more rows
```

Check for significant difference by sex with ANOVA

```
library(broom)

anova_results <- inertia_sex_long %>%
  filter(!is.na(inertia_value), !is.na(sex)) %>%
  group_by(inertia_type) %>%
  do({
    model <- aov(inertia_value ~ sex, data = .)
    tidy(model)
  }) %>%
  filter(term == "sex") %>%
  select(inertia_type, p.value, statistic)
anova_results
```

```
## # A tibble: 12 x 3
## # Groups:   inertia_type [12]
##   inertia_type    p.value statistic
##   <chr>          <dbl>      <dbl>
## 1 aro_inertia      0.190      1.68
## 2 aro_inertia_neg  0.298      1.22
## 3 aro_inertia_neu  0.452      0.570
## 4 aro_inertia_pos  0.225      1.51
## 5 neg_inertia      0.995      0.00487
## 6 neg_inertia_neg  0.988      0.0117
## 7 neg_inertia_neu  0.175      1.77
## 8 neg_inertia_pos  0.531      0.636
## 9 pos_inertia      0.280      1.28
## 10 pos_inertia_neg 0.285      1.27
## 11 pos_inertia_neu 0.262      1.35
## 12 pos_inertia_pos 0.899      0.107
```

- one-way ANOVA revealed that these differences were not statistically significant: among the 12 inertia types, none of them has statistically significant difference in sex

By ethnicity (mean)

```
inertia_full %>%
  group_by(ethn) %>%
  summarise(across(starts_with("pos_") | starts_with("neg_") | starts_with("aro_"), ~mean(., na.rm=T)))
```

0.3.4.2 By ethnicity

```
## # A tibble: 7 x 13
##   ethn    pos_inertia pos_inertia_neg pos_inertia_neu pos_inertia_pos neg_inertia
##   <fct>      <dbl>          <dbl>          <dbl>          <dbl>          <dbl>
## 1 Asian~    -0.0460          0.0420          0.0161         -0.0293         -0.0169
## 2 Black~     0.00711        0.176           0.292           0.0223         -0.0267
## 3 Latin~    -0.0172          0.219           0.333           0.0259         -0.0306
## 4 Other     -0.0102         -0.297          -0.0267         -0.000646       -0.0207
## 5 White~    -0.0373         -0.0209         -0.138          -0.0116         -0.0327
## 6 Ameri~    -0.0393         -0.280           0.264          -0.00919        0.0856
## 7 Decli~    -0.0831         -1.03            0.317           0.148           0.00606
## # i 7 more variables: neg_inertia_neg <dbl>, neg_inertia_neu <dbl>,
## #   neg_inertia_pos <dbl>, aro_inertia <dbl>, aro_inertia_neg <dbl>,
## #   aro_inertia_neu <dbl>, aro_inertia_pos <dbl>
```

On average (without checking for statistical significance): - **American Indian/Native American or Alaskan Native:** the only group with `neg_inertia > 0` (0.086) -> tend to stay in negative states longer - **Black/African American:** the only group with `pos_inertia > 0` (0.007) -> tend to stay in positive states longer (which is unexpected) - **White/Caucasian:** the only group with inertia < 0 across all three emotions (general pos, neg, aro) -> tend to bounce back quickly overall (emotionally adaptive). - This may reflect greater access to resources, social safety nets, and less exposure to systemic stressors for White people. - **Both “Other” and “Decline to state” have much higher aro_inertia than others.** - This may suggest that the people who are less confident or more confused about their identities are likely to face heightened stress, social vigilance, or lack of belonging—all known to elevate arousal. - But these patterns **did not reach statistical significance**

```
# By ethnicity (check for significance)

library(tidyr)
library(dplyr)
library(purrr)
library(broom)

inertia_ethn_long <- inertia_full %>%
  filter(!is.na(ethn)) %>%
  pivot_longer(
    cols = matches("inertia"),
    names_to = "inertia_type",
    values_to = "inertia_value"
  )

# Check for significant between-group difference using ANOVA

library(broom)

anova_ethn_results <- inertia_ethn_long %>%
  filter(!is.na(inertia_value), !is.na(ethn)) %>%
  group_by(inertia_type) %>%
```

```
do(tidy(aov(inertia_value ~ ethn, data = .))) %>%
filter(term == "ethn") %>%
select(inertia_type, p.value, statistic)

anova_ethn_results
```

```
## # A tibble: 12 x 3
## # Groups:   inertia_type [12]
##   inertia_type    p.value statistic
##   <chr>          <dbl>     <dbl>
## 1 aro_inertia      0.496      0.901
## 2 aro_inertia_neg 0.553      0.823
## 3 aro_inertia_neu 0.110      1.78
## 4 aro_inertia_pos 0.501      0.895
## 5 neg_inertia      0.444      0.976
## 6 neg_inertia_neg 0.896      0.371
## 7 neg_inertia_neu 0.0317     2.44
## 8 neg_inertia_pos 0.0243     2.52
## 9 pos_inertia      0.550      0.828
## 10 pos_inertia_neg 0.648      0.703
## 11 pos_inertia_neu 0.685      0.656
## 12 pos_inertia_pos 0.568      0.805
```

2 types show statistically significant difference: - neg_inertia_neu: $p = 0.0317$ - neg_inertia_pos: $p = 0.0243$

