36-617: Applied Linear Models
Fall 2019
HW10 – Due Sun 24 Nov 2019, 11:59pm
Grace until Tue 26 Nov 2019, 11:59pm

Announcements

- Please submit to the gradescope link under "hw10" in the assignments area on canvas.
- The exercises, which begin on p. 3 below, are intended to be the basis of a technical appendix for your last project. So save all of your work and results as raw materials for the project paper.

Background And Data

In 2012, Ivan Jimenez, a composer and musicologist visiting the University of Pittsburgh[1], and student Vincent Rossi, collected data in a designed experiment inteneded 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 by the Axis of Evil (http://www.youtube.com/watch?v=oOlDewpCfZQ) 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.

A powerpoint presentation exploring the data (looking at cell means only, no model fits) is available in the subdirectory "presentation" in the "hw10" area of our canvas pages, in which some of these ideas are explored more fully[2]. You can also click on and listen to some of the stimuli in the powerpoint presentation[3].

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[1] Now at the Sibelius Institute, University of the Arts, Helsinki Finland.

[2] 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.

[3] 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).

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

```
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)
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 FOR THIS ASSIGNMENT.)
```

The data is in the file "ratings.csv"in the hw10 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).

Exercises

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. *You do not need to consider* `X` *or* `first12` *in any of your analyses.* `Classical` *and* `Popular` *are both discrete, but we will treat them as continuous response variables.* 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 fit a random intercept for each participant if we wish. Such a model is sometimes called a "repeated measures" model.

      i. Carefully write this model in mathematical terms as a hierarchical linear model, using notation we have used in class.

      ii. Use at least one method discussed in class to test whether the random intercept is needed in the model. Is the random effect needed? Justify your answer with evidence from your test(s).

      iii. Re-examine the influence of the three main experimental factors (Instrument, Harmony & Voice) on Classical ratings, using the repeated-measures model with the random intercept for participants[4].

   (c) The random intercept in a repeated measures model can account for "personal biases" in ratings: 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)`. One could argue for a similar random effect for each person/harmony combination, and for each person/voice leading combination.

      i. Determine whether the model in 2(b)iii is improved by adding one or more of these three new random effect terms. Find the best combination of these terms[5]; provide suitable evidence for your answer.

      ii. 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.

      iii. 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).

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[4]Please make sure the models are fitted with REML=FALSE (i.e. maximum likelihood) to ensure that the model comparisons make sense.

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

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 may be included if you find them important, but the main effects for the design variables should always be in your models.)

3. *Individual covariates.* For this problem, begin with your best model from problem 2.

   (a) Determine which individual covariates should be added to the model as fixed effects. If you do this by hand, check your work with an automatic method. If you do this with an automatic method, check to make sure that the choices make sense, musically and statistically. 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!*

   (b) 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.

   (c) Briefly interpret the effect of each variable kept in the final model, on Classical ratings.

4. *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.

5. *Classical vs. Popular.* Please re-examine the data in terms of the "Popular" ratings, instead of the "Classical" ratings, using similar hierarchical linear models. Provide brief answers to the following questions:

   (a) Comment on the influence of Instrument, Harmony & Voice on Popular ratings, providing suitable brief evidence for each result.

   (b) Question 3c, for Popular ratings.

   (c) Question 4, for Popular ratings.

6. *Brief writeup.* Write an approximately one page professional-quality summary[6] of your findings for Classical and Popular ratings, 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 indivdual 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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[6]This should look a lot like the discussion section of an IMRAD paper, so please review what should be in a discussion section. Also, try to keep this close to one page.