kxkxk 3-Factor Between Groups ANOVA with EMMEANS Follow-ups

The data come from one of several studies of food preference among Nebraska turtle species of various ages and husbandry histories within different ecological contexts and day-rhythms. This 3-way grew out of an interest in whether food preference was moderated by the age of the turtle, and whether this was different for different species. The original study used 6 foods, 7 species and 5 ages (N ≈ 1600 baby turtles). This example uses a subset of those data, 3 foods, 2 species and 2 ages. We learned early in the research that repeated measures designs produced order effects that could not be counter-balanced (leading to a separate line of research on food preference malleability), so a between subjects design was used here.

About the food stimuli used in this study.

- The crickets were immature House Crickets, of 5-7 mm body length. Animals had been pithed before presentation, so that they were able to move their limbs, but could not escape. Proximate crickets have a substantial odor! Four crickets were presented.
- In order to approximate "carrion" 5-7 mm bits of hamburger were "incubated" for 72 hours in a warm, damp, unsterilized environment. It stank! Four bits were presented.
- The lettuce was fresh mature outer leaves of Romaine lettuce, washed with sterilized water and shredded to a standard size approximating the size of mature "duck weed." 30-40 "shreds" were presented.

Process:
There are a lot of steps to a complete analysis of a 3-way design. Different patterns of significant and non-significant effects will require different subsets of these. Here's a preview…

Initial Analysis

- Get descriptive means, plots & F-tests
- Determine what effects are significant
- Consider what lower-order effects we will need to check for descriptive/misleading patterns
- Consider what lower-order effects are likely to be interesting – based on the aggregations involved

3-way Interaction

- Select the set of simple effects that most directly addresses the research question or research hypothesis
- Getting the related cell means & follow-up analyses
- Describe the pattern of the 3-way
- Compute LSDmmd based on full model error term
- Get the related set of simple 2-way interaction F-tests

2-way Interactions

- Get the 2-way interaction plot and the corresponding simple 2-way plots
- Get 2-way estimated semi-marginal means & follow-up analyses to describe each 2-way interaction
- Why are the "Descriptive" and "Estimated" semi-marginal means different & which are plotted/tested ?
- Use the related depiction of the 3-way to check each 2-way interaction for descriptive/misleading patterns

Main Effects

- Get the main effect and corresponding simple effect plots
- Get estimated marginal means & follow-up analyses to describe each main effect
- Why are the "Descriptive" and "Estimated" marginal means different ?
- Use the related depiction of the 3-way to check each main effect for descriptive/misleading patterns

Initial Analysis

Get descriptive means, plots & F-tests

UNIANOVA feeds2 BY species age foodoff ← DV by IVs
order determines left-to-right ordering of IVs in the Descriptive Statistics table

/METHOD=SSTYPE(3) ← corrects each effect for all other effects
/PRINT=DESCRIPTIVE ← gets descriptive cell, semi-marginal and marginal means
/PLOT=PROFILE(foodoff*age*species) ← gets plot of cell means (x-axis *separate lines * graphs)
/DESIGN= species age foodoff ← specify the design including the interaction that is
species*age species*foodoff age*foodoff automatically calculates from the IVs specified above)
species*age*foodoff.

Arrangement of Descriptive Statistics table and the plots reflects, “This 3-way grew out of an interest in whether food preference was moderated by the age of the turtle, and whether this was different for different species.”

Notice that both look at type of food, within each age group, for each species.

Descriptive Statistics

Dependent Variable: feedwork

species of turtle	age when turtle was tested	type of food offered	Mean	Std. Deviation	N
painted	3 days	live crickets	9.3333	1.21106	6
		ground meat	1.1250	1.12599	8
		lettuce	1.2500	1.03510	8
		Total	3.4091	3.86263	22
	3 months	live crickets	12.6250	1.84681	8
		ground meat	12.2500	1.83225	8
		lettuce	13.2500	1.83225	8
		Total	12.7083	1.80529	24
	Total	live crickets	11.2143	2.29309	14
		ground meat	6.6875	5.92980	16
		lettuce	7.2500	6.36134	16
		Total	8.2609	5.53949	46
snapper	3 days	live crickets	14.1429	3.23669	7
		ground meat	15.5714	1.13389	7
		lettuce	5.3333	1.75119	6
		Total	12.0000	4.99473	20
	3 months	live crickets	14.4000	2.07364	5
		ground meat	14.8571	2.91139	7
		lettuce	15.7143	1.49603	7
		Total	15.0526	2.19782	19
	Total	live crickets	14.2500	2.70101	12
		ground meat	15.2143	2.15473	14
		lettuce	10.9231	5.60449	13
		Total	13.4872	4.14139	39
Total	3 days	live crickets	11.9231	3.47519	13
		ground meat	7.8667	7.53910	15
		lettuce	3.0000	2.48069	14
		Total	7.5000	6.16936	42
	3 months	live crickets	13.3077	2.05688	13
		ground meat	13.4667	2.66905	15
		lettuce	14.4000	2.06328	15
		Total	13.7442	2.28966	43
	Total	live crickets	12.6154	2.88551	26
		ground meat	10.6667	6.24408	30
		lettuce	8.8966	6.21257	29
		Total	10.6588	5.57322	85

The “Descriptive Statistics” are the raw or “uncorrected” means.