```
# post-hoc: check which groups have the difference using TukeyHSD
```

```
# neg_inertia_neu
```

```
model_neu <- aov(inertia_value ~ ethn, data = filter(inertia_ethn_long, inertia_type == "neg_inertia_neu"))
TukeyHSD(model_neu)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = inertia_value ~ ethn, data = filter(inertia_ethn_long, inertia_type == "neg_inertia_neu"))
##
## $ethn
##
## Black/African American-Asian or Pacific Islander 0.69182884
## Latino/Hispanic-Asian or Pacific Islander         1.38296700
## Other-Asian or Pacific Islander                   0.59868053
## White/Caucasian-Asian or Pacific Islander         0.70583536
## American Indian/Native American or Alaskan Native-Asian or Pacific Islander 1.33966690
## Decline to state-Asian or Pacific Islander        0.20305352
## Latino/Hispanic-Black/African American           0.69113816
```

## Other-Black/African American	-0.09314831
## White/Caucasian-Black/African American	0.01400652
## American Indian/Native American or Alaskan Native-Black/African American	0.64783806
## Decline to state-Black/African American	-0.48877532
## Other-Latino/Hispanic	-0.78428647
## White/Caucasian-Latino/Hispanic	-0.67713164
## American Indian/Native American or Alaskan Native-Latino/Hispanic	-0.04330009
## Decline to state-Latino/Hispanic	-1.17991348
## White/Caucasian-Other	0.10715483
## American Indian/Native American or Alaskan Native-Other	0.74098638
## Decline to state-Other	-0.39562701
## American Indian/Native American or Alaskan Native-White/Caucasian	0.63383154
## Decline to state-White/Caucasian	-0.50278184
## Decline to state-American Indian/Native American or Alaskan Native	-1.13661338
##	lwr
## Black/African American-Asian or Pacific Islander	-1.08766914
## Latino/Hispanic-Asian or Pacific Islander	0.12467191
## Other-Asian or Pacific Islander	-0.73594296
## White/Caucasian-Asian or Pacific Islander	-0.03373238
## American Indian/Native American or Alaskan Native-Asian or Pacific Islander	-1.61129665
## Decline to state-Asian or Pacific Islander	-1.93048961
## Latino/Hispanic-Black/African American	-1.29840106
## Other-Black/African American	-2.13181935
## White/Caucasian-Black/African American	-1.69535600
## American Indian/Native American or Alaskan Native-Black/African American	-2.68129781
## Decline to state-Black/African American	-3.12068832
## Other-Latino/Hispanic	-2.38830427
## White/Caucasian-Latino/Hispanic	-1.83411638
## American Indian/Native American or Alaskan Native-Latino/Hispanic	-3.12548100
## Decline to state-Latino/Hispanic	-3.49154916
## White/Caucasian-Other	-1.13241244
## American Indian/Native American or Alaskan Native-Other	-2.37313508
## Decline to state-Other	-2.74968156
## American Indian/Native American or Alaskan Native-White/Caucasian	-2.27537678
## Decline to state-White/Caucasian	-2.57818865
## Decline to state-American Indian/Native American or Alaskan Native	-4.66769521
##	upr
## Black/African American-Asian or Pacific Islander	2.4713268
## Latino/Hispanic-Asian or Pacific Islander	2.6412621
## Other-Asian or Pacific Islander	1.9333040
## White/Caucasian-Asian or Pacific Islander	1.4454031
## American Indian/Native American or Alaskan Native-Asian or Pacific Islander	4.2906305
## Decline to state-Asian or Pacific Islander	2.3365966
## Latino/Hispanic-Black/African American	2.6806774
## Other-Black/African American	1.9455227
## White/Caucasian-Black/African American	1.7233690
## American Indian/Native American or Alaskan Native-Black/African American	3.9769739
## Decline to state-Black/African American	2.1431377

## Other-Latino/Hispanic	0.8197313
## White/Caucasian-Latino/Hispanic	0.4798531
## American Indian/Native American or Alaskan Native-Latino/Hispanic	3.0388808
## Decline to state-Latino/Hispanic	1.1317222
## White/Caucasian-Other	1.3467221
## American Indian/Native American or Alaskan Native-Other	3.8551078
## Decline to state-Other	1.9584275
## American Indian/Native American or Alaskan Native-White/Caucasian	3.5430399
## Decline to state-White/Caucasian	1.5726250
## Decline to state-American Indian/Native American or Alaskan Native	2.3944684
##	p adj
## Black/African American-Asian or Pacific Islander	0.9023234
## Latino/Hispanic-Asian or Pacific Islander	0.0216906
## Other-Asian or Pacific Islander	0.8243852
## White/Caucasian-Asian or Pacific Islander	0.0713795
## American Indian/Native American or Alaskan Native-Asian or Pacific Islander	0.8161324
## Decline to state-Asian or Pacific Islander	0.9999516
## Latino/Hispanic-Black/African American	0.9410264
## Other-Black/African American	0.9999994
## White/Caucasian-Black/African American	1.0000000
## American Indian/Native American or Alaskan Native-Black/African American	0.9970374
## Decline to state-Black/African American	0.9977155
## Other-Latino/Hispanic	0.7584408
## White/Caucasian-Latino/Hispanic	0.5741655
## American Indian/Native American or Alaskan Native-Latino/Hispanic	1.0000000
## Decline to state-Latino/Hispanic	0.7198705
## White/Caucasian-Other	0.9999726
## American Indian/Native American or Alaskan Native-Other	0.9911554
## Decline to state-Other	0.9986965
## American Indian/Native American or Alaskan Native-White/Caucasian	0.9944937
## Decline to state-White/Caucasian	0.9902699
## Decline to state-American Indian/Native American or Alaskan Native	0.9588499

- significant difference in `neg_inertia_neu` (p-value = 0.0217) between Latino/Hispanic (M = 0.7943) and Asian/ Pacific Islander (M = -0.5886)
 - Latino/Hispanic individuals showed greater negative inertia in response to neutral stimuli, potentially reflecting a stronger tendency to maintain negative emotional responses in ambiguous or emotionally neutral contexts

```
# neg_inertia_pos
model_pos <- aov(inertia_value ~ ethn, data = filter(inertia_ethn_long, inertia_type == "neg_inertia_pos"))
TukeyHSD(model_pos)
```

```
## Tukey multiple comparisons of means
## 95% family-wise confidence level
##
```

```

## Fit: aov(formula = inertia_value ~ ethn, data = filter(inertia_ethn_long, inertia_type == "I")
##
## $ethn
##
##                                     diff
## Black/African American-Asian or Pacific Islander -0.64260793
## Latino/Hispanic-Asian or Pacific Islander         0.31865580
## Other-Asian or Pacific Islander                   -0.89275521
## White/Caucasian-Asian or Pacific Islander          -0.03248153
## American Indian/Native American or Alaskan Native-Asian or Pacific Islander -0.87381348
## Decline to state-Asian or Pacific Islander         0.44137562
## Latino/Hispanic-Black/African American            0.96126373
## Other-Black/African American                      -0.25014728
## White/Caucasian-Black/African American            0.61012640
## American Indian/Native American or Alaskan Native-Black/African American -0.23120556
## Decline to state-Black/African American           1.08398355
## Other-Latino/Hispanic                             -1.21141101
## White/Caucasian-Latino/Hispanic                   -0.35113733
## American Indian/Native American or Alaskan Native-Latino/Hispanic -1.19246929
## Decline to state-Latino/Hispanic                  0.12271982
## White/Caucasian-Other                             0.86027368
## American Indian/Native American or Alaskan Native-Other 0.01894172
## Decline to state-Other                            1.33413083
## American Indian/Native American or Alaskan Native-White/Caucasian -0.84133196
## Decline to state-White/Caucasian                  0.47385715
## Decline to state-American Indian/Native American or Alaskan Native 1.31518911
##
##                                     lwr
## Black/African American-Asian or Pacific Islander -1.6424471
## Latino/Hispanic-Asian or Pacific Islander         -0.6085569
## Other-Asian or Pacific Islander                   -2.1173032
## White/Caucasian-Asian or Pacific Islander          -0.6766360
## American Indian/Native American or Alaskan Native-Asian or Pacific Islander -2.4227577
## Decline to state-Asian or Pacific Islander         -1.6796036
## Latino/Hispanic-Black/African American            -0.1610530
## Other-Black/African American                      -1.6283305
## White/Caucasian-Black/African American            -0.2925399
## American Indian/Native American or Alaskan Native-Black/African American -1.9042566
## Decline to state-Black/African American           -1.1292549
## Other-Latino/Hispanic                             -2.5378476
## White/Caucasian-Latino/Hispanic                   -1.1726307
## American Indian/Native American or Alaskan Native-Latino/Hispanic -2.8231577
## Decline to state-Latino/Hispanic                  -2.0586718
## White/Caucasian-Other                             -0.2863063
## American Indian/Native American or Alaskan Native-Other -1.7973564
## Decline to state-Other                            -0.9892855
## American Indian/Native American or Alaskan Native-White/Caucasian -2.3294033
## Decline to state-White/Caucasian                  -1.6030831
## Decline to state-American Indian/Native American or Alaskan Native -1.1943874
##
##                                     upr

```

## Black/African American-Asian or Pacific Islander	0.3572313
## Latino/Hispanic-Asian or Pacific Islander	1.2458685
## Other-Asian or Pacific Islander	0.3317927
## White/Caucasian-Asian or Pacific Islander	0.6116730
## American Indian/Native American or Alaskan Native-Asian or Pacific Islander	0.6751308
## Decline to state-Asian or Pacific Islander	2.5623549
## Latino/Hispanic-Black/African American	2.0835805
## Other-Black/African American	1.1280360
## White/Caucasian-Black/African American	1.5127927
## American Indian/Native American or Alaskan Native-Black/African American	1.4418454
## Decline to state-Black/African American	3.2972220
## Other-Latino/Hispanic	0.1150256
## White/Caucasian-Latino/Hispanic	0.4703561
## American Indian/Native American or Alaskan Native-Latino/Hispanic	0.4382191
## Decline to state-Latino/Hispanic	2.3041114
## White/Caucasian-Other	2.0068537
## American Indian/Native American or Alaskan Native-Other	1.8352399
## Decline to state-Other	3.6575472
## American Indian/Native American or Alaskan Native-White/Caucasian	0.6467394
## Decline to state-White/Caucasian	2.5507974
## Decline to state-American Indian/Native American or Alaskan Native	3.8247656
##	p adj
## Black/African American-Asian or Pacific Islander	0.4682202
## Latino/Hispanic-Asian or Pacific Islander	0.9464785
## Other-Asian or Pacific Islander	0.3119936
## White/Caucasian-Asian or Pacific Islander	0.9999990
## American Indian/Native American or Alaskan Native-Asian or Pacific Islander	0.6246782
## Decline to state-Asian or Pacific Islander	0.9959664
## Latino/Hispanic-Black/African American	0.1456406
## Other-Black/African American	0.9981132
## White/Caucasian-Black/African American	0.4049371
## American Indian/Native American or Alaskan Native-Black/African American	0.9996011
## Decline to state-Black/African American	0.7641887
## Other-Latino/Hispanic	0.0978488
## White/Caucasian-Latino/Hispanic	0.8601370
## American Indian/Native American or Alaskan Native-Latino/Hispanic	0.3083842
## Decline to state-Latino/Hispanic	0.9999980
## White/Caucasian-Other	0.2784172
## American Indian/Native American or Alaskan Native-Other	1.0000000
## Decline to state-Other	0.6046372
## American Indian/Native American or Alaskan Native-White/Caucasian	0.6222010
## Decline to state-White/Caucasian	0.9933425
## Decline to state-American Indian/Native American or Alaskan Native	0.7022672

- No pairwise group differences are significant for neg_inertia_pos


