

Uncertain emotion discrimination differences between musicians and nonmusicians is determined by fine structure association: Hilbert transform psychophysics

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OSF: <https://osf.io/8ws7a>

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Abstract

We perceive musical sound as a complex phenomenon, which is known to induce an emotional response in humans. The cues used to perceive emotion in music have not been unequivocally elucidated. Here, we sought to identify the attributes of sound that confer an emotion to music and determine if professional musicians have different musical emotion perception than nonmusicians. The objective was to determine which sound cues are used to resolve emotional signals. Happy or sad classical music excerpts modified in fine structure or envelope conveyed different degrees of emotional certainty. The psychophysical emotional response of the modified excerpts was measure based on the originals. Certainty was determined by identification of the emotional characteristic presented during a forced-choice discrimination task. Participants were categorized as good or poor performers ($n = 32$, age 21.17 ± 2.63 SD) and in a separate group as musicians in the first or last year of music education at a conservatory ($n = 32$, age 21.97 ± 2.42). We found that temporal fine structure information is essential for correct emotional identification. Non-musically educated individuals used less fine structure information to discriminate emotion in music compared with musically educated individuals. The present psychophysical experiments revealed what cues are used to resolve emotional signals and how they differ between nonmusicians and musically educated individuals.

Code and Methods

The code for **figure 2** and **figure 4** can be found in `Final_figures.R`.

R 3.4.4, required packages

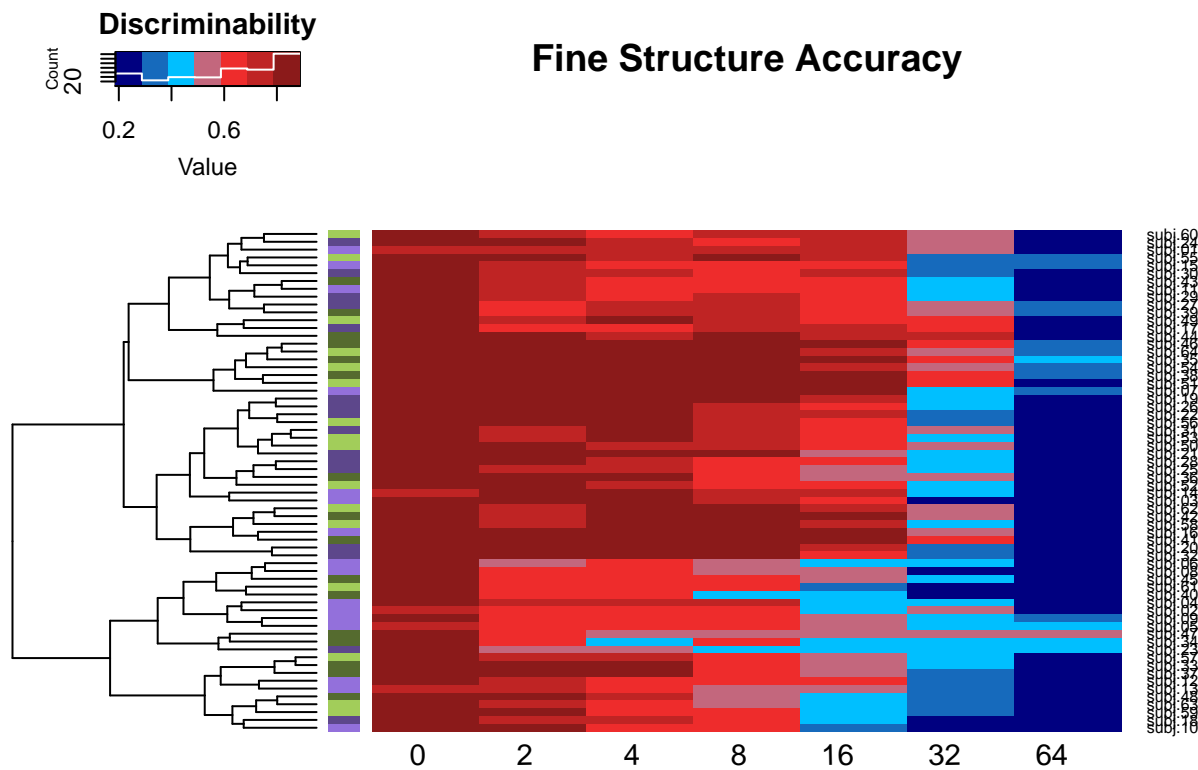
```
library(gplots)
library(gridExtra)
library(MASS)
library(pander)
library(magrittr)
library(dplyr)
library(ggplot2)
library(RCurl)
library(scatterplot3d)
library(klaR)
```

```
library(pander)
library(candisc)
```

