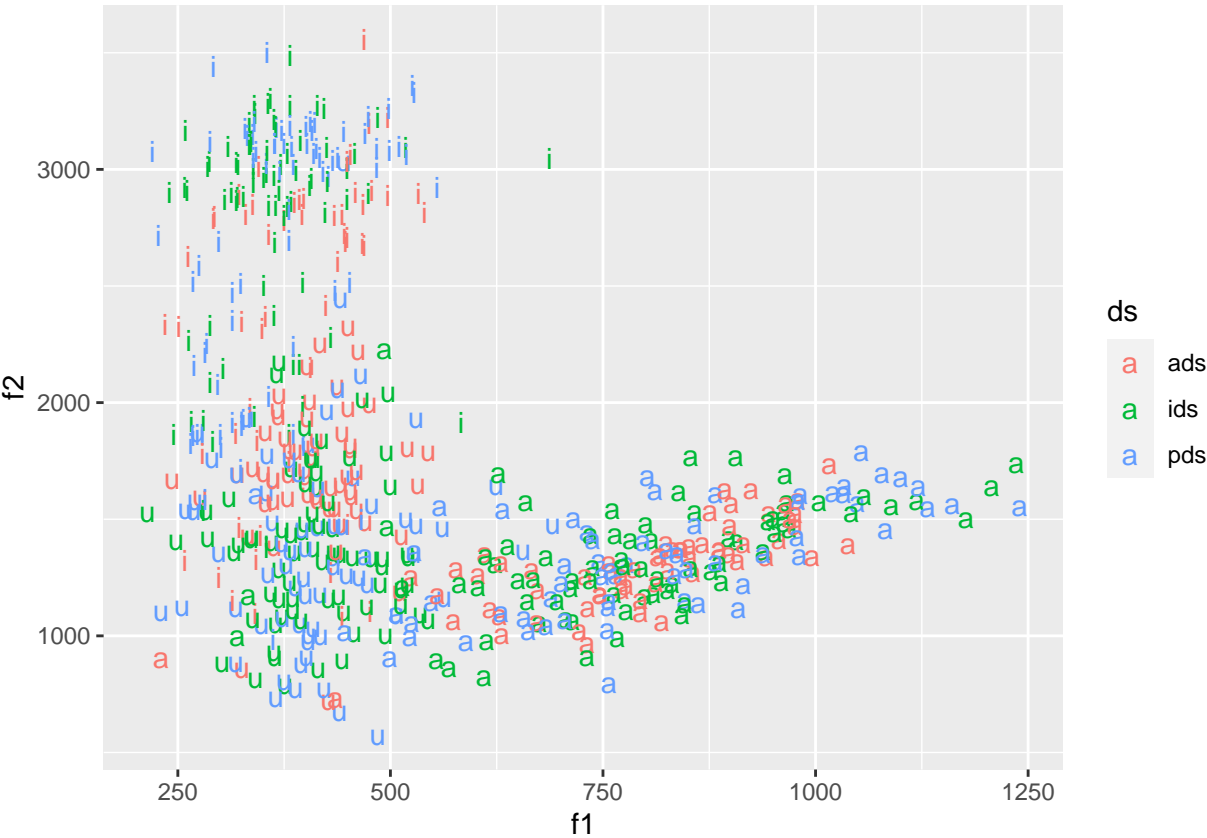# Supplementary materials: Hyperarticulation in Infant-Directed Speech as an Unintentional Consequence of Vocal Emotion

Contents

Initial data cleaning

[1] 614 11

Note there are no outliers:

Warning: Removed 3 rows containing missing values (geom_text).