The marginal means for the main effects are weighted by the differential sizes of the cell means being aggregated.

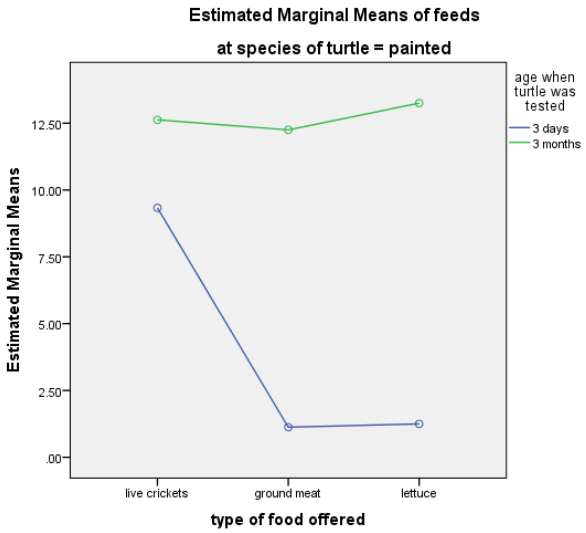
For example, the marginal mean for painted turtles is

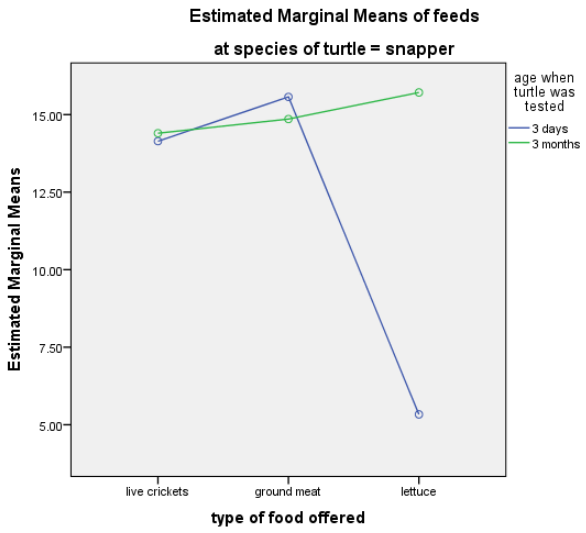
((9.333 * 6) + (1.125 * 8) + (1.250 * 8) + (12.625 * 8) + (12.250 * 8) + (13.250 * 8)) / 46 = 8.2609

Likewise, the semi-marginal means for the 2-way interactions are weighted by the differential sizes of the cell means being aggregated.

For example, the semi-marginal mean for 3day old painted turtles is

((9.333 * 6) + (1.125 * 8) + (1.250 * 8)) / 22 = 3.4091





From the means and plots, it looks like younger turtles make more feeding attempts and show little food preference. Older turtles show a food preference, but the preference is somewhat different for Paints & Snappers.

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Determine what effects are significant

Tests of Between-Subjects Effects

Dependent Variable: feedwork

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2347.132[a]	11	213.376	59.458	.000
Intercept	9747.955	1	9747.955	2716.305	.000
species	526.765	1	526.765	146.785	.000
age	763.475	1	763.475	212.745	.000
foodoff	189.142	2	94.571	26.353	.000
species * age	157.255	1	157.255	43.820	.000
species * foodoff	132.061	2	66.030	18.400	.000
age * foodoff	308.892	2	154.446	43.037	.000
species * age * foodoff	111.318	2	55.659	15.510	.000
Error	261.974	73	3.589		
Total	12266.000	85			
Corrected Total	2609.106	84			

a. R Squared = .900 (Adjusted R Squared = .884)

All 7 effects are significant.

One thing to notice about these data is how small are the standard deviations!

Baby turtles are an amazingly homogeneous group!

So, small mean differences are reliably different & we get lots of significant effects!!

Consider what lower-order effects we will need to check for descriptive/misleading patterns

Because of the significant 3-way, the means patterns of all 6 lower-order effects -- all 3 2-way interactions and all 3 main effects -- will have to be carefully checked against the corresponding higher-order effects to determine if they are descriptive or misleading. Remember, this will have to be done whether the lower-order effect is significant or not – 2-way and main effect nulls can be misleading!

Consider what lower-order effects are likely to be interesting – based on the aggregations involved

Species

- Paints and Snappers represent just 2 of the 7 native Nebraskan species and of the 256 species worldwide. So aggregating across them doesn't represent any important population.
- These two species do represent about 85% of "pet" turtles sold in the US – but most pets aren't fed these foods at these ages, so the lack of external population & stimulus validity makes the aggregate of these conditions uninteresting.
- So, the main effect of age (aggregating across species & foods), the main effect of food (aggregating across species and age) and the age*food interaction (aggregating across species) would only be interesting ***as a simplifying description*** if the means pattern was descriptive because it matched the corresponding simple effect means patterns!

