

36-617: Applied Linear Models  
Fall 2022  
HW09 – Due Fri Nov 18, 11:59pm  
Grace until Sun Nov 20, 5:00pm

## Announcements

- Please submit a single pdf to Gradescope using the link in the Assignments page on Canvas, as usual.
- There are six exercises, beginning on p. 3 below. They are intended to be raw materials for the **Data, Technical Appendix** and **Discussion** sections of your final IDMRAD paper. So save all of your work and results as raw materials for the project paper.
- As with all hw in this class, you *are* allowed to collaborate on this. Please remember to list your collaborators and any other resources you used, in the pdf that you turn in.

## Background And Data

In 2012, Ivan Jimenez, a composer and musicologist visiting the University of Pittsburgh<sup>1</sup>, and student Vincent Rossi, collected data in a designed experiment intended to measure the influence of instrument, harmonic motion, and voice leading on listeners' identification of music as "classical" or "popular".

They presented 36 musical stimuli to 70 listeners, recruited from the population of undergraduates at the University of Pittsburgh, and asked the listeners to rate the music on two different scales:

- How classical does the music sound (1 to 10, 1 = not at all, 10 = very classical sounding);
- How popular does the music sound (1 to 10, 1 = not at all, 10 = very popular sounding).

Listeners were told that a piece could be rated as both classical and popular, neither classical nor popular, or mostly classical and not popular (or vice versa), so that the scales should have functioned more or less independently.

The 36 stimuli were chosen by completely crossing these factors:

**Instrument:** String Quartet, Piano, Electric Guitar

**Harmonic Motion:** I-V-vi, I-VI-V, I-V-IV, IV-I-V

**Voice Leading:** Contrary Motion, Parallel 3rds, Parallel 5ths

The researchers' main hypotheses were roughly these:

- Instrument should have the largest influence on rating;
- One particular harmonic progression, I-V-vi, might be frequently rated as classical, because it is the beginning progression for Pachelbel's *Canon in D*, which many people have heard. On the other hand, it is also a very common chord progression in popular music of the past 20 years or so—so common that comedy bits have been written about it, e.g. by the Axis of Awesome (<http://www.youtube.com/watch?v=o0lDewpCfZQ>) and by Rob Paravonian (<https://www.youtube.com/watch?v=JdxkVQy7QLM>).
- Based on previous research, it was expected that contrary motion would also be frequently rated as classical.

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<sup>1</sup>Now at the Sibelius Academy, University of the Arts, Helsinki Finland.

A powerpoint presentation exploring the data (looking at cell means only, no model fits) is available in the subdirectory “presentation” in the “hw09” area of our canvas pages, in which some of these ideas are explored more fully<sup>2</sup>. You can also click on and listen to some of the stimuli in the powerpoint presentation<sup>3</sup>.

A brief description of all variables in the data set follows:

X	Line number in the data set (IGNORE.)
Classical	How classical does the stimulus sound?
Popular	How popular does the stimulus sound?
Subject	Unique subject ID
Harmony	Harmonic Motion (4 levels)
Instrument	Instrument (3 levels)
Voice	Voice Leading (3 levels)
Selfdeclare	Are you a musician? (1-6, 1=not at all)
OMSI	Score on a test of musical knowledge
X16.minus.17	Auxiliary measure of listener’s ability to distinguish classical vs popular music
ConsInstr	How much did you concentrate on the instrument while listening (0-5, 0=not at all)
ConsNotes	How much did you concentrate on the notes while listening? (0-5, 0=not at all)
Instr.minus.Notes	Difference between prev. two variables
PachListen	How familiar are you with Pachelbel’s Canon in D (0-5, 0=not at all)
ClsListen	How much do you listen to classical music? (0-5, 0=not at all)
KnowRob	Have you heard Rob Paravonian’s Pachelbel Rant (0-5, 0=not at all)
KnowAxis	Have you heard Axis of Evil’s Comedy bit on the 4 Pachelbel chords in popular music? (0-5, 0=not at all)
X1990s2000s	How much do you listen to pop and rock from the 90’s and 2000’s? (0-5, 0=not at all)
X1990s2000s.minus.1960s1970s	Difference between prev variable and a similar variable referring to 60’s and 70’s pop and rock.
CollegeMusic	Have you taken music classes in college (0=no, 1=yes)
NoClass	How many music classes have you taken?
APTheory	Did you take AP Music Theory class in High School (0=no, 1=yes)
Composing	Have you done any music composing (0-5, 0=not at all)
PianoPlay	Do you play piano (0-5, 0=not at all)

<sup>2</sup>The data set you will be working with is slightly different from the one in the powerpoint presentation, so not all numerical summaries will be the same.

<sup>3</sup>You will have to download the directory, and enable access to external content in the dialog box at the beginning of the presentation, to hear the stimuli during the presentation (even so, I wasn’t able to get all of the audio to work; ymmv).

GuitarPlay	Do you play guitar (0-5, 0=not at all)
X1stInstr	How proficient are you at your first musical instrument (0-5, 0=not at all)
X2ndInstr	Same, for second musical instrument
first12	In the experiment, which instrument was presented to the subject in the first 12 stimuli? (IGNORE.)

The data is in the file “ratings.csv” in the hw09 area of the class website. While the data is fairly clean and well-organized, there are a few anomalies that you will have to decide what to do with as you work through data analyses. If you encounter any of these anomalies, please say how you dealt with each of them (including, possibly, not changing the data at all). Notes:

- You do not need to consider `X` or `first12` in any of your analyses.
- `Classical` and `Popular` are both discrete, but you should treat them as continuous response variables in all of your analyses.