```
# Inertia types by Age (continuous)
```

```
inertia_full %>%
  summarise(across(
    starts_with("pos_") | starts_with("neg_") | starts_with("aro_"),
    ~ cor(., age, use = "complete.obs")
  ))
```

0.3.4.3 by age

```
## # A tibble: 1 x 12
##   pos_inertia pos_inertia_neg pos_inertia_neu pos_inertia_pos neg_inertia
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1   -0.0107      -0.0459      -0.196        0.0220      -0.128
## # i 7 more variables: neg_inertia_neg <dbl>, neg_inertia_neu <dbl>,
## #   neg_inertia_pos <dbl>, aro_inertia <dbl>, aro_inertia_neg <dbl>,
## #   aro_inertia_neu <dbl>, aro_inertia_pos <dbl>
```

- On average, as age increases, neg_inertia (-0.128) decreases more than pos_inertia (-0.011).
 - Negative emotion may drop slightly faster with increasing age than positive emotion
- Arousal shows a slight increase with age (0.029)
- However, none of these associations reached statistical significance

```
# Check for significant difference of inertia by age
```

```
inertia_long_age <- inertia_full %>%
  pivot_longer(cols = starts_with("pos_") | starts_with("neg_") | starts_with("aro_"),
    names_to = "inertia_type",
    values_to = "inertia_value")
```

```
# run correlation tests
```

```
age_corr_results <- inertia_long_age %>%
  filter(!is.na(inertia_value), !is.na(age)) %>%
  group_by(inertia_type) %>%
  summarise(
    cor_test = list(cor.test(inertia_value, age, method = "pearson")),
    .groups = "drop"
  ) %>%
  mutate(
    r = map_dbl(cor_test, ~ .x$estimate),
    p_value = map_dbl(cor_test, ~ .x$p.value)
  )
age_corr_results
```

```
## # A tibble: 12 x 4
##   inertia_type    cor_test      r p_value
##   <chr>          <list>    <dbl>  <dbl>
## 1 aro_inertia    <htest>    0.0286  0.723
## 2 aro_inertia_neg <htest>    0.117   0.145
## 3 aro_inertia_neu <htest>   -0.0335  0.720
## 4 aro_inertia_pos <htest>   -0.0164  0.840
## 5 neg_inertia    <htest>   -0.128   0.111
## 6 neg_inertia_neg <htest>    0.0270  0.738
## 7 neg_inertia_neu <htest>    0.0708  0.496
## 8 neg_inertia_pos <htest>    0.00600  0.944
## 9 pos_inertia    <htest>   -0.0107  0.895
## 10 pos_inertia_neg <htest>   -0.0459  0.591
## 11 pos_inertia_neu <htest>   -0.196   0.0257
## 12 pos_inertia_pos <htest>    0.0220  0.785
```

- only pos_inertia_neu vary significantly by age: $r = -0.1956$, $p = 0.0257$
 - as age increases, positive emotion inertia under neutral conditions tends to decrease
 - **older individuals may be less likely to maintain positive emotions in response to neutral stimuli**

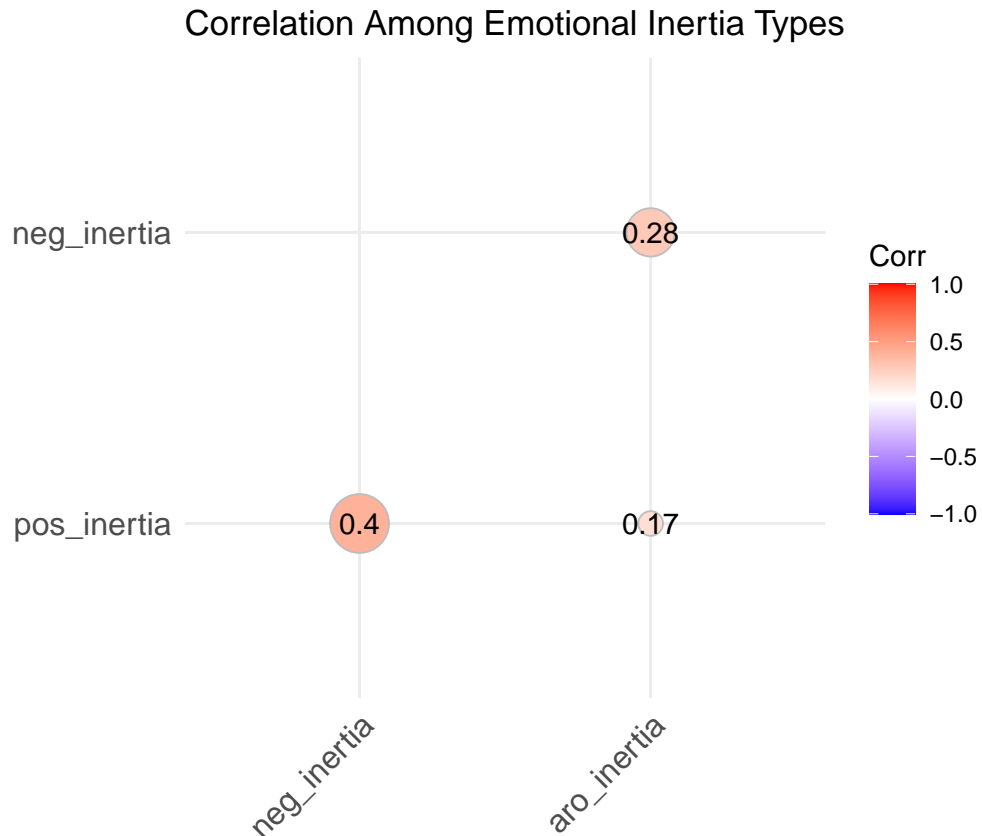
0.3.5 Correlation between inertia types