Age

- There are very few behaviors that are age-related such that aggregating 3-day-old and 3-month-old juveniles tells us about an interesting population.
- So, the main effect of species (aggregating across age & foods), the main effect of food group (aggregating across age and species) and the species*food interaction (aggregating across age) would only be interesting ***as a simplifying description*** if the means pattern was descriptive because it matched the corresponding simple effect means patterns!

Food Offered

- These three foods were very carefully chosen to represent the three major types of foods available to juvenile turtles: 1) available insects, 2) carrion, & 3) vegetation (specifically duckweed). Therefore, aggregating across these three foods into an "available foods group" would be interesting.
- Still the the main effect of species (aggregating across age & foods), the main effect of age (aggregating across species and foods) and the species*age interaction (aggregating across foods) would only be interesting ***as a meaningful aggregation*** if the means pattern was descriptive because it matched the corresponding simple effect means patterns!

Remember – though we have no such cases to address here ***– non-significant lower-order effects that are involved in a significant higher order effect must be cwhether they are descriptive or misleading*****!!!**

3-way Interaction

Select the set of simple effects that most directly addresses the research question or research hypothesis

The statement that, “This 3-way grew out of an interest in whether food preference was moderated by the age of the turtle, and whether this was different for different species” makes the selection of the simple effects to use to describe the interaction straightforward.

From this, we’ll want to focus on the simple effects of Food Offered within the simple 2-way Food Offered * Age, and then examine how this 2-way is different for different Species.

Get the related cell means & follow-up analyses

/EMMEANS=TABLES (species * age * foodoff) compare (foodoff)

← “compare (foodoff)” asks for pairwise comparisons among the 3 food off conditions – live crickets, ground meat & lettuce

← “species*age*food” specifies that those pairwise comparisons are made within each age group, for each species

Estimates

Dependent Variable: feeds

species of turtle	age when turtle was tested	type of food offered	Mean	Std. Error
painted	3 days	live crickets	9.333	.773
		ground meat	1.125	.670
		lettuce	1.250	.670
	3 months	live crickets	12.625	.670
		ground meat	12.250	.670
		lettuce	13.250	.670
snapper	3 days	live crickets	14.143	.716
		ground meat	15.571	.716
		lettuce	5.333	.773
	3 months	live crickets	14.400	.847
		ground meat	14.857	.716
		lettuce	15.714	.716

These cell means “Estimates” are the same as the cell mean “Descriptive Statistics” given above and the same means that are plotted above.

The F-tests shown below test the simple effect of Food Offered for every combination of Age & Species.

For both species, there are Food Offered effects for younger, but not for older, animals.

Notice that the MSe for these F-tests is the same as for the full model – based on the full sample size. It is also possible to get these tests by splitting the file into these 4 groups and getting the Foodoff ANOVA for each. However, that approach will use a separately composed error term for each F, will have lower power, greater chance of inconsistent effects & of Type II Errors.

Univariate Tests

Dependent Variable: feeds

species of turtle	age when turtle was tested		Sum of Squares	df	Mean Square	F	Sig.
painted	3 days	Contrast	289.610	2	144.805	40.350	.000
		Error	261.974	73	3.589		
	3 months	Contrast	4.083	2	2.042	.569	.569
		Error	261.974	73	3.589		
snapper	3 days	Contrast	388.095	2	194.048	54.072	.000
		Error	261.974	73	3.589		
	3 months	Contrast	5.462	2	2.731	.761	.471
		Error	261.974	73	3.589		

Each F tests the simple effects of type of food offered within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

Pairwise Comparisons

Dependent Variable: feeds

species of turtle	age when turtle was tested	(I) type of food offered	(J) type of food offered	Mean Difference (I-J)	Std. Error	Sig.[b]
painted	3 days	live crickets	ground meat	8.208*	1.023	.000
			lettuce	8.083*	1.023	.000
		ground meat	live crickets	-8.208*	1.023	.000
			lettuce	-.125	.947	.895
		lettuce	live crickets	-8.083*	1.023	.000
			ground meat	.125	.947	.895
	3 months	live crickets	ground meat	.375	.947	.693
			lettuce	-.625	.947	.511
		ground meat	live crickets	-.375	.947	.693
			lettuce	-1.000	.947	.295
		lettuce	live crickets	.625	.947	.511
			ground meat	1.000	.947	.295
snapper	3 days	live crickets	ground meat	-1.429	1.013	.163
			lettuce	8.810*	1.054	.000
		ground meat	live crickets	1.429	1.013	.163
			lettuce	10.238*	1.054	.000
		lettuce	live crickets	-8.810*	1.054	.000
			ground meat	-10.238*	1.054	.000
	3 months	live crickets	ground meat	-.457	1.109	.681
			lettuce	-1.314	1.109	.240
		ground meat	live crickets	.457	1.109	.681
			lettuce	-.857	1.013	.400
		lettuce	live crickets	1.314	1.109	.240
			ground meat	.857	1.013	.400

Based on estimated marginal means

*. The mean difference is significant at the .050 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

From the cell means given above and these pairwise results we can explicate the pattern of the 3-way as…

		Crickets v Ground Meat	Crickets v Lettuce	Ground Meat v Lettuce
Painted Turtles	3-days	>	>	=
	3-months	=	=	=
Snapping Turtles	3-days	=	>	>
	3-months	=	=	=

Describe the pattern of the 3-way

In words – following the SE of food for within each age group, for each species …

For painted turtles, 3-day-olds preferred crickets to ground meat and lettuce, whereas 3-month-olds showed no preference. However, for snappers, the 3-days preferred crickets and ground meat to lettuce, whereas the 3-month-olds showed no preference.