Group Heatmaps

This was created calculating the accuracy of each subject per stimuli. First, stimuli were binarized based on the answer of **Fine structure emotion**, with 1 if it is correct and 0 when wrong. The total was divided by the total amount of stimuli or each category (nb0...nb64).

Accuracy for both emotions: All subjects



Fine Structure Accuracy by Gender

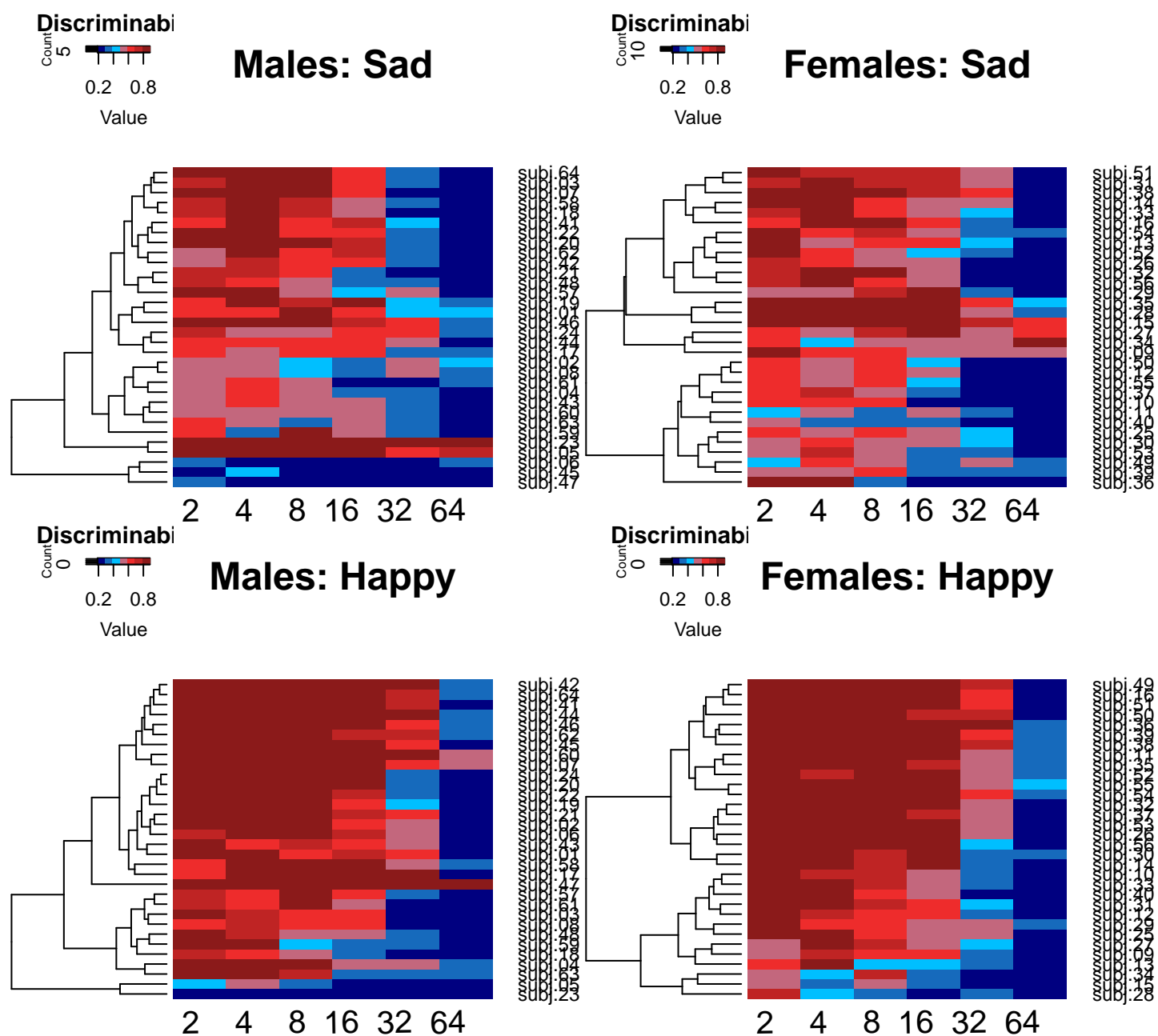
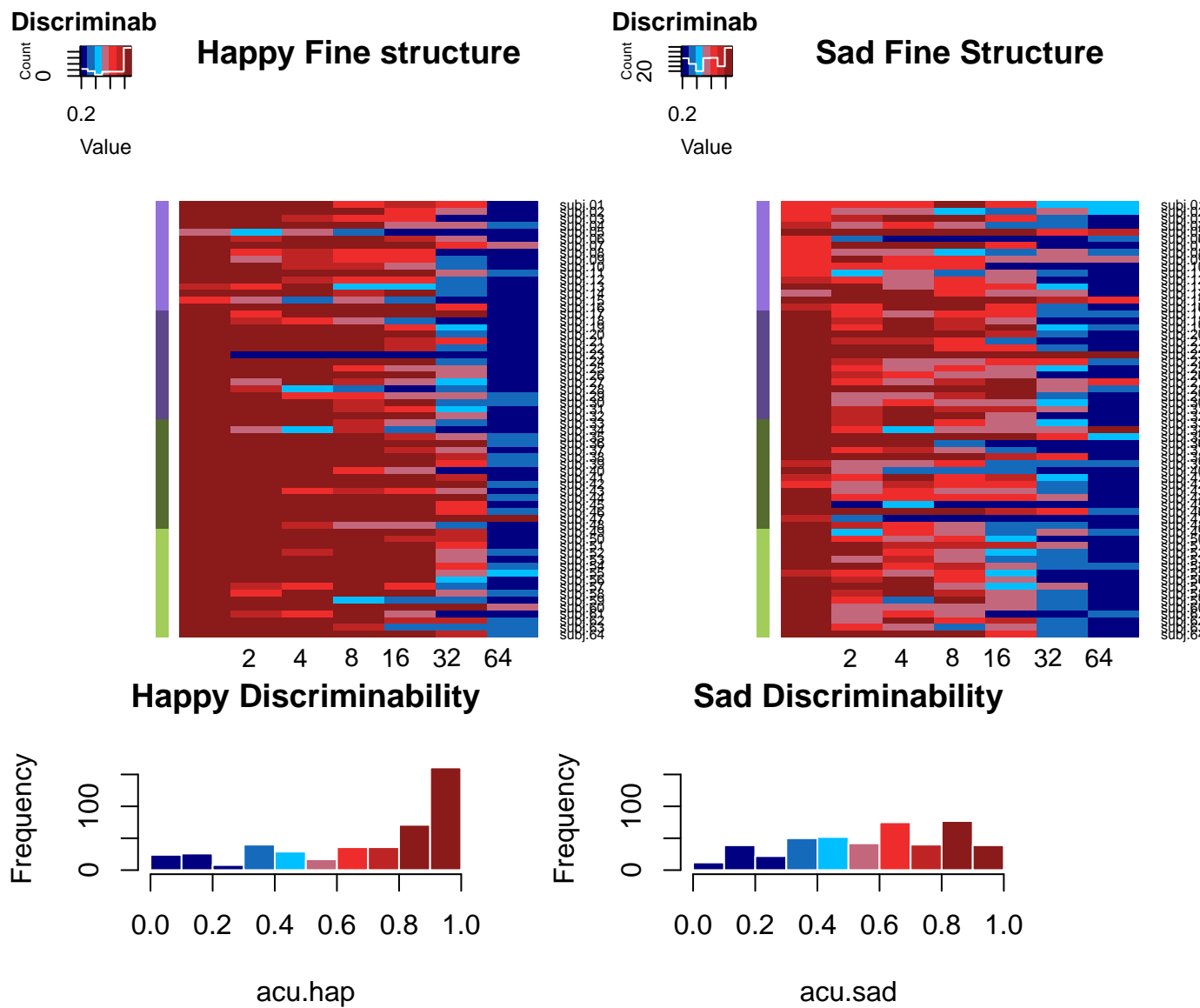
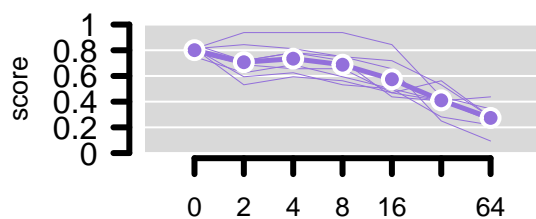


