WELCOME TO PSY 653 LAB!

MODULE 11: MINIMUM EFFECTS TESTING & BAYESIAN ANALYSES

*Thanks to Gemma Wallace for her help with these slides

OBJECTIVES

1) PRACTICE IDENTIFYING MINIMUM EFFECTS FOR REJECTING SPECIFIC HYPOTHESES

2) CONDUCT REGULAR AND BAYESIAN ANOVAS TO DETERMINE WHETHER GENDER AND OCCUPATION ARE RELATED TO MENTAL HEALTH

   a) Interpret and compare results from the two analytic approaches

PART 1: MINIMUM EFFECTS PRACTICE

MINIMUM EFFECTS TESTING (MET)

- It tests the hypothesis that the effect of treatments falls somewhere in an interval between zero and some number

× Rather than testing if an effect is precisely zero, we can test if it falls above a range of values (The minimum effect you are testing)

THE AUTHORS USED RIGHT WING AUTHORITARIANISM (RWA) TO PREDICT DIFFERENCES IN RESPONSE TIME TO IN-GROUP AND OUT-GROUP FACES, AND FOUND A SQUARED CORRELATION OF .07, WHICH WAS SIGNIFICANT, WITH $F(1,161) = 4.81$

IDENTIFYING MINIMUM EFFECTS: KEVIN'S MINIMUM EFFECTS CODE

```
# 1a Applied to Bret et al. (Right Wing Authoritarianism)
```{r}
dfhyp=1
dferr=161
alpha=.05
effect=.01  #enter the minimum effect you are testing
sse=100
mse=(((1/effect)-1)*sse)/dferr
noncen=sse/mse
qf((1-alpha),dfhyp,dferr,noncen)
```
```

```
[1] 8.683388
```

F(**1**,**161**) = 4.81,

α = **.05**,

Minimum effect = **1%**

Don't change

DETECTING MINIMUM EFFECTS: KEVIN'S MINIMUM EFFECTS CODE

```
# 1a Applied to Bret et al. (Right Wing Authoritarianism)
```{r}
dfhyp=1
dferr=161
alpha=.05
effect=.01  #enter the minimum effect you are testing
sse=100
mse=(((1/effect)-1)*sse)/dferr
noncen=sse/mse
qf((1-alpha),dfhyp,dferr,noncen)
```
```

```
[1] 8.683388
```

$F(1,161) = \boxed{\mathbf{4.81}}$

Compare the resulting minimum F-value needed to test an effect of 1% or more to the obtained F-value.
In this case we did NOT reach the threshold F-value to have a significant effect at 1%. The authors need an F-value of 8.68 to obtain a significant effect at a minimum effect of 1%.

IDENTIFYING MINIMUM EFFECTS VIA MURPHY, MYORS & WOLOCH (2014) "ONE STOP" F-TABLE (APPENDIX B)

MINIMUM F REQUIRED (APPENDIX B)

With a DF_{hyp} = 1 and DF_{err} = 161, the Authors need an F-value of 3.89 or more to obtain a significant effect.