Or, alternatively…

The 3-day-old painted turtles preferred crickets to ground meat or lettuce, while he 3-day old snappers preferred crickets and ground meat to lettuce. The 3-month-old turtles of neither species showed a preference.

For either description, notice that the pattern of the pairwise comparisons guarantees that the main effect of Food Offered and the 2-way interaction of Food Offered * Age will be misleading! In each case, different subsets of data show different means patterns, and, so, they cannot all match the means pattern of the corresponding main effect or 2-way.

Compute LSDmmd based on full model error term

This is a BG model, so all the F-tests and follow-up analyses are based on a single error term (MSe=111.852), though the Standard Errors of the follow-ups calculated by SPSS vary with sample size. Why care? Because, the follow-up analyses are based on a t-test (that isn't shown in the output) that uses the standard error in the denominator.

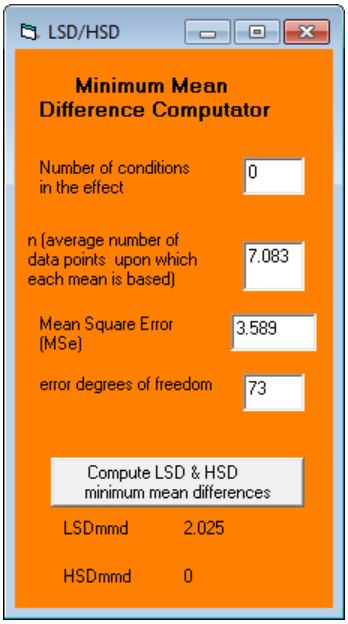
So, depending on whether the cells being compared have larger or smaller sample sizes, the standard error can be larger (smaller ns) or smaller (larger ns), and the same cell mean difference can be significant for one comparison and not significant for another!!

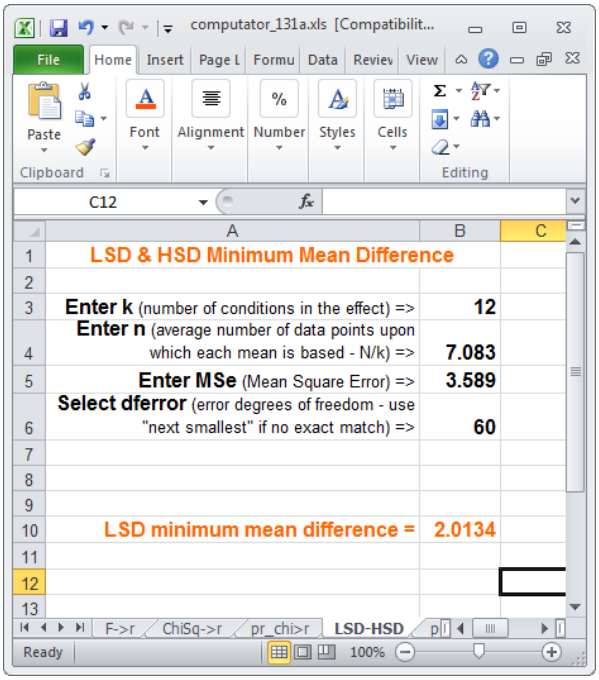
An alternative is to use this "full model error term" as the basis for computing an LSDmmd value that is then used to compare any two cell means. This is an extension of the "homogeneity of variance" assumption that is made when we compute the ANOVA error term for BG models. That assumption is that it makes sense to combine the within-group variability from the different design cells, because they each represent a sample taken from different populations that all have the same variability, so the aggregate of them all is the best estimate of the variability of each. The extension in the "full model error term" approach is that since the best estimate is derived from using the full design sample, the significance test should be based on the df from all the participants.

Why do people who like this approach like it?

1. It is based on the same estimate of variability, but larger sample size, and, so, uses a smaller standard error than the pairwise error term approach. So, it provides a more powerful significance test, and more pairwise cell mean comparisons are significantly different using this approach (though the reverse can happen on occasion).

2. This approach provides an easy method for the comparison of nonadjacent cells means. We might want to know whether the mean number of strikes made by 3-month-old painted turtles offered lettuce (mean = 13.250) is different than by 3-day-old snappers offered ground meat (mean = 14.857) there is no easy to get SPSS to provide this significance test, but the Computators will give us an LSDmmd that we can use to compare these means. For this analysis k = 12 conditions of the 2x2x3 design, n = N/k = 85/12 = 7/083 & MSe = 3.589. Using the LSDmmd value, we would conclude these two groups have equivalent performances.