Figure 2. Accuracy and discriminability concerning Happy and Sad

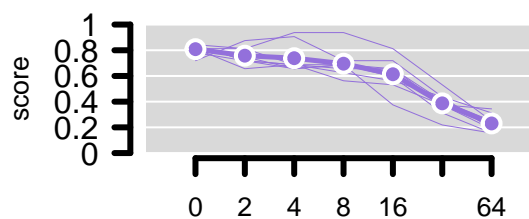


Accuracy calculated by subjects and group

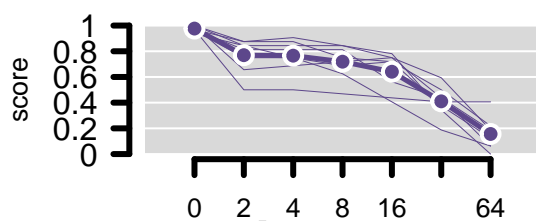
Poor Male



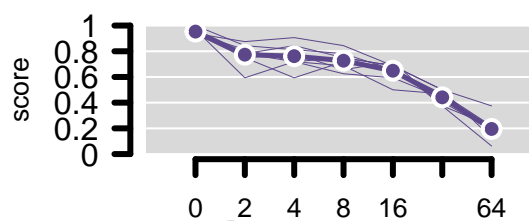
Poor Female



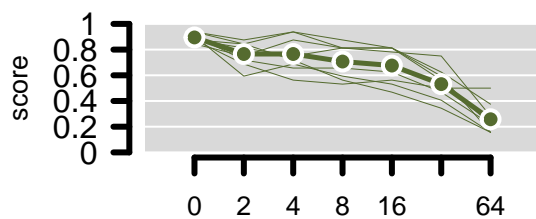
Good Male



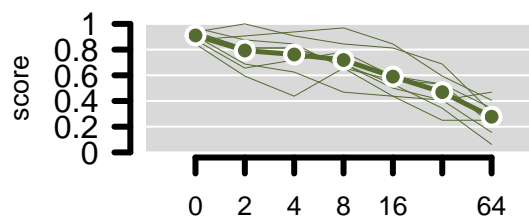
Good Female



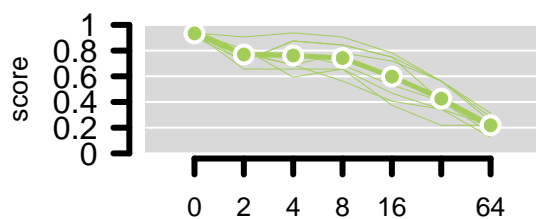
High Male



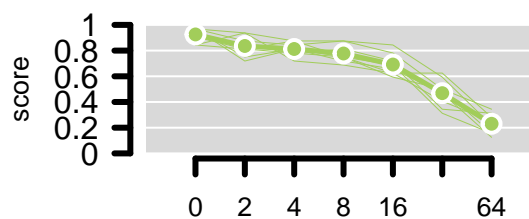
High Female



Low Male



Low Female



ANOVA: Comparisons between groups

Is accuracy in the response given by the class belonging and gender?