```
inertia_core <- inertia_full %>%
  select(subj, pos_inertia, neg_inertia, aro_inertia)
cor_matrix <- cor(inertia_core[, -1], use = "complete.obs")
cor_matrix
```

```
##           pos_inertia neg_inertia aro_inertia
## pos_inertia  1.0000000  0.4013880  0.1681746
## neg_inertia  0.4013880  1.0000000  0.2784501
## aro_inertia  0.1681746  0.2784501  1.0000000
```

```
library(ggcorrplot)

ggcorrplot(cor_matrix,
  method = "circle",
  type = "lower",
  lab = TRUE,
  title = "Correlation Among Emotional Inertia Types")
```



- `pos_inertia` and `neg_inertia` have moderate positive correlation ($r = 0.401$): people who tend to hold onto positive emotions also tend to hold onto negative emotions, suggesting emotional stickiness
- `aro_inertia` and `neg_inertia` have small-to-moderate positive correlation ($r = 0.278$): those who hold onto negative emotions also tend to stay aroused longer

0.4 CLPM

0.4.1 Cross-lag paths (how one emotion affect another at the next time point) & Inertia

```
library(lavaan)
```

```
## This is lavaan 0.6-19
```

```
## lavaan is FREE software! Please report any bugs.
```

```
##
```

```
## Attaching package: 'lavaan'
```

```
## The following object is masked from 'package:psych':
```

```
##
##      cor2cov
```

```
library(dplyr)

clpm_data <- dat %>%
  arrange(subj, trial.num) %>%
  group_by(subj) %>%
  mutate(
    Ipos_lag1 = lag(Ipos),
    Ineg_lag1 = lag(Ineg),
    Iaro_lag1 = lag(Iaro)
  ) %>%
  filter(!is.na(Ipos_lag1))

model_clpm <- '
  # Autoregressive (inertia) paths
  Ipos ~ a1 * Ipos_lag1
  Ineg ~ a2 * Ineg_lag1
  Iaro ~ a3 * Iaro_lag1

  # Cross-lagged paths
  Ipos ~ b1 * Ineg_lag1 + b2 * Iaro_lag1
  Ineg ~ c1 * Ipos_lag1 + c2 * Iaro_lag1
  Iaro ~ d1 * Ipos_lag1 + d2 * Ineg_lag1
'

fit_clpm <- sem(model_clpm, data = clpm_data)
summary(fit_clpm, standardized = TRUE, fit.measures = TRUE)
```

```
## lavaan 0.6-19 ended normally after 30 iterations
##
##      Estimator                      ML
##      Optimization method          NLMINB
##      Number of model parameters    15
##
##      Number of observations        16224
##
## Model Test User Model:
##
##      Test statistic                  0.000
##      Degrees of freedom              0
##
## Model Test Baseline Model:
##
##      Test statistic                  17555.797
##      Degrees of freedom              12
```

```

##      P-value                                0.000
##
## User Model versus Baseline Model:
##
##      Comparative Fit Index (CFI)              1.000
##      Tucker-Lewis Index (TLI)                1.000
##
## Loglikelihood and Information Criteria:
##
##      Loglikelihood user model (H0)            -102945.652
##      Loglikelihood unrestricted model (H1)    -102945.652
##
##      Akaike (AIC)                            205921.305
##      Bayesian (BIC)                          206036.718
##      Sample-size adjusted Bayesian (SABIC)    205989.049
##
## Root Mean Square Error of Approximation:
##
##      RMSEA                                    0.000
##      90 Percent confidence interval - lower    0.000
##      90 Percent confidence interval - upper    0.000
##      P-value H_0: RMSEA <= 0.050              NA
##      P-value H_0: RMSEA >= 0.080              NA
##
## Standardized Root Mean Square Residual:
##
##      SRMR                                    0.000
##
## Parameter Estimates:
##
##      Standard errors                        Standard
##      Information                          Expected
##      Information saturated (h1) model      Structured
##
## Regressions:
##
##      Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      Ipos ~
##      Ipos_lag1 (a1)    0.137    0.011   12.869    0.000    0.137    0.137
##      Ineg ~
##      Ineg_lag1 (a2)    0.143    0.011   12.894    0.000    0.143    0.143
##      Iaro ~
##      Iaro_lag1 (a3)    0.414    0.009   43.903    0.000    0.414    0.414
##      Ipos ~
##      Ineg_lag1 (b1)    0.165    0.011   14.920    0.000    0.165    0.166
##      Iaro_lag1 (b2)    0.010    0.012    0.795    0.427    0.010    0.008
##      Ineg ~
##      Ipos_lag1 (c1)    0.173    0.011   16.158    0.000    0.173    0.172
##      Iaro_lag1 (c2)   -0.008    0.013   -0.650    0.516   -0.008   -0.007

```

```

## Iaro ~
## Ipos_lag1 (d1) -0.043 0.008 -5.289 0.000 -0.043 -0.053
## Ineg_lag1 (d2) -0.063 0.008 -7.507 0.000 -0.063 -0.078
##
## Covariances:
## Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .Ipos ~~
## .Ineg -3.425 0.058 -59.271 0.000 -3.425 -0.526
## .Iaro 1.218 0.040 30.743 0.000 1.218 0.249
## .Ineg ~~
## .Iaro 1.886 0.041 45.562 0.000 1.886 0.383
##
## Variances:
## Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .Ipos 6.482 0.072 90.067 0.000 6.482 0.974
## .Ineg 6.549 0.073 90.067 0.000 6.549 0.975
## .Iaro 3.700 0.041 90.067 0.000 3.700 0.860

```

- Positive inertia (0.137) and negative inertia (0.143) are about the same. Negative is slightly higher than positive.
- Arousal inertia (0.414) is much higher than the other two, meaning that arousal emotion is more likely to persist (slightly higher arousal inertia)
- All three types of emotional states (positive, negative, and arousal) exhibit significant inertia, with arousal showing the strongest carry-over effect from one trial to the next
- $Ipos \sim Ineg_lag1$ ($\beta = 0.166$, $p < .001$): negative emotion predicts positive emotion in the next moment, which might reflect emotional rebound
- $Ineg \sim Ipos_lag1$ ($\beta = 0.172$, $p < .001$): positive emotion enhances negative emotion in the next moment, which might reflect emotional mix or trial order effect
- $Iaro \sim Ipos_lag1$ ($\beta = -0.053$): positive emotion decreases arousal at the later stage
- $Iaro \sim Ineg_lag1$ ($\beta = -0.078$): negative emotion decreases arousal at the later stage
- $Ipos \sim Iaro_lag1$ and $Ineg \sim Iaro_lag1$ are not significant
- Conclusion:
 - **Both positive and negative emotions predict more of the opposite in the next moment**
 - **Arousal is reduced by both positive and negative emotions**
 - * maybe a sign of emotional rebound or recovery
 - * more likely to be a result of individual differences (some people are more responsive than others) under random trials within an experimental context, where individuals have “regression to the mean”. This might not be the case in real/natural context