Getting the related set of simple 2-way interaction F-tests

Having decides to describe the 3-way interaction as "the different 2-way interaction pattern of Food Offered and Age for each Species" we might want to have those two simple 2-way F-tests.

SORT CASES BY species. ← sorts the data file into snappers and painted turtles

SPLIT FILE LAYERED BY species. ← tells SPSS to compute the requested analyses separately for each split file.

UNIANOVA feeds BY age foodoff. ← requests the age & food 2-way ANOVA

Tests of Between-Subjects Effects

Dependent Variable: feeds

species of turtle	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
painted	Corrected Model	1286.286[a]	5	257.257	108.796	.000
	Intercept	3136.877	1	3136.877	1326.609	.000
	age	881.482	1	881.482	372.786	.000
	foodoff	156.932	2	78.466	33.184	.000
	age * foodoff	165.707	2	82.854	35.039	.000
	Error	94.583	40	2.365		
	Total	4520.000	46			
	Corrected Total	1380.870	45			
snapper	Corrected Model	484.353[b]	5	96.871	19.097	.000
	Intercept	6825.584	1	6825.584	1345.622	.000
	age	104.981	1	104.981	20.696	.000
	foodoff	161.782	2	80.891	15.947	.000
	age * foodoff	245.396	2	122.698	24.189	.000
	Error	167.390	33	5.072		
	Total	7746.000	39			
	Corrected Total	651.744	38			

a. R Squared = .932 (Adjusted R Squared = .923)

b. R Squared = .743 (Adjusted R Squared = .704)

Of the various F-tests presented, only the 2-way interactions are interesting/meaningful. These 2-ways analyses each use an error term based on the data and sample size from a single species. As a result, each of these 2-way F-tests has less power than the 3-way F-test they are being used to explore. So, it is possible to have one of those "significant effects that aren't anywhere"

We can also re-compute these simple 2-way F-tests using the $MS_{age*foodoff}$ from the table above, and the MS_{error} from the 3-way full model (MSe = 3.589). This would lead to…

Food Offered * Age for Painted Turtles

$$F(2, 73) = \frac{82.854}{3.589} = 23.086 \quad p < .0001$$

Food Offered * Age for Snappers

$$F(2, 73) = \frac{122.698}{3.589} = 34.187 \quad p < .0001$$

2-way Interactions

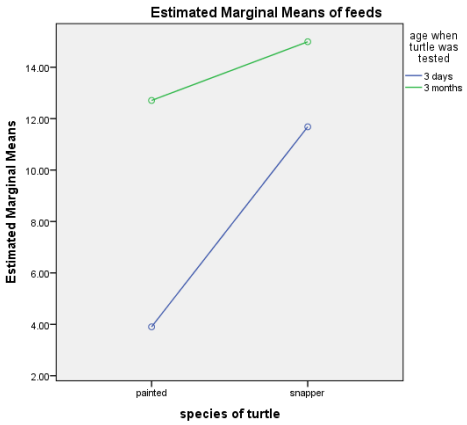
Using the Age*Species 2-way as an example, here is how to get the plot & follow-ups for that 2-way and the corresponding simple-2-way of Age*Species for each Food Offered.

Get the 2-way interaction plot and the corresponding simple 2-way plots

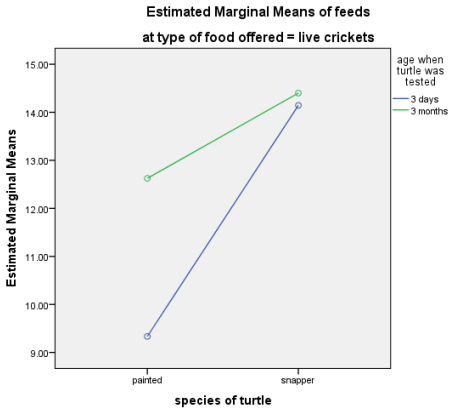
/PLOT=PROFILE(species * age) ← gets plot of estimated semi-marginal means for Species * Age 2-way interaction (x-axis *separate lines)

/PLOT=PROFILE(species * age * foodoff) ← gets plot of the cell means arranged to check if the pattern of the Species * Age interaction is the same for each Food Offered (x-axis * separate lines * separate graphs)

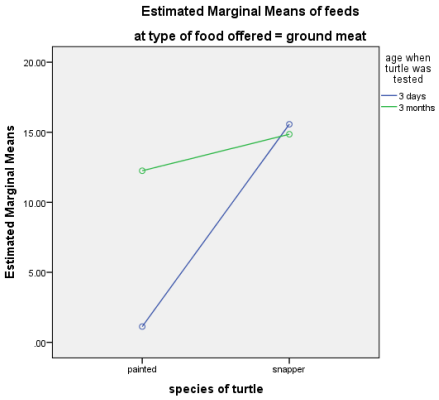
2-way plot of Species * Age



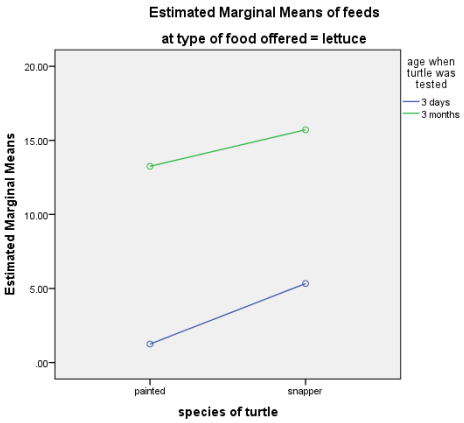
Simple 2-way plot of Species * Age for Live Crickets



