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Notes from the Emerson Lab

Demystifying Statistics: On the interpretation of ANOVA effects

August 12, 2008 Leave a comment Go to comments

One of the statistical concepts that is very difficult for many people to grasp, yet critically important for an understanding of statistics, is the interpretation of significant effects in an Analysis of Variance (ANOVA). In this post, I will use a graphical approach to describe how to interpret effects from a two-way factorial ANOVA. I will not delve into the design, implementation, or computation involved in such ANOVAs.

Suppose we have an experiment where we are measuring a biological trait from each of two species (Sp1, Sp2) raised in each of two environments (Env1, Env2). We set up a two-way ANOVA and out pops an ANOVA table with four lines, one each for the species effect, the environment effect, the species-by-environment interaction effect, and one for the residuals (which I hope to discuss in detail in a later post, and will not talk about here.

ANOVAs are designed to look for differences in mean values accross different groupings of the data. In the case above, it is looking for a difference in mean trait values between the two species and between the two environments, while simultaneously testing for their independence (with the interaction term). So in order to look at a graph and think about ANOVAs, you have to think about mentally picturing the various means.

The first two effects are pretty straightforward to interpret. Suppose the analysis showed a significant Species effect. This means that there is a significant difference among species in the mean trait measure when pooled accross environments. Maybe that Sp1 always has a bigger eyeball width than Sp2, or something like that. Same thing with a significant environment effect; maybe both species do better in tropical vs. desert conditions.

It is the interaction term that is the hard term to understand for many people. A significant interaction term signifies a *lack of independence* of the other two variables, in this case species and environment. In this example, an interaction term may imply that there is environmental preference among species, with Sp1, say, preferring Env1 and Sp preferring Env2. Another way to think about significant interaction terms is in an Analysis of CoVAriance (ANCOVA) setting, where the two slopes are different (see below).

I find it easiest to think about these things graphically so below you will find the 7 different qualitative results for significant effects in a two-way ANOVA. These are the pics that always pop into my head when I think about ANOVAs. They are interaction plots of the two variables.

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(Disclaimer – These graphs do not include error bars. This is purely for clarity of making my point, any time figures like these are published, they should include estimates of error – as discussed here).

Let's start with cases where there is no, or only one, significant effect:

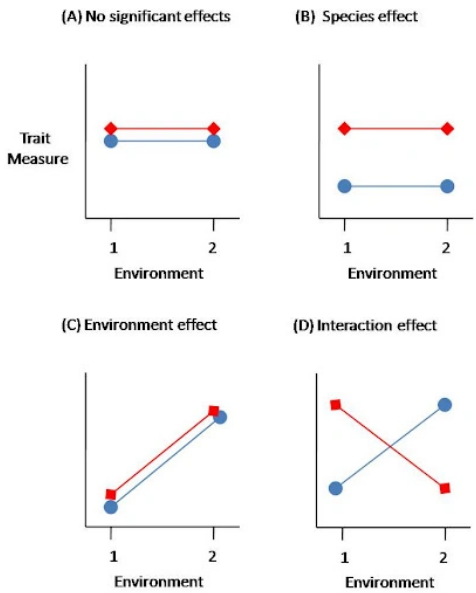


Figure (A) – there are no significant effects. There is no difference in means either between environments or species, and there is no interaction term as the two are independent, and the slopes of the lines are the same.

Figure (B) – a significant species effect. In this case there is no difference in the mean trait value across environments (it falls between the two lines), but the mean for each species is different. The slopes are equal so there is no significant interaction.

Figure (C) – a significant environment effect. Here there is a difference among the means of the two environments, but not a difference in the means among species. Again the slopes are equal.

Figure (D) – a significant interaction effect. In this case there is a significant interaction effect as the slopes are not equal. In this case there are no other effects as the means of the environments nor species differ. *This is important as many people mistakingly believe that there cannot be a significant interaction term if neither of the main effects are significant. This shows that it is possible.*

Now let's move on to cases where there is more than one significant effect:

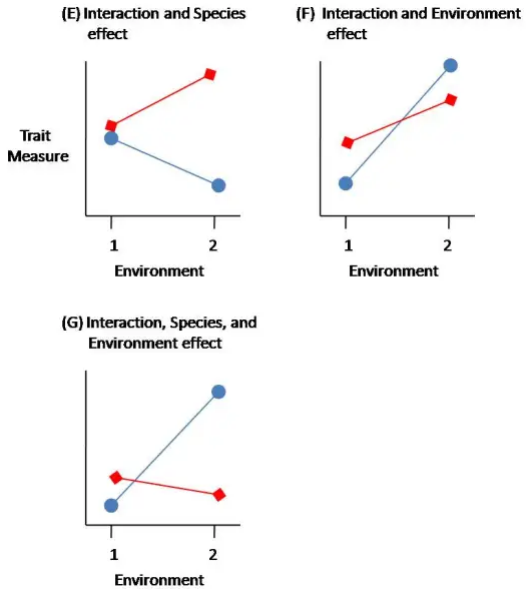
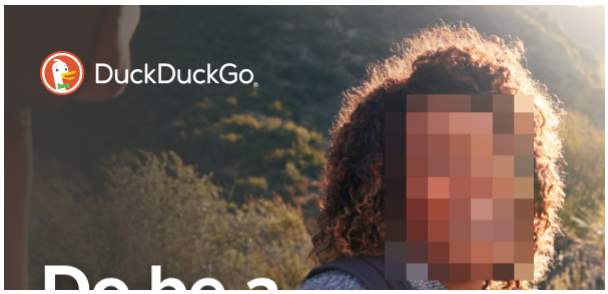


Figure (E) – a significant species effect and interaction term. In this case you can see that the slopes are unequal and thus there is an interaction term. The species means are different, but the environmental means are not.

Figure (F) – a significant environment effect and interaction term. As above, the slopes are unequal, but in this case the species means are the same while the environmental means differ.

Figure (G) – everything is significant. You can figure this one out. All the means are different, as are the slopes.

That's the basics. Now ANOVAs can get really complicated with many levels of factors and complicated designs, but this relatively simple graphical understanding of ANOVAs has greatly helped me to understand more complex designs.



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1. Anonymous
March 23, 2009 at 9:52 pm
Reply

Thanks for the explanation.We are all the products of significant interactions. I need sunshine, earth, love. I use the word synergy too when talking about significant interaction terms.

2. library
June 21, 2009 at 6:36 pm
Reply

Thanks, Kevin. I found your discussion on interaction effects very useful and illuminating. Thanks!

–Sajeev Varki
Associate Professor, USF

3. Anonymous
September 15, 2009 at 4:44 pm
Reply

Useful!! Thank you!!

4. Anonymous
November 12, 2011 at 9:08 am
Reply

thanks kevin, u explained it vry well. u dipicct all the things vry well. i wud like to no one thing that if ther wud be significant btween environment and species, hw we wud depict it through graph.

5.

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