```
# Group by sex
```

```
fit_clpm_sex <- sem(model_clpm,  
                    data = clpm_data,  
                    group = "sex")
```

0.4.1.1 Difference in paths by sex

```
## Warning: lavaan->lavParTable():  
##   using a single label per parameter in a multiple group setting implies  
##   imposing equality constraints across all the groups; If this is not  
##   intended, either remove the label(s), or use a vector of labels (one for  
##   each group); See the Multiple groups section in the man page of  
##   model.syntax.
```

```
summary(fit_clpm_sex, standardized = TRUE, fit.measures = TRUE)
```

```
## lavaan 0.6-19 ended normally after 161 iterations  
##  
##   Estimator                      ML  
##   Optimization method           NLMINB  
##   Number of model parameters     54  
##   Number of equality constraints   18  
##  
##   Number of observations per group:  
##     female                      8632  
##     other                       104  
##     male                        7488  
##  
## Model Test User Model:  
##  
##   Test statistic                  70.669  
##   Degrees of freedom              18  
##   P-value (Chi-square)            0.000  
##   Test statistic for each group:  
##     female                      19.632  
##     other                       30.323  
##     male                        20.714  
##  
## Model Test Baseline Model:  
##  
##   Test statistic                  17419.660  
##   Degrees of freedom              36  
##   P-value                        0.000  
##
```

```

## User Model versus Baseline Model:
##
##   Comparative Fit Index (CFI)                0.997
##   Tucker-Lewis Index (TLI)                  0.994
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -102756.204
##   Loglikelihood unrestricted model (H1)      -102720.870
##
##   Akaike (AIC)                              205584.409
##   Bayesian (BIC)                            205861.402
##   Sample-size adjusted Bayesian (SABIC)     205746.996
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                     0.023
##   90 Percent confidence interval - lower     0.018
##   90 Percent confidence interval - upper     0.029
##   P-value H_0: RMSEA <= 0.050              1.000
##   P-value H_0: RMSEA >= 0.080              0.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                     0.011
##
## Parameter Estimates:
##
##   Standard errors                          Standard
##   Information                              Expected
##   Information saturated (h1) model          Structured
##
##
## Group 1 [female]:
##
## Regressions:
##           Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
## Ipos ~
##   Ipos_lag1 (a1)    0.136    0.011   12.796   0.000    0.136    0.136
## Ineg ~
##   Ineg_lag1 (a2)    0.137    0.011   12.379   0.000    0.137    0.137
## Iaro ~
##   Iaro_lag1 (a3)    0.408    0.009   43.375   0.000    0.408    0.413
## Ipos ~
##   Ineg_lag1 (b1)    0.163    0.011   14.827   0.000    0.163    0.164
##   Iaro_lag1 (b2)    0.005    0.012    0.385   0.700    0.005    0.004
## Ineg ~
##   Ipos_lag1 (c1)    0.167    0.011   15.630   0.000    0.167    0.166

```



```

##      Iaro_lag1 (c2)  -0.009    0.012   -0.705    0.481   -0.009   -0.007
##      Iaro ~
##      Ipos_lag1 (d1)  -0.045    0.008   -5.657    0.000   -0.045   -0.058
##      Ineg_lag1 (d2)  -0.065    0.008   -7.826    0.000   -0.065   -0.083
##
## Covariances:
##              Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      .Ipos ~~
##      .Ineg      -3.913    0.087  -44.726    0.000   -3.913   -0.549
##      .Iaro       1.264    0.058   21.802    0.000    1.264    0.241
##      .Ineg ~~
##      .Iaro       2.077    0.061   34.120    0.000    2.077    0.395
##
## Intercepts:
##              Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      .Ipos       2.204    0.057   38.710    0.000    2.204    0.818
##      .Ineg       2.299    0.057   40.163    0.000    2.299    0.850
##      .Iaro       2.366    0.043   55.253    0.000    2.366    1.118
##
## Variances:
##              Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      .Ipos       7.090    0.108   65.696    0.000    7.090    0.977
##      .Ineg       7.158    0.109   65.696    0.000    7.158    0.978
##      .Iaro       3.866    0.059   65.696    0.000    3.866    0.863
##
##
## Group 2 [other]:
##
## Regressions:
##              Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      Ipos ~
##      Ipos_lag1 (a1)   0.136    0.011   12.796    0.000    0.136    0.132
##      Ineg ~
##      Ineg_lag1 (a2)   0.137    0.011   12.379    0.000    0.137    0.134
##      Iaro ~
##      Iaro_lag1 (a3)   0.408    0.009   43.375    0.000    0.408    0.356
##      Ipos ~
##      Ineg_lag1 (b1)   0.163    0.011   14.827    0.000    0.163    0.213
##      Iaro_lag1 (b2)   0.005    0.012    0.385    0.700    0.005    0.004
##      Ineg ~
##      Ipos_lag1 (c1)   0.167    0.011   15.630    0.000    0.167    0.121
##      Iaro_lag1 (c2)  -0.009    0.012   -0.705    0.481   -0.009   -0.005
##      Iaro ~
##      Ipos_lag1 (d1)  -0.045    0.008   -5.657    0.000   -0.045   -0.048
##      Ineg_lag1 (d2)  -0.065    0.008   -7.826    0.000   -0.065   -0.093
##
## Covariances:
##              Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all

```

```

## .Ipos ~~
## .Ineg          -1.115    0.287   -3.881    0.000   -1.115   -0.412
## .Iaro          -0.095    0.175   -0.541    0.589   -0.095   -0.053
## .Ineg ~~
## .Iaro           1.072    0.258    4.149    0.000    1.072    0.445
##
## Intercepts:
##           Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .Ipos           1.176   0.144   8.159   0.000   1.176   0.815
## .Ineg           2.231   0.192  11.631   0.000   2.231   1.155
## .Iaro           1.197   0.127   9.441   0.000   1.197   0.900
##
## Variances:
##           Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .Ipos           2.003   0.278   7.211   0.000   2.003   0.962
## .Ineg           3.667   0.508   7.211   0.000   3.667   0.983
## .Iaro           1.581   0.219   7.211   0.000   1.581   0.894
##
##
## Group 3 [male]:
##
## Regressions:
##           Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## Ipos ~
## Ipos_lag1 (a1)    0.136   0.011  12.796   0.000   0.136   0.136
## Ineg ~
## Ineg_lag1 (a2)    0.137   0.011  12.379   0.000   0.137   0.137
## Iaro ~
## Iaro_lag1 (a3)    0.408   0.009  43.375   0.000   0.408   0.402
## Ipos ~
## Ineg_lag1 (b1)    0.163   0.011  14.827   0.000   0.163   0.163
## Iaro_lag1 (b2)    0.005   0.012   0.385   0.700   0.005   0.004
## Ineg ~
## Ipos_lag1 (c1)    0.167   0.011  15.630   0.000   0.167   0.166
## Iaro_lag1 (c2)   -0.009   0.012  -0.705   0.481  -0.009  -0.007
## Iaro ~
## Ipos_lag1 (d1)   -0.045   0.008  -5.657   0.000  -0.045  -0.055
## Ineg_lag1 (d2)   -0.065   0.008  -7.826   0.000  -0.065  -0.079
##
## Covariances:
##           Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .Ipos ~~
## .Ineg          -2.915   0.075 -38.669   0.000  -2.915  -0.500
## .Iaro           1.155   0.054  21.448   0.000   1.155   0.256
## .Ineg ~~
## .Iaro           1.651   0.056  29.644   0.000   1.651   0.365
##
## Intercepts:

```

	Estimate	Std.Err	z-value	P(> z)	Std.lv	Std.all
## .Ipos	2.062	0.053	39.082	0.000	2.062	0.844
## .Ineg	2.033	0.053	38.352	0.000	2.033	0.830
## .Iaro	2.178	0.040	54.163	0.000	2.178	1.083
##						
## Variances:						
	Estimate	Std.Err	z-value	P(> z)	Std.lv	Std.all
## .Ipos	5.821	0.095	61.188	0.000	5.821	0.975
## .Ineg	5.849	0.096	61.188	0.000	5.849	0.976
## .Iaro	3.504	0.057	61.188	0.000	3.504	0.867

- Most of the paths are similar between men and women
- Only arousal inertia for women is slightly higher than men

Check for significant difference between men and women