Simple 2-way plot of Species * Age for Ground Meat



Simple 2-way plot of Species * Age for Letttuce



None of the simple 2-ways looks quite like the 2-way, but it all hinges on the age effects for Snappers. Significance tests can be comforting, concentrating on the simple effects of Age for each Species (for each Food Offered).

Get 2-way estimated semi-marginal means & follow-up analyses to describe the 2-way interactions

/EMMEANS=TABLES (species * age) compare (age) ← gets pairwise comparisons of estimated age group semi-marginal means for each species – used to describe the pattern of the Species * Age 2-way

Why are the "Descriptive" and "Estimated" semi-marginal means different & which are plotted/tested ?

You should notice the estimated semi-marginal means shown in the graphs above and the "Estimates" table below are not the same as the raw semi-marginal means from the "Descriptive Statistics" up above. Those raw semi-marginal means were 3.41 for 3-day Painted, 12.71 for 3-month Painted, 12.00 for 3-day Snappers & 15.05 for 3-month Snappers.

The difference between the raw and estimated semi-marginal means reflects that the effects in the design are not orthogonal (because of unequal-n). The estimated semi-marginal means are predicted based on the model (not the raw data) and provide for the comparisons among these groups, after correcting for the other effects in the model.

Estimates

Dependent Variable: feeds

species of turtle	age when turtle was tested	Mean	Std. Error
painted	3 days	3.903	.408
	3 months	12.708	.387
snapper	3 days	11.683	.425
	3 months	14.990	.440

Univariate Tests

Dependent Variable: feeds

species of turtle		Sum of Squares	df	Mean Square	F	Sig.
painted	Contrast	881.482	1	881.482	245.628	.000
	Error	261.974	73	3.589		
snapper	Contrast	104.981	1	104.981	29.253	.000
	Error	261.974	73	3.589		

Each F tests the simple effects of age when turtle was tested within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

The F-tests compare the corrected/estimated semi-marginal means.

The pairwise comparisons are redundant with the F-tests because these are all 2-group comparisons.

Be sure to check the ***direction*** of each significant comparison !!!

Pairwise Comparisons

Dependent Variable: feeds

species of turtle	(I) age when turtle was tested	(J) age when turtle was tested	Mean Difference (I-J)	Std. Error	Sig.[b]
painted	3 days	3 months	-8.806*	.562	.000
	3 months	3 days	8.806*	.562	.000
snapper	3 days	3 months	-3.308*	.612	.000
	3 months	3 days	3.308*	.612	.000

Based on estimated marginal means

*. The mean difference is significant at the .050 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

The pattern of the 2-way interaction is…

Painted 3 day <<< 3 month

Snapper 3-day < 3 month

The Age effect is the same direction for both Species, but is much larger for Painted turtles.

Use related depiction of the 3-way to check the 2-way interaction for descriptive/misleading patterns

/EMMEANS=TABLES (foodoff * species * age) compare (age) ← gets pairwise comparisons of age group cell means at each combination of species and food offered, to check whether the pattern of the species*age 2-way is descriptive or misleading

Estimates

Dependent Variable: feeds

type of food offered	species of turtle	age when turtle was tested	Mean	Std. Error
live crickets	painted	3 days	9.333	.773
		3 months	12.625	.670
	snapper	3 days	14.143	.716
		3 months	14.400	.847
ground meat	painted	3 days	1.125	.670
		3 months	12.250	.670
	snapper	3 days	15.571	.716
		3 months	14.857	.716
lettuce	painted	3 days	1.250	.670
		3 months	13.250	.670
	snapper	3 days	5.333	.773
		3 months	15.714	.716

Univariate Tests

Dependent Variable: feeds

type of food offered	species of turtle		Sum of Squares	df	Mean Square	F	Sig.
live crickets	painted	Contrast	37.149	1	37.149	10.352	.002
		Error	261.974	73	3.589		
	snapper	Contrast	.193	1	.193	.054	.817
		Error	261.974	73	3.589		
ground meat	painted	Contrast	495.063	1	495.063	137.951	.000
		Error	261.974	73	3.589		
	snapper	Contrast	1.786	1	1.786	.498	.483
		Error	261.974	73	3.589		
lettuce	painted	Contrast	576.000	1	576.000	160.505	.000
		Error	261.974	73	3.589		
	snapper	Contrast	348.161	1	348.161	97.016	.000
		Error	261.974	73	3.589		

Each F tests the simple effects of age when turtle was tested within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

(from above) The pattern of the 2-way interaction was…

Painted 3 day <<< 3 month
Snapper 3-day < 3 month

For **live crickets**, the corresponding simple 2-way is…

Painted 3 day < 3 month
Snapper 3-day = 3 month

For **ground meat**, the corresponding simple 2-way is…

Painted 3 day <<< 3 month
Snapper 3-day = 3 month

For **lettuce**, the corresponding simple 2-way is…

Painted 3 day <<<< 3 month
Snapper 3-day <<< 3 month

So, the 2-way interaction pattern is descriptive only for crickets, and is misleading for ground mean & lettuce.