Table 1: ANOVA, accuracy by class

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|------------------------------|----|-----------|-----------|---------|-----------|
| factor(cases\$class) | 3 | 0.2268 | 0.0756 | 60.55 | 5.292e-18 |
| factor(cases\$gender) | 1 | 6.104e-05 | 6.104e-05 | 0.04888 | 0.8258 |
| Residuals | 59 | 0.07367 | 0.001249 | NA | NA |

- **factor(cases\$class):**

| | diff | lwr | upr | p adj |
|------------------|----------|-----------|-----------|-----------|
| high-best | -0.0625 | -0.09553 | -0.02947 | 3.147e-05 |
| low-best | -0.03516 | -0.06819 | -0.002127 | 0.03271 |
| poor-best | -0.1602 | -0.1932 | -0.1271 | 1.795e-11 |
| low-high | 0.02734 | -0.005686 | 0.06037 | 0.1383 |
| poor-high | -0.09766 | -0.1307 | -0.06463 | 6.858e-10 |
| poor-low | -0.125 | -0.158 | -0.09197 | 1.813e-11 |

- **factor(cases\$gender):**

| | diff | lwr | upr | p adj |
|------------|----------|----------|---------|--------|
| M-F | 0.001953 | -0.01572 | 0.01963 | 0.8258 |

Linear Discriminant Analysis: Happy

$Groupb0 + nb2 + nb4 + nb8 + nb16 + nb32 + nb64$

| best | high | low | poor |
|--------|--------|---------|-------|
| 0.2031 | 0.1406 | 0.07812 | 0.125 |

Table 5: LDA happy: Observed vs. Predicted Frequencies

| | best | high | low | poor | Sum |
|-----------------------|------|------|-----|------|-----|
| Predicted best | 13 | 2 | 4 | 2 | 21 |
| Predicted high | 1 | 9 | 5 | 2 | 17 |
| Predicted low | 1 | 4 | 5 | 4 | 14 |
| Predicted poor | 1 | 1 | 2 | 8 | 12 |
| Sum | 16 | 16 | 16 | 16 | 64 |