```
model_clpm_free <- '
# Inertia paths
Ipos ~ c(a1f, a1m, a1o)*Ipos_lag1
Ineg ~ c(a2f, a2m, a2o)*Ineg_lag1
Iaro ~ c(a3f, a3m, a3o)*Iaro_lag1

# Cross-lag
Ipos ~ c(b1f, b1m, b1o)*Ineg_lag1 + c(b2f, b2m, b2o)*Iaro_lag1
Ineg ~ c(c1f, c1m, c1o)*Ipos_lag1 + c(c2f, c2m, c2o)*Iaro_lag1
Iaro ~ c(d1f, d1m, d1o)*Ipos_lag1 + c(d2f, d2m, d2o)*Ineg_lag1
'

fit_free <- sem(model_clpm_free, data = clpm_data, group = "sex")

# Whether there's significant difference between sex in at least one path
anova(fit_clpm_sex, fit_free)
```

```
##
## Chi-Squared Difference Test
##
##          Df    AIC    BIC  Chisq Chisq diff    RMSEA Df diff Pr(>Chisq)
## fit_free      0 205550 205965  0.000
## fit_clpm_sex  18 205584 205861 70.669    70.669 0.023261    18 3.482e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

- This shows that at least one or more paths (inertia or cross-lag) differ between males and females

```
# Check which paths are significantly different
```

```
lavTestScore(fit_clpm_sex)
```

```
## $test
##
## total score test:
##
##      test      X2 df p.value
## 1 score 68.394 18      0
##
## $uni
##
## univariate score tests:
##
##      lhs op      rhs      X2 df p.value
## 1 .p1. == .p28.  0.493  1  0.483
## 2 .p1. == .p55.  3.462  1  0.063
## 3 .p2. == .p29.  3.167  1  0.075
## 4 .p2. == .p56.  1.512  1  0.219
## 5 .p3. == .p30. 10.313  1  0.001
## 6 .p3. == .p57. 17.559  1  0.000
## 7 .p4. == .p31.  3.800  1  0.051
## 8 .p4. == .p58.  1.048  1  0.306
## 9 .p5. == .p32.  0.254  1  0.614
## 10 .p5. == .p59.  0.120  1  0.729
## 11 .p6. == .p33.  1.387  1  0.239
## 12 .p6. == .p60.  1.372  1  0.241
## 13 .p7. == .p34.  0.082  1  0.775
## 14 .p7. == .p61.  0.722  1  0.396
## 15 .p8. == .p35.  0.353  1  0.552
## 16 .p8. == .p62.  3.460  1  0.063
## 17 .p9. == .p36.  0.131  1  0.717
## 18 .p9. == .p63.  2.193  1  0.139
```

- .p3. vs. .p30. and .p3. vs. .p57. are significant ($p < 0.05$)

```
# Understand which paths are them
```

```
pe <- parameterEstimates(fit_clpm_sex, standardized = TRUE)
pe[c(3, 30, 57), c("lhs", "op", "rhs", "group", "est", "std.all")]
```

```
##      lhs op      rhs group  est std.all
## 3  Iaro ~ Iaro_lag1      1 0.408  0.413
## 30 Iaro ~ Iaro_lag1      2 0.408  0.356
## 57 Iaro ~ Iaro_lag1      3 0.408  0.402
```

- females (0.413) and males (0.402) are significantly different in arousal inertia
- females (0.413) and other (0.356) are also significantly different in arousal inertia

```
model_clpm_nolabel <- '
  Ipos ~ Ipos_lag1 + Ineg_lag1 + Iaro_lag1
  Ineg ~ Ineg_lag1 + Ipos_lag1 + Iaro_lag1
  Iaro ~ Iaro_lag1 + Ipos_lag1 + Ineg_lag1
'

fit_multigroup_free <- sem(model_clpm_nolabel, data = clpm_data, group = "ethn")
summary(fit_multigroup_free, standardized = TRUE)
```

0.4.1.2 Difference in paths by ethnicity

```
## lavaan 0.6-19 ended normally after 343 iterations
##
##      Estimator                      ML
##      Optimization method          NLMINB
##      Number of model parameters      126
##
##      Number of observations per group:
##      Asian or Pacific Islander      3536
##      Black/African American         1456
##      Latino/Hispanic                1664
##      White/Caucasian                8112
##      Other                          832
##      American Indian/Native American or Alaskan Native 416
##      Decline to state                208
##
## Model Test User Model:
##
##      Test statistic                  0.000
##      Degrees of freedom              0
##      Test statistic for each group:
##      Asian or Pacific Islander      0.000
##      Black/African American         0.000
##      Latino/Hispanic                0.000
##      White/Caucasian                0.000
##      Other                          0.000
##      American Indian/Native American or Alaskan Native 0.000
##      Decline to state                0.000
##
## Parameter Estimates:
##
##      Standard errors                Standard
```

```

##      Information                               Expected
##      Information saturated (h1) model          Structured
##
##
## Group 1 [Asian or Pacific Islander]:
##
## Regressions:
##      Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      Ipos ~
##      Ipos_lag1      0.095   0.023   4.173   0.000   0.095   0.095
##      Ineg_lag1      0.109   0.023   4.730   0.000   0.109   0.112
##      Iaro_lag1      0.028   0.026   1.088   0.277   0.028   0.023
##      Ineg ~
##      Ineg_lag1      0.143   0.023   6.096   0.000   0.143   0.143
##      Ipos_lag1      0.172   0.023   7.438   0.000   0.172   0.168
##      Iaro_lag1      0.021   0.026   0.800   0.424   0.021   0.017
##      Iaro ~
##      Iaro_lag1      0.428   0.020  21.743   0.000   0.428   0.427
##      Ipos_lag1     -0.037   0.017  -2.163   0.031  -0.037  -0.046
##      Ineg_lag1     -0.062   0.017  -3.552   0.000  -0.062  -0.078
##
## Covariances:
##      Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      .Ipos ~~
##      .Ineg      -3.417   0.123  -27.687   0.000  -3.417  -0.526
##      .Iaro       1.187   0.084  14.189   0.000   1.187   0.246
##      .Ineg ~~
##      .Iaro       1.771   0.088  20.117   0.000   1.771   0.360
##
## Intercepts:
##      Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      .Ipos      2.334   0.110  21.223   0.000   2.334   0.918
##      .Ineg      2.090   0.112  18.646   0.000   2.090   0.801
##      .Iaro      2.134   0.083  25.587   0.000   2.134   1.026
##
## Variances:
##      Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      .Ipos      6.371   0.152  42.048   0.000   6.371   0.986
##      .Ineg      6.619   0.157  42.048   0.000   6.619   0.972
##      .Iaro      3.665   0.087  42.048   0.000   3.665   0.847
##
##
## Group 2 [Black/African American]:
##
## Regressions:
##      Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      Ipos ~
##      Ipos_lag1      0.187   0.037   5.103   0.000   0.187   0.187