Pairwise Comparisons

Dependent Variable: feeds

type of food offered	species of turtle	(I) age when turtle was tested	(J) age when turtle was tested	Mean Difference (I-J)	Std. Error	Sig.[b]
live crickets	painted	3 days	3 months	-3.292*	1.023	.002
		3 months	3 days	3.292*	1.023	.002
	snapper	3 days	3 months	-.257	1.109	.817
		3 months	3 days	.257	1.109	.817
ground meat	painted	3 days	3 months	-11.125*	.947	.000
		3 months	3 days	11.125*	.947	.000
	snapper	3 days	3 months	.714	1.013	.483
		3 months	3 days	-.714	1.013	.483
lettuce	painted	3 days	3 months	-12.000*	.947	.000
		3 months	3 days	12.000*	.947	.000
	snapper	3 days	3 months	-10.381*	1.054	.000
		3 months	3 days	10.381*	1.054	.000

Based on estimated marginal means

*. The mean difference is significant at the .050 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

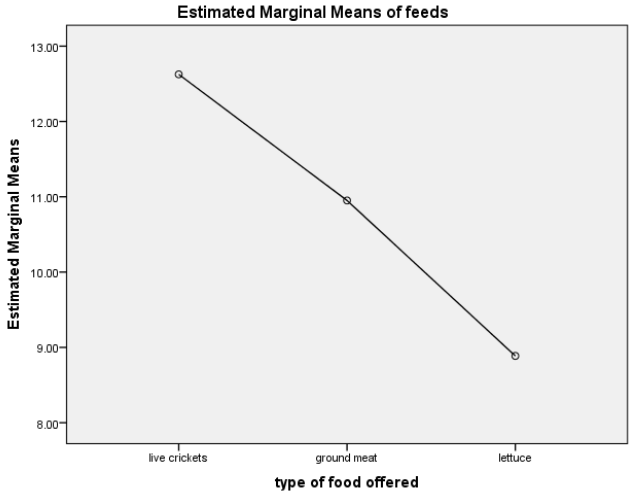
Main Effects

Using the Food Offered main effect as an example, here is how to get the plot & follow-ups for that main effect and the corresponding simple effects of Food Offered for each combination of Age & Species.

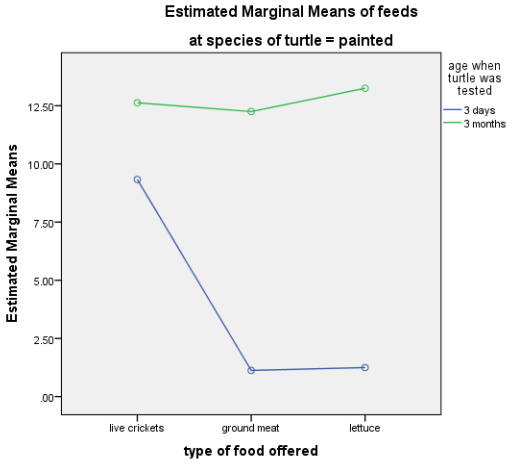
Get the main effect and corresponding simple effect plots

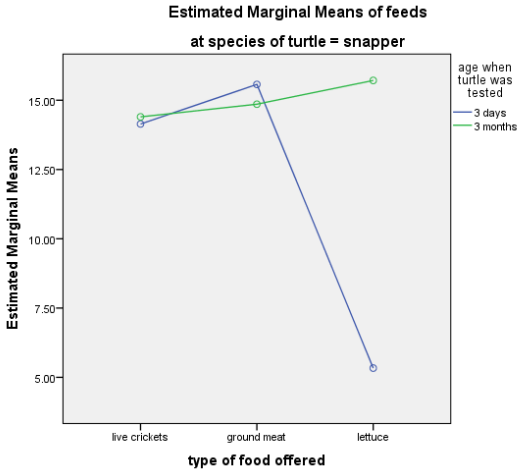
/PLOT=PROFILE(foodoff) ← gets plot of estimated marginal means

/PLOT=PROFILE(foodoff * age * species) ← gets plot of the cell means arranged to check if the pattern of the Food Offered main effect is the same for every combination of Age & Species (x-axis * separate lines * separate graphs)



None of the simple effects of Food Offered look much like the pattern of the marginal means.





Get estimated marginal means & follow-up analyses to describe the main effect

/EMMEANS=TABLES (foodoff) compare (foodoff) ← get pairwise comparisons among marginal means

Why are the "Descriptive" and "Estimated" marginal means different ?

You should notice the estimated marginal means shown in the graphs above and the "Estimates" table below are not the same as the raw marginal means from the "Descriptive Statistics" up above. Those raw marginal means were 12.62 for live crickets, 10.67 for ground meat, and 8.90 for lettuce.