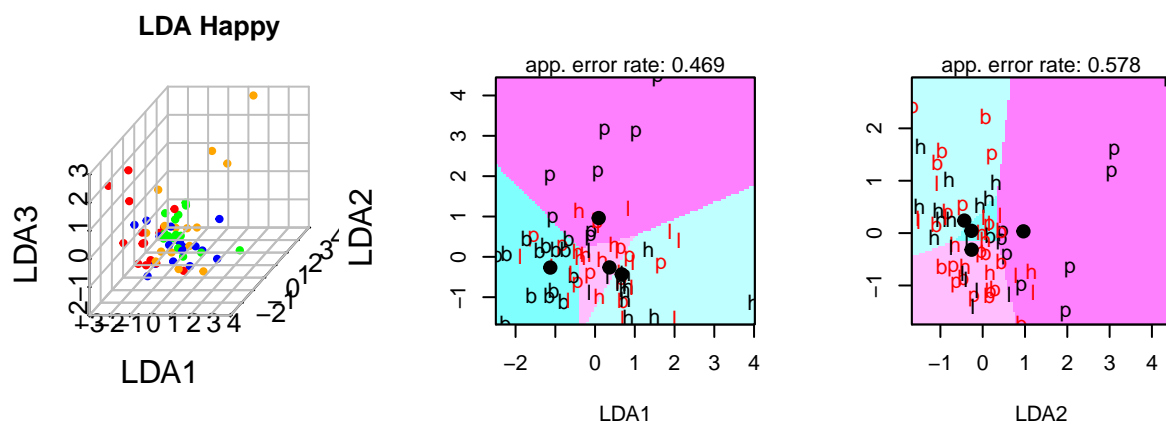
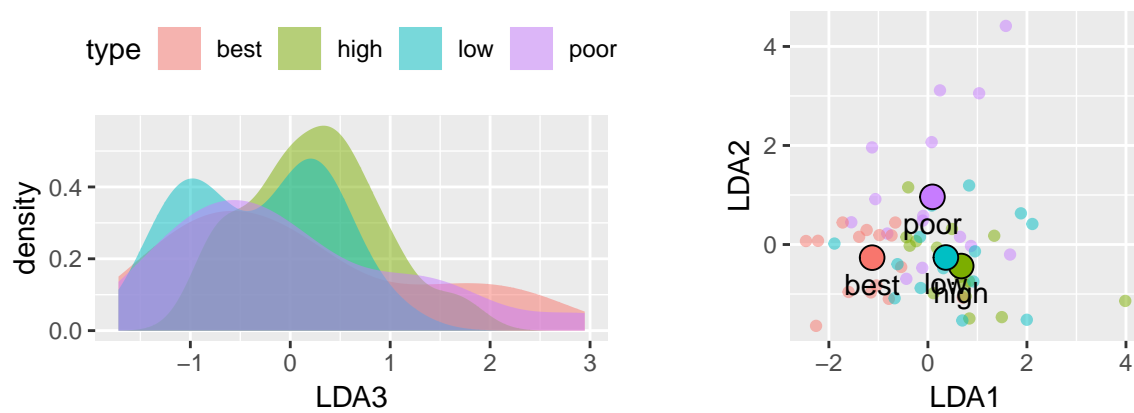
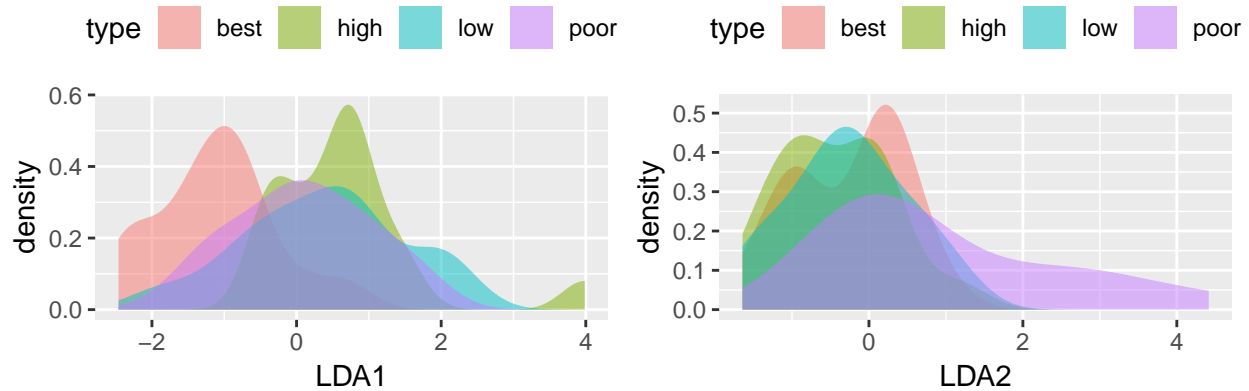
Happy total % correct: 0.546875

Table 6: LDA sad: Observed vs. Predicted Proportions %

| | best | high | low | poor | Sum |
|-----------------------|---------|---------|---------|---------|--------|
| Predicted best | 0.2031 | 0.03125 | 0.0625 | 0.03125 | 0.3281 |
| Predicted high | 0.01562 | 0.1406 | 0.07812 | 0.03125 | 0.2656 |
| Predicted low | 0.01562 | 0.0625 | 0.07812 | 0.0625 | 0.2188 |
| Predicted poor | 0.01562 | 0.01562 | 0.03125 | 0.125 | 0.1875 |
| Sum | 0.25 | 0.25 | 0.25 | 0.25 | 1 |