```

```

##      Ineg_lag1      0.192    0.039    4.939    0.000    0.192    0.191
##      Iaro_lag1     -0.107    0.043   -2.519    0.012   -0.107   -0.085
##      Ineg ~
##      Ineg_lag1      0.126    0.039    3.276    0.001    0.126    0.126
##      Ipos_lag1      0.148    0.036    4.077    0.000    0.148    0.149
##      Iaro_lag1      0.047    0.042    1.116    0.264    0.047    0.038
##      Iaro ~
##      Iaro_lag1      0.384    0.032   11.904    0.000    0.384    0.383
##      Ipos_lag1     -0.063    0.028   -2.256    0.024   -0.063   -0.079
##      Ineg_lag1     -0.070    0.029   -2.373    0.018   -0.070   -0.087
##
## Covariances:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
##      .Ipos ~~
##      .Ineg      -3.878    0.208  -18.626    0.000   -3.878   -0.559
##      .Iaro       1.324    0.143    9.241    0.000    1.324    0.250
##      .Ineg ~~
##      .Iaro       1.987    0.147   13.488    0.000    1.987    0.378
##
## Intercepts:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
##      .Ipos      2.358    0.179   13.156    0.000    2.358    0.882
##      .Ineg      2.015    0.178   11.343    0.000    2.015    0.759
##      .Iaro      2.529    0.136   18.606    0.000    2.529    1.187
##
## Variances:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
##      .Ipos      6.995    0.259   26.981    0.000    6.995    0.979
##      .Ineg      6.873    0.255   26.981    0.000    6.873    0.974
##      .Iaro      4.024    0.149   26.981    0.000    4.024    0.887
##
##
## Group 3 [Latino/Hispanic]:
##
## Regressions:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
##      Ipos ~
##      Ipos_lag1      0.075    0.037    2.005    0.045    0.075    0.075
##      Ineg_lag1      0.103    0.038    2.718    0.007    0.103    0.103
##      Iaro_lag1      0.194    0.040    4.903    0.000    0.194    0.189
##      Ineg ~
##      Ineg_lag1      0.135    0.038    3.516    0.000    0.135    0.135
##      Ipos_lag1      0.182    0.038    4.795    0.000    0.182    0.182
##      Iaro_lag1      0.041    0.040    1.034    0.301    0.041    0.040
##      Iaro ~
##      Iaro_lag1      0.484    0.035   13.933    0.000    0.484    0.483
##      Ipos_lag1      0.034    0.033    1.032    0.302    0.034    0.035
##      Ineg_lag1      0.004    0.033    0.120    0.905    0.004    0.004

```

```

##
## Covariances:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .Ipos ~~
## .Ineg      -2.914    0.168  -17.385    0.000   -2.914   -0.471
## .Iaro       1.895    0.139   13.610    0.000    1.895    0.354
## .Ineg ~~
## .Iaro       2.274    0.144   15.761    0.000    2.274    0.419
##
## Intercepts:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .Ipos        1.608    0.134   12.015    0.000    1.608    0.626
## .Ineg        1.754    0.136   12.923    0.000    1.754    0.684
## .Iaro        1.631    0.117   13.885    0.000    1.631    0.651
##
## Variances:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .Ipos        6.101    0.212   28.844    0.000    6.101    0.925
## .Ineg        6.273    0.217   28.844    0.000    6.273    0.955
## .Iaro        4.699    0.163   28.844    0.000    4.699    0.749
##
##
## Group 4 [White/Caucasian]:
##
## Regressions:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## Ipos ~
## Ipos_lag1     0.133    0.015    8.914    0.000    0.133    0.133
## Ineg_lag1     0.179    0.016   11.465    0.000    0.179    0.177
## Iaro_lag1    -0.014    0.018   -0.784    0.433   -0.014   -0.011
## Ineg ~
## Ineg_lag1     0.122    0.015    7.871    0.000    0.122    0.122
## Ipos_lag1     0.152    0.015   10.276    0.000    0.152    0.154
## Iaro_lag1    -0.046    0.018   -2.528    0.011   -0.046   -0.034
## Iaro ~
## Iaro_lag1     0.396    0.013   30.688    0.000    0.396    0.396
## Ipos_lag1    -0.078    0.011   -7.339    0.000   -0.078   -0.104
## Ineg_lag1    -0.090    0.011   -8.122    0.000   -0.090   -0.119
##
## Covariances:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .Ipos ~~
## .Ineg      -3.668    0.085  -42.934    0.000   -3.668   -0.542
## .Iaro       1.130    0.055   20.450    0.000    1.130    0.233
## .Ineg ~~
## .Iaro       1.761    0.057   30.889    0.000    1.761    0.365
##
## Intercepts:

```



```

##               Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .Ipos          2.241   0.077  29.102   0.000   2.241   0.849
## .Ineg          2.435   0.077  31.791   0.000   2.435   0.932
## .Iaro          2.493   0.055  45.420   0.000   2.493   1.260
##
## Variances:
##               Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .Ipos          6.800   0.107  63.687   0.000   6.800   0.977
## .Ineg          6.728   0.106  63.687   0.000   6.728   0.985
## .Iaro          3.457   0.054  63.687   0.000   3.457   0.882
##
##
## Group 5 [Other]:
##
## Regressions:
##               Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## Ipos ~
##   Ipos_lag1      0.086   0.050   1.721   0.085   0.086   0.086
##   Ineg_lag1      0.083   0.055   1.511   0.131   0.083   0.089
##   Iaro_lag1      0.094   0.062   1.530   0.126   0.094   0.078
## Ineg ~
##   Ineg_lag1      0.223   0.058   3.812   0.000   0.223   0.222
##   Ipos_lag1      0.241   0.053   4.534   0.000   0.241   0.225
##   Iaro_lag1     -0.013   0.065  -0.204   0.838  -0.013  -0.010
## Iaro ~
##   Iaro_lag1      0.225   0.049   4.595   0.000   0.225   0.225
##   Ipos_lag1      0.112   0.040   2.802   0.005   0.112   0.135
##   Ineg_lag1      0.072   0.044   1.647   0.099   0.072   0.093
##
## Covariances:
##               Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .Ipos ~~
##   .Ineg         -3.165   0.221 -14.296   0.000  -3.165  -0.571
##   .Iaro          0.464   0.145   3.190   0.001   0.464   0.111
## .Ineg ~~
##   .Iaro          2.278   0.172  13.219   0.000   2.278   0.516
##
## Intercepts:
##               Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .Ipos          2.175   0.229   9.483   0.000   2.175   0.940
## .Ineg          1.885   0.243   7.755   0.000   1.885   0.760
## .Iaro          2.331   0.183  12.760   0.000   2.331   1.216
##
## Variances:
##               Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .Ipos          5.233   0.257  20.396   0.000   5.233   0.977
## .Ineg          5.879   0.288  20.396   0.000   5.879   0.955
## .Iaro          3.320   0.163  20.396   0.000   3.320   0.904