##

```
## ball bead boot  box
##  105  209  201   99

## [1] 614  16

## `summarise()` has grouped output by 'motID', 'ds', 'v', 'stim_group'. You can override using the `.gr
```

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

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

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

Next we calculate vowel space for each mom and register.

```
## # A tibble: 3 x 2
##   ds        vss
##   <chr>   <dbl>
## 1 ads   596848.
## 2 ids   886587.
## 3 pds   842918.
```

Additional information on main analyses

Paired contrasts in vowel space size.

```
##
##  Paired t-test
##
## data:  vs$vss[vs$ds == "pds"] and vs$vss[vs$ds == "ids"]
## t = -0.4956, df = 9, p-value = 0.6321
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -242997.1  155658.9
## sample estimates:
## mean of the differences
##               -43669.08

##
## Cohen's d
##
## d estimate: 0.1559337 (negligible)
## 95 percent confidence interval:
##      lower      upper
## -0.7850539  1.0969214

##
##  Paired t-test
##
## data:  vs$vss[vs$ds == "ids"] and vs$vss[vs$ds == "ads"]
## t = 2.4351, df = 9, p-value = 0.03767
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##    20572.94 558905.61
## sample estimates:
## mean of the differences
```

```
##                  289739.3

##
## Cohen's d
##
## d estimate: -1.121556 (large)
## 95 percent confidence interval:
##       lower      upper
## -2.1322879 -0.1108244

##
##   Paired t-test
##
## data:  vs$vss[vs$ds == "pds"] and vs$vss[vs$ds == "ads"]
## t = 1.9906, df = 9, p-value = 0.07773
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##   -33574.0 525714.4
## sample estimates:
## mean of the differences
##                  246070.2

##
## Cohen's d
##
## d estimate: -0.9882865 (large)
## 95 percent confidence interval:
##         lower          upper
## -1.983551077   0.006978064
```

Duration and pitch analyses

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula: Vowel.Duration ~ ds * target + (1 + ds | motID)
##    Data: dat
##
## REML criterion at convergence: -1202.6
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.5120 -0.5243 -0.0814  0.3421  5.3534
##
## Random effects:
##  Groups   Name        Variance  Std.Dev. Corr
##  motID    (Intercept) 0.0007915 0.02813
##           dsids       0.0049585 0.07042  0.71
##           dspds       0.0016792 0.04098  0.41 0.42
##  Residual             0.0067777 0.08233
## Number of obs: 614, groups:  motID, 10
##
## Fixed effects:
##                    Estimate Std. Error        df t value Pr(>|t|)
## (Intercept)        0.195420   0.018230 32.341259  10.720 3.54e-12 ***
## dsids              0.071922   0.031004 23.340307   2.320   0.0294 *
```

```
## dspds               0.028832   0.025617  43.263609   1.126   0.2666
## targetbead          0.014766   0.019373 253.452590   0.762   0.4467
## targetboot         -0.025244   0.019137 254.312247  -1.319   0.1883
## targetbox          -0.007169   0.022381  84.997033  -0.320   0.7495
## dsids:targetbead    0.018547   0.025530 371.954675   0.726   0.4680
## dspds:targetbead    0.008486   0.026016 382.948878   0.326   0.7445
## dsids:targetboot   -0.038286   0.025470 375.205621  -1.503   0.1336
## dspds:targetboot   -0.012732   0.026305 366.612811  -0.484   0.6287
## dsids:targetbox    -0.014377   0.031213 160.492273  -0.461   0.6457
## dspds:targetbox     0.008059   0.032281 166.800408   0.250   0.8032
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##               (Intr) dsids  dspds  trgtbd trgtbt trgtbx dsds:trgtbd dspds:trgtbd
## dsids         -0.183
## dspds         -0.426  0.457
## targetbead    -0.714  0.405  0.494
## targetboot    -0.723  0.410  0.500  0.677
## targetbox     -0.658  0.365  0.448  0.616  0.624
## dsds:trgtbd    0.528 -0.567 -0.370 -0.746 -0.501 -0.449
## dspds:trgtbd   0.521 -0.300 -0.711 -0.735 -0.494 -0.445  0.552
## dsds:trgtbt    0.529 -0.571 -0.371 -0.496 -0.738 -0.449  0.675       0.365
## dspds:trgtbt   0.512 -0.296 -0.717 -0.480 -0.715 -0.435  0.360       0.686
## dsds:trgtbx    0.446 -0.525 -0.312 -0.418 -0.423 -0.681  0.605       0.308
## dspds:trgtbx   0.436 -0.250 -0.640 -0.409 -0.414 -0.666  0.304       0.603
##               dsds:trgtbt dspds:trgtbt dsds:trgtbx
## dsids
## dspds
## targetbead
## targetboot
## targetbox
## dsds:trgtbd
## dspds:trgtbd
## dsds:trgtbt
## dspds:trgtbt  0.532
## dsds:trgtbx   0.609        0.303
## dspds:trgtbx  0.305        0.613        0.467