Table 7: Happy: group means by LDA

| type | LDA1 | LDA2 | LDA3 |
|------|---------|---------|---------|
| best | -1.126 | -0.2657 | 0.04361 |
| high | 0.6722 | -0.4348 | 0.2395 |
| low | 0.3626 | -0.262 | -0.317 |
| poor | 0.09148 | 0.9625 | 0.03394 |



Linear Discriminant Analysis: Sad

| best | high | low | poor |
|--------|-------|--------|--------|
| 0.1562 | 0.125 | 0.1562 | 0.2031 |

Table 9: LDA sad: Observed vs. Predicted Frequencies

| | best | high | low | poor | Sum |
|-----------------------|------|------|-----|------|-----|
| Predicted best | 10 | 0 | 1 | 2 | 13 |
| Predicted high | 2 | 8 | 4 | 0 | 14 |
| Predicted low | 4 | 4 | 10 | 1 | 19 |
| Predicted poor | 0 | 4 | 1 | 13 | 18 |
| Sum | 16 | 16 | 16 | 16 | 64 |

Sad total % correct: 0.640625

Table 10: LDA sad: Observed vs. Predicted Proportions %

| | best | high | low | poor | Sum |
|-----------------------|---------|--------|---------|---------|--------|
| Predicted best | 0.1562 | 0 | 0.01562 | 0.03125 | 0.2031 |
| Predicted high | 0.03125 | 0.125 | 0.0625 | 0 | 0.2188 |
| Predicted low | 0.0625 | 0.0625 | 0.1562 | 0.01562 | 0.2969 |
| Predicted poor | 0 | 0.0625 | 0.01562 | 0.2031 | 0.2812 |
| Sum | 0.25 | 0.25 | 0.25 | 0.25 | 1 |

Table 11: Happy: group means by LDA

| type | LDA1 | LDA2 | LDA3 |
|------|---------|---------|----------|
| best | -1.362 | 0.4542 | 0.1613 |
| high | 0.04957 | -0.4957 | 0.3254 |
| low | -0.6249 | -0.2197 | -0.4475 |
| poor | 1.937 | 0.2612 | -0.03927 |