```

```

##
##
## Group 6 [American Indian/Native American or Alaskan Native]:
##
## Regressions:
##           Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##   Ipos ~
##     Ipos_lag1      0.068    0.065    1.045    0.296    0.068    0.068
##     Ineg_lag1      0.089    0.061    1.456    0.145    0.089    0.112
##     Iaro_lag1     -0.131    0.072   -1.816    0.069   -0.131   -0.130
##   Ineg ~
##     Ineg_lag1      0.214    0.077    2.796    0.005    0.214    0.212
##     Ipos_lag1      0.177    0.081    2.178    0.029    0.177    0.140
##     Iaro_lag1     -0.013    0.090   -0.144    0.886   -0.013   -0.010
##   Iaro ~
##     Iaro_lag1      0.008    0.072    0.108    0.914    0.008    0.008
##     Ipos_lag1      0.125    0.065    1.919    0.055    0.125    0.124
##     Ineg_lag1      0.127    0.061    2.084    0.037    0.127    0.159
##
## Covariances:
##           Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##   .Ipos ~~
##     .Ineg          -1.208    0.152   -7.928    0.000   -1.208   -0.422
##     .Iaro           0.473    0.114    4.134    0.000    0.473    0.207
##   .Ineg ~~
##     .Iaro           1.578    0.160    9.840    0.000    1.578    0.551
##
## Intercepts:
##           Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##   .Ipos           1.975    0.189   10.472    0.000    1.975    1.302
##   .Ineg           1.486    0.236    6.288    0.000    1.486    0.770
##   .Iaro           1.681    0.189    8.904    0.000    1.681    1.097
##
## Variances:
##           Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##   .Ipos           2.284    0.158   14.422    0.000    2.284    0.992
##   .Ineg           3.587    0.249   14.422    0.000    3.587    0.963
##   .Iaro           2.287    0.159   14.422    0.000    2.287    0.974
##
##
## Group 7 [Decline to state]:
##
## Regressions:
##           Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##   Ipos ~
##     Ipos_lag1      0.050    0.100    0.507    0.612    0.050    0.050
##     Ineg_lag1      0.051    0.111    0.460    0.645    0.051    0.050
##     Iaro_lag1      0.123    0.114    1.075    0.282    0.123    0.116

```

```

##      Ineg ~
##      Ineg_lag1      0.143    0.108    1.322    0.186    0.143    0.144
##      Ipos_lag1      0.196    0.098    2.010    0.044    0.196    0.199
##      Iaro_lag1     -0.006    0.112   -0.049    0.961   -0.006   -0.005
##      Iaro ~
##      Iaro_lag1      0.286    0.105    2.725    0.006    0.286    0.286
##      Ipos_lag1      0.027    0.091    0.300    0.764    0.027    0.029
##      Ineg_lag1     -0.030    0.102   -0.300    0.764   -0.030   -0.032
##
## Covariances:
##              Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      .Ipos ~~
##      .Ineg      -1.966    0.363   -5.410    0.000   -1.966   -0.405
##      .Iaro       1.453    0.331    4.391    0.000    1.453    0.320
##      .Ineg ~~
##      .Iaro       2.285    0.347    6.577    0.000    2.285    0.512
##
## Intercepts:
##              Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      .Ipos       1.949    0.360    5.413    0.000    1.949    0.864
##      .Ineg       1.784    0.353    5.050    0.000    1.784    0.801
##      .Iaro       2.242    0.330    6.784    0.000    2.242    1.052
##
## Variances:
##              Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      .Ipos       4.953    0.486   10.198    0.000    4.953    0.973
##      .Ineg       4.766    0.467   10.198    0.000    4.766    0.962
##      .Iaro       4.173    0.409   10.198    0.000    4.173    0.919

```

- Black/African American:
 - Strongest Ipos inertia (0.187).
 - Arousal -> Positive emotion path is negative and significant (-0.085), suggesting arousal suppresses positivity here
- Latino/Hispanic:
 - Uniquely positive effect from arousal to positive emotion (0.189).
 - Had the strongest Iaro inertia (0.483).
- White/Caucasian:
 - Negative cross-effects from both Ipos to Iaro (-0.078) and Ineg to Iaro (-0.090), showing a strong regulatory suppression of arousal by both emotion valences.
 - Effects tend to be more stable across emotional domains.
- American Indian/Native American or Alaskan Native:
 - Strong influence of Ineg -> Iaro (0.127), suggesting arousal is reactive to negativity here

```

library(dplyr)
library(broom)

# cross-lagged paths to analyze
paths <- list(
  Ipos_on_Ineg = c("Ipos", "Ineg_lag1"),
  Ipos_on_Aro = c("Ipos", "Iaro_lag1"),
  Ineg_on_Ipos = c("Ineg", "Ipos_lag1"),
  Ineg_on_Aro = c("Ineg", "Iaro_lag1"),
  Iaro_on_Ipos = c("Iaro", "Ipos_lag1"),
  Iaro_on_Ineg = c("Iaro", "Ineg_lag1")
)

results <- data.frame(path = character(), r = numeric(), p = numeric())

# run regression for each path + correlation with age
for (path_name in names(paths)) {
  lhs <- paths[[path_name]][1]
  rhs <- paths[[path_name]][2]

  # model each participant
  path_df <- clpm_data %>%
    group_by(subj) %>%
    filter(!is.na(.data[[lhs]]), !is.na(.data[[rhs]])) %>%
    do(tidy(lm(as.formula(paste(lhs, "~", rhs)), data = .))) %>%
    filter(term == rhs) %>%
    rename(estimate = estimate) %>%
    left_join(select(dat, subj, age), by = "subj")

  # find correlation with age
  cor_result <- cor.test(path_df$estimate, path_df$age)

  results <- rbind(results, data.frame(
    path = path_name,
    r = cor_result$estimate,
    p = cor_result$p.value
  ))
}

print(results)

```

0.4.1.3 Difference in paths by age

```

##           path           r           p
## cor  Ipos_on_Ineg 0.124382721 1.763779e-57
## cor1 Ipos_on_Aro 0.202148879 1.272849e-150

```

```
## cor2 Ineg_on_Ipos -0.029140986 1.914050e-04
## cor3 Ineg_on_Aro -0.215376975 3.457817e-171
## cor4 Iaro_on_Ipos 0.009095577 2.444131e-01
## cor5 Iaro_on_Ineg -0.037882643 1.236128e-06
```

- Ipos_on_Ineg: As age increases, negative emotion exerts a stronger influence on subsequent positive emotion ($r = 0.124$, $p < .001$)
- Ipos_on_Aro: Higher arousal increasingly boosts next-step positive emotion with greater age ($r = 0.202$, $p < .001$)
- Ineg_on_Aro: Higher arousal is linked with lower next-step negative emotion, especially as age increases
- Iaro_on_Ineg: With age, the influence of negative emotion on subsequent arousal slightly decreases ($r = -0.038$, $p < .001$)