## Warning: NAs introduced by coercion

## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula: Pitch ~ ds * target + (1 + ds | motID)
##    Data: dat
##
## REML criterion at convergence: 6746.6
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.3545 -0.5564 -0.1364  0.4836  8.8010
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  motID    (Intercept) 348.8    18.68
```

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```
##          dsids       3636.3   60.30    -0.59
##          dspds       1946.0   44.11    -0.44  0.98
##   Residual           4369.5   66.10
## Number of obs: 606, groups:  motID, 10
##
## Fixed effects:
##                  Estimate Std. Error       df t value Pr(>|t|)
## (Intercept)      200.1587    14.7500  42.3778  13.570   <2e-16 ***
## dsids             27.1051    26.6546  24.2858   1.017   0.3192
## dspds             46.6849    22.5136  31.7025   2.074   0.0463 *
## targetbead        -2.0223    16.1501 298.5380  -0.125   0.9004
## targetboot        11.7437    15.9741 294.1606   0.735   0.4628
## targetbox         -3.3188    18.8580 117.0155  -0.176   0.8606
## dsids:targetbead  16.4764    21.4548 503.9741   0.768   0.4429
## dspds:targetbead   0.1623    21.0737 336.0349   0.008   0.9939
## dsids:targetboot  25.0384    21.4710 504.4648   1.166   0.2441
## dspds:targetboot  11.1454    21.1429 288.3700   0.527   0.5985
## dsids:targetbox   10.9551    26.8979 343.5838   0.407   0.6841
## dspds:targetbox  -13.5956    25.4359 111.5193  -0.535   0.5941
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##              (Intr) dsids  dspds  trgtbd trgtbt trgtbx dsds:trgtbd dspds:trgtbd
## dsids        -0.660
## dspds        -0.630  0.768
## targetbead   -0.762  0.443  0.474
## targetboot   -0.772  0.449  0.479  0.701
## targetbox    -0.710  0.423  0.428  0.644  0.651
## dsds:trgtbd   0.595 -0.582 -0.395 -0.772 -0.546 -0.511
## dspds:trgtbd  0.562 -0.349 -0.651 -0.748 -0.517 -0.466  0.596
## dsds:trgtbt   0.597 -0.586 -0.397 -0.541 -0.765 -0.512  0.704       0.419
## dspds:trgtbt  0.554 -0.351 -0.653 -0.505 -0.730 -0.456  0.418       0.690
## dsds:trgtbx   0.536 -0.544 -0.371 -0.485 -0.491 -0.750  0.641       0.387
## dspds:trgtbx  0.485 -0.331 -0.573 -0.441 -0.445 -0.689  0.387       0.602
##              dsds:trgtbt dspds:trgtbt dsds:trgtbx
## dsids
## dspds
## targetbead
## targetboot
## targetbox
## dsds:trgtbd
## dspds:trgtbd
## dsds:trgtbt
## dspds:trgtbt  0.583
## dsds:trgtbx   0.645        0.390
## dspds:trgtbx  0.389        0.605        0.586
```