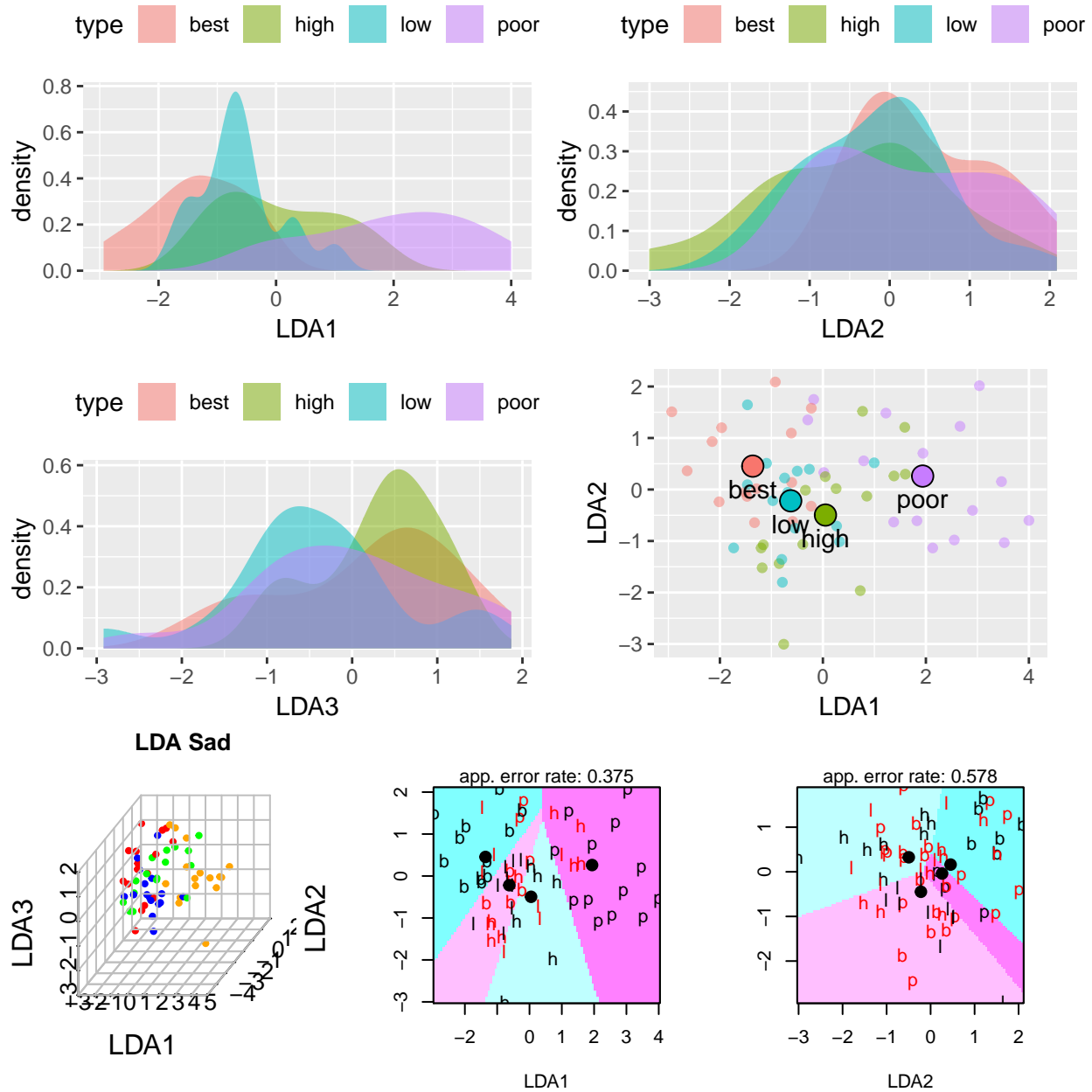


Figure 4. Cannonical Discriminant Analysis (CDA)

Two generalized canonical discriminant analysis was compute using the multivariate linear model:

$$\text{Group } nb0 + nb2 + nb4 + nb8 + nb16 + nb32 + nb64$$

to obtain the canonical scores and vectors, one for HAPPY and the other for SAD. It represents a transformation of the original variables in the sspace of maximal differences for the group. The biplot shows the canonical scores for the groups defined by the term as points and the canonical structure coefficients as vectors from the origin.

Standardized beta coefficients are given for each variable in each discriminant (canonical) function, and the larger the standardized coefficient, the greater is the contribution of the respective variable to the discrimination between groups. However, these coefficients do not tell us between which of the groups the respective functions discriminate.

Happy standardized coefficients

Table 12: Happy CDA standardized coefficients

| | Can1 | Can2 | Can3 |
|-------------|----------|----------|---------|
| nb0 | 0.6264 | 0.7113 | -0.3907 |
| nb2 | -0.1806 | 0.3608 | 0.1146 |
| nb4 | 0.507 | -0.6772 | -0.4067 |
| nb8 | -0.5025 | 0.3103 | -0.6578 |
| nb16 | -0.2266 | -0.4923 | -0.2479 |
| nb32 | -0.05239 | 0.7701 | 1.224 |
| nb64 | -0.7641 | -0.08169 | -0.24 |

Sad standardized coefficients

Table 13: Sad CDA standardized coefficients

| | Can1 | Can2 | Can3 |
|-------------|----------|----------|---------|
| nb0 | -1.011 | -0.05111 | 0.04974 |
| nb2 | -0.01097 | -0.1844 | 0.3217 |
| nb4 | 0.2952 | -0.4591 | -0.4602 |
| nb8 | -0.08152 | 0.8909 | 1.472 |
| nb16 | -0.2719 | 0.5762 | -1.304 |
| nb32 | 0.06616 | -0.4042 | -0.1513 |
| nb64 | 0.4193 | 0.4013 | -0.2076 |

The discriminant function coefficients denote the unique contribution of each variable to the discriminant function, while the structure coefficients denote the simple correlations between the variables and the functions