## Exercises

*Your answer to question #1 will be raw materials for the **Data** section in your final IDMRAD paper. Your answers to the other questions below will be most or all of the technical appendix for your final IDMRAD paper, and will be summarized in a possibly reorganized form in the **Results** section of your paper.*

1. Explore the data, looking for usual or unusual relationships, usual or unusual data values, etc. Perform any data cleaning, transformations, etc. that may be needed; justify your actions. Submit a brief but interesting summary, with justifications.

In your work below, `Classical` should not appear in any models for `Popular`, nor vice-versa. When evaluating models, please remember to look at appropriate plots as well as test statistics.

2. The three main experimental factors.

- (a) Examine the influence of the three main experimental factors (Instrument, Harmony & Voice) on Classical ratings, using conventional linear models and/or analysis of variance models. Comment briefly on your findings, providing suitable brief evidence for each result. *Hint: Since there are only three factors here, it is worth considering interactions of all orders.*
- (b) Since we have approximately 36 ratings from each participant, we can expand the model in part 2a by including a random intercept for each participant. Such a model is sometimes called a “repeated measures” model.
  - i. Write this expanded model in mathematical terms as a multi-level model, using notation we have used in class. Be sure to carefully identify what are the groups, and what are the individual observations.
  - ii. Re-examine the influence of the three main experimental factors (Instrument, Harmony & Voice) on Classical ratings (that is, repeat part 2a), using models that always include the random intercept for participants<sup>4</sup>.
  - iii. Is the random effect needed? Justify your answer with evidence. You may (or may not) find valid evidence in fitted models, in statistical tests, and/or in fit indices.

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<sup>4</sup>Please make sure the models are fitted with `REML=FALSE` (i.e. maximum likelihood) to ensure that the model comparisons make sense.

- (c) The random intercept in a repeated measures model can account for “personal biases” in ratings: for example, perhaps person A is more inclined to rate everything as classical, and person B is more inclined to rate everything as popular. This can be accounted for by the random intercept. Alternatively, perhaps personal biases vary with the type of instrument, type of harmony, and/or type of voice leading. For example, perhaps people vary in the degree to which they are inclined to call music played by a string quartet “classical”. This suggests, e.g., a random effect of the form (Instrument|Subject) or  $(0 + \text{Instrument}|\text{Subject})$  (and similarly for Harmony and Voice). One could argue for a similar random effect for each person/harmony combination, and for each person/voice leading combination.
- Determine whether the model in 2(b)ii is improved by adding one or more of these three new random effect terms. Find the best combination of these terms<sup>5</sup> and provide suitable evidence for your answer.
  - Re-examine the influence of the three main experimental factors (Instrument, Harmony & Voice) on Classical ratings, using the random effects you found in part (i). Comment briefly on your findings, providing suitable brief evidence for each result. In addition, comment on the sizes of the variances of whichever random effects you added to the model, with respect to each other and with respect to the estimated residual variance.
  - Carefully write this model in mathematical terms as a hierarchical linear model, using notation from class. Indicate values of estimated parameters (and their SE’s, if available).

Because they are design variables in the experiment, the main effects for the three experimental factors, Instrument, Harmony, and Voice, should be included in all models for the remainder of this homework, regardless of what you found about their influence or lack of influence on ratings. (Interactions among the design variables need not be included if you do not find them important, but the main effects for the design variables should **always** be in your models.)

- Person covariates. For this problem, begin with your best model from problem 2.
  - Determine which person covariates should be added to the model as fixed effects. Show a suitable summary of your work, and list the final set of variables that you would include in the model. *Hint: Some covariates that are actually factor variables are coded as numeric. Be careful to treat them as factors!*
  - Once the fixed effects are settled, go back and check to see whether there should be any change in the random effects; focus on random slopes for design variables and their interactions. Provide suitable evidence to justify your results.
  - Briefly interpret the effect of each variable kept in the final model, on Classical ratings.
- Musicians vs. Non-musicians. One of the secondary hypotheses of the researchers is that people who self-identify as musicians may be influenced by things that do not influence non-musicians. Dichotomize “Self-declare” (“are you a musician?”) so that about half the participants are categorized as self-declared musicians, and half not. Examine and report on any interactions between the dichotomized musician variable and other predictors in the model. Check to see if the results are sensitive to where you dichotomize. Provide suitable evidence for, and comment on, your results.
- Classical vs. Popular. It would be totally appropriate to repeat problems 3, 4 and 5 using “Popular” ratings as the response, rather than classical, and then compare the results for “Classical” ratings, vs. “Popular” ratings. *In the interest of time, you do not have to do this for this hw/project. It would make good “future work” for the paper; and/or it is something you could pursue on your own, if you are curious about it.*

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<sup>5</sup>A good rule of thumb is to only include a term like (Voice|Subject) in the model if Voice is already a fixed effect.

6. *Brief writeup*. Write an approximately one or two page professional-quality summary<sup>6</sup> of your findings, suitable for Dr. Jimenez. Be sure to address:

- The influence of the three main experimental factors (Instrument, Harmony & Voice);
- A brief discussion of variance components—is this a standard repeated measures model, or did we need to include other variance components?
- A discussion of other individual covariates in the model.

You may refer to your earlier work (e.g. “As I showed in my answer to part 2b, blah-blah-blah. . .”). Don’t be sloppy about the statistical findings, but try to highlight things that will be of substantive interest to Dr. Jimenez. Make your summary very readable and clear.

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<sup>6</sup>This should form raw materials for the **Discussion** section of your final IDMRAD paper, so please review what should be in the **Discussion** section of an IDMRAD or IMRAD paper. Also, try to keep this close to one or two pages.