

Least-Squares Repeated Measures ANOVA in R Using aov()

Another way linear least-squares RM ANOVA can be performed is in the same way we have done with other ANOVA models in R up to now—that is, by using an `aov()` linear model, and I will demonstrate that method in this section. An advantage of this type of analysis is that it is consistent with the approach we’ve taken in ANOVA up to now, the modeling makes what we are doing transparent, and if you understand what’s going on here you will feel very comfortable with the mixed-effects model syntax in the section titled “Mixed-effect Models in R.” In order to model the repeated measures, we add an “Error” term that contains the “subjects” term, plus the within-subjects variables with variables listed from largest to smallest if there is any hierarchy to the data (Baron & Li, 2003; Crawley, 2007; Revelle, 2005). However, one drawback of this method is that it does not give any correction factors for violations of sphericity.

For the Murphy (2004) data, we will be using the `murphy.long` dataset. We are asking whether verb type, verb similarity, and age/NS status (in the “group” variable) affect how often participants attach the regular past-tense [-ed] ending. The response variable with scores is called `value`. The variables `type`, `similarity` and `group` are categorical explanatory variables. Two are within-subject variables (`type` and `similarity`) and one is a between-subject variable (`group`). We will put only the within-subject variables in the “Error” section of the model, not the between-subject variable.

In order for this modeling to work properly, it is very important that your data have the correct structure. Check the structure with the `str()` command, and make sure all of your categorical variables are factors *as well as* your subject or participant variable.

```
> str(murphy.long)
'data.frame':  360 obs. of  6 variables:
 $ group      : Factor w/ 3 levels "NS children",...: 1 1 1
 $ participant: Factor w/ 60 levels "1","2","3","4",...: 1 2
 $ variable   : Factor w/ 6 levels "reg_proto","reg_int",...
 $ value      : num  5 5 5 5 5 5 5 5 5 5 ...
 $ type       : chr  "reg" "reg" "reg" "reg" ...
 $ similarity  : chr  "proto" "proto" "proto" "proto" ...
```

If your participant variable is not a factor then make it one like this:

```
murphy.long$participant=as.factor(murphy.long$participant)
```

Now we can model:

```
murphy.aov=aov(value~(type*similarity*group)+
Error(participant/type*similarity),data=murphy.long)
summary(murphy.aov)
```

Table 1 gives the syntax that would be used for differing numbers of within-subject and between-subject variables (Revelle, 2005).

Table 1 Syntax for RM ANOVA **aov()** command with differing numbers of within-subject and between-subject variables

| Number of within-subject variables | Number of between-subject variables | Model formula |
|------------------------------------|-------------------------------------|---|
| 1 | 0 | <code>aov(DV~IV + Error (Subject/IV), data=data)</code> |
| 2 | 0 | <code>aov(DV~IV*IV + Error (Subject/IV*IV), data=data)</code> |
| 3 | 0 | <code>aov(DV~IV*IV*IV + Error(Subject/(IV*IV*IV)), data=data)</code> |
| 2 | 1 | <code>aov(DV~~(IV_{btw}*IV*IV) + Error(Subject/(IV*IV)), data=data)</code> |
| 2 | 2 | <code>aov(DV~~(IV_{btw}* IV_{btw} *IV*IV) + Error(Subject/(IV*IV)) , data=data)</code> |

The pattern for how many times to enter the variable (only in the main part of the model or also in the “Error” term of the variable as well is clear—within-subject variables are entered twice, but between-subject variables are only entered once, in the main part of the model. Note that the order of the between-subject variables and within-subject variables actually doesn’t matter.

I will now analyze the output of the repeated measures **aov()** model, which seems a little more convoluted than the **ezANOVA** output but which pretty much gives the same results. All of the sections are labeled “Error” but the first section (“Error: participant”) concerns the between-subjects effect. This is the first section of output:

```
Error: participant
      Df Sum Sq Mean Sq F value Pr(>F)
group    2  21.51   10.753    5.665 0.0057 **
Residuals 57 108.19    1.898
```

Here we only have one between-subjects variable, that of group, and so we can see that the effect of group is statistical because the p -value, found in the column labeled “Pr(>F)” is less than .05.

We will want to note a couple more pieces of information about this interaction, which are the F -value and the degrees of freedom, and report that the main effect of group was statistical,

($F_{2,57}=5.67$, $p=.006$, partial eta-squared= $(2*5.67 / ((2*5.67) + 57) = .17)$).

For the within-subject effects we get a result for the main effect of verb similarity (similarity):

```
Error: similarity
      Df Sum Sq Mean Sq
similarity  2  32.37   16.19
```

Next is the main effect for verb type, and the two-way interaction between verb type and group:

```
Error: participant:type
      Df Sum Sq Mean Sq F value Pr(>F)
type    1 138.14   138.14   233.2 <2e-16 ***
type:group  2   2.61    1.30    2.2  0.12
Residuals 57  33.76    0.59
```

Remember, one of the features of repeated measures is that instead of using the same error term as the denominator for every entry in the ANOVA table, an RM ANOVA is able to use different

(appropriate) error terms as denominators and thus factor out subject differences. In R these error terms are the row labeled “Residuals,” and each section that is separated is using a different error term, that is why it is separated.

Next is the two-way interaction between verb similarity and group:

```
Error: participant:similarity
              Df Sum Sq Mean Sq F value    Pr(>F)
similarity:group  4   6.68   1.6694     3.942 0.00492 **
Residuals       114  48.28   0.4235
```

And last is the two-way interaction between type and similarity, and the three-way interaction between verb similarity, verb type, and group:

```
Error: participant:type:similarity
              Df Sum Sq Mean Sq F value    Pr(>F)
type:similarity  2  62.54  31.269    62.630 <2e-16 ***
type:similarity:group  4   6.54   1.636     3.277 0.0139 *
Residuals         114  56.92   0.499
```

The process of understanding and reporting on these effects is the same as for the `ezANOVA()` command so I will refer the reader back to Section 11.5.3 for that. There is no test for sphericity and we cannot use correction factors as none are given. For descriptive statistics, use the `tapply()` command, substituting in mean and `sd` at the end of the term where I now show the syntax that will give you counts:

```
tapply(murphy.long$value, list(Group=murphy.long$group,
VerbType=murphy.long$type, Similarity= murphy.long$similarity), function(x)
```

```
sum(!is.na(x)))
```

Performing an RM ANOVA with R the aov() way (fixed effects only)

Use an `aov()` linear model and add an “Error” term that contains the “subjects” term, plus the within-subjects variables with variables listed from largest to smallest if there is any hierarchy to the data. Here is one example for 2 within-group variables (A and B) and one between-group variable (`Group`).

```
model.aov=aov(DepVar~(VarA*VarB*Group)+  
Error(Participant/VarA*VarB), data=dataset
```

Examples of other configurations are shown in the text.

Bibliography

Baron, J., & Li, Y. (2003). Notes on the use of R for psychology experiments and questionnaires.

Retrieved February 15, 2006, from

<http://www.psych.upenn.edu/~baron/rpsych/rpsych.html>

Crawley, M. J. (2007). *The R book*. New York: Wiley.

Murphy, V. A. (2004). Dissociable systems in second language inflectional morphology. *Studies in Second Language Acquisition*, 26(3), 433–459.

Revelle, W. (2005). Using R for psychological research: A simple guide to an elegant package.

In www.personality-project.org/r/r.guide.html (Ed.)