The difference between the raw and estimated marginal means reflects that the effects in the design are not orthogonal (because of unequal-n). The estimated marginal means are predicted based on the model (not the raw data) and provide for the comparisons among these groups, after correcting for the other effects in the model.

Estimates

Dependent Variable: feeds

type of food offered	Mean	Std. Error
live crickets	12.625	.377
ground meat	10.951	.347
lettuce	8.887	.354

Univariate Tests

Dependent Variable: feeds

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	189.142	2	94.571	26.353	.000
Error	261.974	73	3.589		

The F tests the effect of type of food offered. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Pairwise Comparisons

Dependent Variable: feeds

(I) type of food offered	(J) type of food offered	Mean Difference (I-J)	Std. Error	Sig.[b]
live crickets	ground meat	1.674*	.512	.002
	lettuce	3.738*	.518	.000
ground meat	live crickets	-1.674*	.512	.002
	lettuce	2.064*	.496	.000
lettuce	live crickets	-3.738*	.518	.000
	ground meat	-2.064*	.496	.000

Based on estimated marginal means

*. The mean difference is significant at the .050 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

The pattern of the main effect is …

crickets v. meat	crickets v. lettuce	mean v. lettuce
>	>>	>

The F-test is the same as the test of the Foodoff main effects in the overall analysis up above.

Use the related depiction of the 3-way to check the main effects for descriptive/misleading patterns

/EMMEANS=TABLES (species * age * foodoff) compare (foodoff) ← gets pairwise comparisons of foodoff cell means at each combination of species age, to check whether the pattern of the foodoff main effect is descriptive or misleading

Estimates

Dependent Variable: feeds

species of turtle	age when turtle was tested	type of food offered	Mean	Std. Error
painted	3 days	live crickets	9.333	.773
		ground meat	1.125	.670
		lettuce	1.250	.670
	3 months	live crickets	12.625	.670
		ground meat	12.250	.670
		lettuce	13.250	.670
snapper	3 days	live crickets	14.143	.716
		ground meat	15.571	.716
		lettuce	5.333	.773
	3 months	live crickets	14.400	.847
		ground meat	14.857	.716
		lettuce	15.714	.716

Univariate Tests

Dependent Variable: feeds

species of turtle	age when turtle was tested		Sum of Squares	df	Mean Square	F	Sig.
painted	3 days	Contrast	289.610	2	144.805	40.350	.000
		Error	261.974	73	3.589		
	3 months	Contrast	4.083	2	2.042	.569	.569
		Error	261.974	73	3.589		
snapper	3 days	Contrast	388.095	2	194.048	54.072	.000
		Error	261.974	73	3.589		
	3 months	Contrast	5.462	2	2.731	.761	.471
		Error	261.974	73	3.589		

Each F tests the simple effects of type of food offered within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

Pairwise Comparisons

Dependent Variable: feeds

species of turtle	age when turtle was tested	(I) type of food offered	(J) type of food offered	Mean Difference (I-J)	Std. Error	Sig.[b]
painted	3 days	live crickets	ground meat	8.208*	1.023	.000
			lettuce	8.083*	1.023	.000
		ground meat	live crickets	-8.208*	1.023	.000
			lettuce	-.125	.947	.895
		lettuce	live crickets	-8.083*	1.023	.000
			ground meat	.125	.947	.895
	3 months	live crickets	ground meat	.375	.947	.693
			lettuce	-.625	.947	.511
		ground meat	live crickets	-.375	.947	.693
			lettuce	-1.000	.947	.295
		lettuce	live crickets	.625	.947	.511
			ground meat	1.000	.947	.295
snapper	3 days	live crickets	ground meat	-1.429	1.013	.163
			lettuce	8.810*	1.054	.000
		ground meat	live crickets	1.429	1.013	.163
			lettuce	10.238*	1.054	.000
		lettuce	live crickets	-8.810*	1.054	.000
			ground meat	-10.238*	1.054	.000
	3 months	live crickets	ground meat	-.457	1.109	.681
			lettuce	-1.314	1.109	.240
		ground meat	live crickets	.457	1.109	.681
			lettuce	-.857	1.013	.400
		lettuce	live crickets	1.314	1.109	.240
			ground meat	.857	1.013	.400

Based on estimated marginal means

*. The mean difference is significant at the .050 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

The pattern of the main effect is …

crick v. meat	crick v. lettuce	mean v. lettuce
>	>>	>

For **3-day painted**, the corresponding simple effect is…

crick v. meat	crick v. lettuce	mean v. lettuce
>>	>>	=

For **3-month painted**, corresponding simple effect is…

crick v. meat	crick v. lettuce	mean v. lettuce
=	=	=

For **3-day snapper**, the corresponding simple effect is…

crick v. meat	crick v. lettuce	mean v. lettuce
=	>>	>>

For **3-month snapper**, corresponding simple effect is…

crick v. meat	crick v. lettuce	mean v. lettuce
=	=	=

So, the main effect marginal mean pattern of Food Offered is not descriptive for any combination of age and species.