F1 and F2 analyses

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula: f1 ~ ds * target + (1 + ds | motID)
```

```
##    Data: dat
##
## REML criterion at convergence: 7352.5
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -4.9580 -0.5054 -0.0140  0.5005  3.6533
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  motID    (Intercept) 1802     42.46
##           dsids       1336     36.55    -0.69
##           dspds       2056     45.35    -0.75 0.75
##  Residual             11086    105.29
## Number of obs: 611, groups:  motID, 10
##
## Fixed effects:
##                  Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)        716.49      25.49   40.48  28.106  < 2e-16 ***
## dsids               16.74      30.00   45.67   0.558    0.580
## dspds               38.90      32.50   49.79   1.197    0.237
## targetbead        -322.74      25.82  458.13 -12.498  < 2e-16 ***
## targetboot        -306.20      25.51  458.03 -12.005  < 2e-16 ***
## targetbox          146.59      31.04  264.54   4.723 3.78e-06 ***
## dsids:targetbead   -38.79      33.04  424.12  -1.174    0.241
## dspds:targetbead   -55.05      34.15  492.90  -1.612    0.108
## dsids:targetboot   -12.69      32.94  417.43  -0.385    0.700
## dspds:targetboot   -35.35      34.39  447.67  -1.028    0.305
## dsids:targetbox    -12.15      40.21  148.61  -0.302    0.763
## dspds:targetbox    -37.64      42.66  239.88  -0.882    0.378
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##              (Intr) dsids  dspds  trgtbd trgtbt trgtbx dsds:trgtbd dspds:trgtbd
## dsids        -0.731
## dspds        -0.736  0.602
## targetbead   -0.707  0.579  0.550
## targetboot   -0.716  0.586  0.557  0.701
## targetbox    -0.666  0.535  0.516  0.652  0.659
## dsds:trgtbd   0.538 -0.758 -0.428 -0.767 -0.534 -0.489
## dspds:trgtbd  0.532 -0.446 -0.749 -0.753 -0.528 -0.489  0.584
## dsds:trgtbt   0.539 -0.762 -0.429 -0.528 -0.759 -0.489  0.683        0.404
## dspds:trgtbt  0.527 -0.445 -0.753 -0.516 -0.738 -0.483  0.402        0.701
## dsds:trgtbx   0.486 -0.694 -0.395 -0.476 -0.482 -0.734  0.613        0.369
## dspds:trgtbx  0.479 -0.404 -0.679 -0.469 -0.474 -0.720  0.364        0.625
##              dsds:trgtbt dspds:trgtbt dsds:trgtbx
## dsids
## dspds
## targetbead
## targetboot
## targetbox
## dsds:trgtbd
## dspds:trgtbd
```

```
## dsds:trgtbt
## dspds:trgtbt   0.569
## dsds:trgtbx    0.616        0.369
## dspds:trgtbx   0.364        0.632        0.552

## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula: f2 ~ ds * target + (1 | motID)
##    Data: dat
##
## REML criterion at convergence: 8892.5
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -4.3784 -0.4657  0.0809  0.6162  3.5867
##
## Random effects:
##  Groups    Name         Variance Std.Dev.
##  motID    (Intercept)  20970    144.8
##  Residual              146885    383.3
## Number of obs: 611, groups:  motID, 10
##
## Fixed effects:
##                   Estimate Std. Error       df t value Pr(>|t|)
## (Intercept)       1215.902     86.546   77.610  14.049  < 2e-16 ***
## dsids              121.682     92.610  589.882   1.314  0.18938
## dspds                5.147     96.225  590.271   0.053  0.95736
## targetbead        1166.371     89.679  597.501  13.006  < 2e-16 ***
## targetboot         500.447     88.580  597.450   5.650 2.49e-08 ***
## targetbox          189.969    103.213  598.231   1.841  0.06618 .
## dsids:targetbead   277.876    114.914  590.458   2.418  0.01590 *
## dspds:targetbead   327.536    117.963  590.915   2.777  0.00567 **
## dsids:targetboot  -454.262    114.473  590.218  -3.968 8.13e-05 ***
## dspds:targetboot  -330.646    117.766  590.092  -2.808  0.00516 **
## dsids:targetbox   -139.676    131.426  590.281  -1.063  0.28832
## dspds:targetbox     65.126    137.244  590.525   0.475  0.63530
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) dsids  dspds  trgtbd trgtbt trgtbx dsds:trgtbd dspds:trgtbd
## dsids       -0.613
## dspds       -0.592  0.551
## targetbead  -0.692  0.592  0.572
## targetboot  -0.701  0.599  0.578  0.674
## targetbox   -0.637  0.514  0.496  0.612  0.619
## dsds:trgtbd  0.507 -0.806 -0.445 -0.749 -0.495 -0.431
## dspds:trgtbd 0.495 -0.450 -0.817 -0.731 -0.483 -0.422  0.563
## dsds:trgtbt  0.507 -0.809 -0.446 -0.488 -0.740 -0.430  0.654        0.365
## dspds:trgtbt 0.485 -0.450 -0.816 -0.469 -0.713 -0.408  0.364        0.667
## dsds:trgtbx  0.432 -0.705 -0.389 -0.416 -0.422 -0.691  0.567        0.317
## dspds:trgtbx 0.415 -0.387 -0.701 -0.401 -0.405 -0.664  0.312        0.573
##             dsds:trgtbt dspds:trgtbt dsds:trgtbx
## dsids
```

```
## dspds
## targetbead
## targetboot
## targetbox
## dsds:trgtbd
## dspds:trgtbd
## dsds:trgtbt
## dspds:trgtbt  0.549
## dsds:trgtbx   0.570          0.317
## dspds:trgtbx  0.312          0.572          0.522
```

Variability analyses

We first get standard deviation of f1 and f2, separating by mom and register.

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

We then fit separate regressions to each?

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula: f1.sd ~ ds * target + (1 | motID)
##    Data: sds
##
## REML criterion at convergence: 803.1
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.5964 -0.5157  0.0173  0.4615  3.2291
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  motID    (Intercept)   95.23   9.758
##  Residual             1211.56  34.807
## Number of obs: 90, groups:  motID, 10
##
## Fixed effects:
##                 Estimate Std. Error     df t value Pr(>|t|)
## (Intercept)       112.08      17.95  77.95   6.245 2.07e-08 ***
## dsids             -10.49      24.61  69.22  -0.426 0.671215
## dspds              37.71      24.61  69.22   1.532 0.130086
## targetbead        -62.41      20.83  73.75  -2.997 0.003716 **
## targetboot        -69.92      20.83  73.75  -3.357 0.001247 **
## targetbox         -50.30      23.06  77.33  -2.181 0.032210 *
## dsids:targetbead   21.06      29.12  69.22   0.723 0.472112
## dspds:targetbead  -15.93      29.12  69.22  -0.547 0.586190
## dsids:targetboot   19.44      29.12  69.22   0.667 0.506734
## dspds:targetboot  -11.49      29.12  69.22  -0.394 0.694478
## dsids:targetbox   111.52      31.77  69.22   3.510 0.000794 ***
## dspds:targetbox    70.58      31.77  69.22   2.221 0.029616 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##              (Intr) dsids  dspds  trgtbd trgtbt trgtbx dsds:trgtbd dspds:trgtbd
```

```
## dsids          -0.686
## dspds          -0.686  0.500
## targetbead     -0.836  0.591  0.591
## targetboot     -0.836  0.591  0.591  0.721
## targetbox      -0.771  0.534  0.534  0.664  0.664
## dsds:trgtbd     0.580 -0.845 -0.423 -0.699 -0.499 -0.451
## dspds:trgtbd    0.580 -0.423 -0.845 -0.699 -0.499 -0.451  0.500
## dsds:trgtbt     0.580 -0.845 -0.423 -0.499 -0.699 -0.451  0.714        0.357
## dspds:trgtbt    0.580 -0.423 -0.845 -0.499 -0.699 -0.451  0.357        0.714
## dsds:trgtbx     0.531 -0.775 -0.387 -0.458 -0.458 -0.689  0.655        0.327
## dspds:trgtbx    0.531 -0.387 -0.775 -0.458 -0.458 -0.689  0.327        0.655
##               dsds:trgtbt dspds:trgtbt dsds:trgtbx
## dsids
## dspds
## targetbead
## targetboot
## targetbox
## dsds:trgtbd
## dspds:trgtbd
## dsds:trgtbt
## dspds:trgtbt  0.500
## dsds:trgtbx   0.655        0.327
## dspds:trgtbx  0.327        0.655        0.500

## boundary (singular) fit: see ?isSingular

## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula: f2.sd ~ ds * target + (1 | motID)
##    Data: sds
##
## REML criterion at convergence: 1019.6
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.7122 -0.5822 -0.0900  0.4701  3.3161
##
## Random effects:
##  Groups    Name         Variance Std.Dev.
##  motID     (Intercept)      0       0.0
##  Residual               20638     143.7
## Number of obs: 90, groups:  motID, 10
##
## Fixed effects:
##                  Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)        121.25      71.83   78.00   1.688  0.09541 .
## dsids               80.26     101.58   78.00   0.790  0.43189
## dspds               42.89     101.58   78.00   0.422  0.67400
## targetbead         488.77      84.99   78.00   5.751 1.65e-07 ***
## targetboot          65.34      84.99   78.00   0.769  0.44435
## targetbox          -45.07      92.73   78.00  -0.486  0.62831
## dsids:targetbead  -396.78     120.20   78.00  -3.301  0.00145 **
## dspds:targetbead  -212.95     120.20   78.00  -1.772  0.08035 .
## dsids:targetboot   -29.54     120.20   78.00  -0.246  0.80654
## dspds:targetboot    50.50     120.20   78.00   0.420  0.67553
```

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```
## dsids:targetbox      31.85      131.14   78.00    0.243  0.80876
## dspds:targetbox      21.80      131.14   78.00    0.166  0.86843
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##              (Intr) dsids  dspds  trgtbd trgtbt trgtbx dsds:trgtbd dspds:trgtbd
## dsids        -0.707
## dspds        -0.707  0.500
## targetbead   -0.845  0.598  0.598
## targetboot   -0.845  0.598  0.598  0.714
## targetbox    -0.775  0.548  0.548  0.655  0.655
## dsds:trgtbd   0.598 -0.845 -0.423 -0.707 -0.505 -0.463
## dspds:trgtbd  0.598 -0.423 -0.845 -0.707 -0.505 -0.463  0.500
## dsds:trgtbt   0.598 -0.845 -0.423 -0.505 -0.707 -0.463  0.714       0.357
## dspds:trgtbt  0.598 -0.423 -0.845 -0.505 -0.707 -0.463  0.357       0.714
## dsds:trgtbx   0.548 -0.775 -0.387 -0.463 -0.463 -0.707  0.655       0.327
## dspds:trgtbx  0.548 -0.387 -0.775 -0.463 -0.463 -0.707  0.327       0.655
##              dsds:trgtbt dspds:trgtbt dsds:trgtbx
## dsids
## dspds
## targetbead
## targetboot
## targetbox
## dsds:trgtbd
## dspds:trgtbd
## dsds:trgtbt
## dspds:trgtbt  0.500
## dsds:trgtbx   0.655        0.327
## dspds:trgtbx  0.327        0.655        0.500
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see ?isSingular
```

Figure of the vowel space