Obtained F = 4.81

One Stop *F* Table

dfErr			1	2	3	4	5	6	7	8	9	10	12	15	20	30	40	60	120
90	nil	.05	3.94	3.10	2.71	2.47	2.32	2.20	2.11	2.04	1.98	1.94	1.86	1.78	1.69	1.58	1.53	1.46	1.39
	nil	.01	6.92	4.85	4.01	3.53	3.23	3.01	2.84	2.72	2.61	2.52	2.39	2.24	2.09	1.91	1.82	1.72	1.60
	pow	.50	3.86	2.53	1.93	1.66	1.43	1.26	1.21	1.10	1.01	0.94	0.89	0.81	0.70	0.59	0.54	0.46	0.40
	pow	.80	7.97	4.95	3.75	3.12	2.69	2.38	2.18	2.00	1.86	1.74	1.58	1.40	1.20	0.98	0.86	0.73	0.59
	1%	.05	6.97	4.37	3.48	3.00	2.71	2.52	2.38	2.26	2.18	2.11	2.00	1.88	1.76	1.63	1.56	1.48	1.40
	1%	.01	11.29	6.64	5.06	4.26	3.77	3.43	3.19	3.01	2.86	2.74	2.56	2.38	2.18	1.97	1.86	1.74	1.61
	pow	.50	6.86	3.74	2.66	2.18	1.83	1.58	1.47	1.33	1.21	1.12	1.03	0.87	0.79	0.65	0.55	0.49	0.40
	pow	.80	12.12	6.62	4.74	3.19	3.19	2.78	2.52	2.28	2.10	1.95	1.75	1.51	1.29	1.04	0.89	0.76	0.60
	5%	.05	15.17	8.31	6.02	4.88	4.15	3.70	3.37	3.12	2.93	2.77	2.54	2.30	2.07	1.83	1.70	1.58	1.44
	5%	.01	21.57	11.59	8.25	6.59	5.58	4.92	4.44	4.08	3.80	3.57	3.24	2.90	2.55	2.21	2.03	1.85	1.66
	pow	.50	14.87	7.58	5.14	3.92	3.29	2.78	2.41	2.14	1.92	1.82	1.55	1.34	1.09	0.85	0.69	0.58	0.45
	pow	.80	22.43	11.51	7.87	6.04	4.97	4.23	3.70	3.30	2.99	2.77	2.39	2.03	1.65	1.27	1.06	0.87	0.65
100	nil	.05	3.93	3.09	2.70	2.46	2.30	2.19	2.10	2.03	1.97	1.92	1.85	1.77	1.67	1.57	1.51	1.45	1.37
	nil	.01	6.89	4.82	3.98	3.51	3.21	2.99	2.82	2.69	2.59	2.50	2.37	2.22	2.07	1.89	1.80	1.69	1.57
	pow	.50	3.85	2.52	1.92	1.66	1.43	1.26	1.20	1.10	1.01	0.93	0.88	0.80	0.70	0.59	0.50	0.46	0.39
	pow	.80	7.95	4.94	3.73	3.10	2.67	2.37	2.17	1.99	1.84	1.72	1.56	1.38	1.18	0.97	0.83	0.71	o.57
	1%	.05	7.24	4.49	3.55	3.04	2.74	2.54	2.39	2.28	2.19	2.11	2.00	1.88	1.76	1.62	1.55	1.47	1.38
	1%	.01	11.60	6.76	5.13	4.30	3.80	3.45	3.21	3.02	2.87	2.75	2.56	2.37	2.17	1.96	1.84	1.72	1.58
	pow	.50	7.11	3.84	2.71	2.22	1.85	1.59	1.49	1.34	1.22	1.12	1.04	0.87	0.74	0.61	0.55	0.49	0.39
	pow	.80	12.45	6.76	4.82	3.83	3.22	2.80	2.53	2.29	2.11	1.95	1.75	1.50	1.26	1.01	0.88	0.74	0.58
	5%	.05	16.18	8.81	6.27	5.05	4.32	3.83	3.49	3.21	3.00	2.84	2.60	2.34	2.09	1.84	1.71	1.57	1.43
	5%	.01	22.59	12.08	8.57	6.82	5.76	5.06	4.56	4.18	3.88	3.65	3.29	2.94	2.58	2.21	2.03	1.84	1.64
	pow	.50	15.62	7.93	5.51	4.19	3.40	2.87	2.49	2.29	2.06	1.87	1.58	1.36	1.11	0.86	0.70	0.59	0.44
	pow	.80	23.49	12.03	8.22	6.30	5.14	4.36	3.81	3.43	3.10	2.83	2.43	2.06	1.67	1.28	1.06	0.86	0.63
120	nil	.05	3.91	3.07	2.68	2.45	2.29	2.17	2.09	2.01	1.96	1.91	1.83	1.75	1.66	1.55	1.49	1.43	1.35
	nil	.01	6.85	4.79	3.95	3.48	3.17	2.96	2.79	2.66	2.56	2.47	2.34	2.19	2.03	1.86	1.76	1.65	1.53
	pow	.50	3.84	2.51	1.91	1.56	1.42	1.25	1.11	1.09	1.00	0.92	0.87	0.74	0.64	0.54	0.50	0.43	0.36
	pow	.80	7.93	4.91	3.71	3.05	2.65	2.34	2.12	1.97	1.82	1.70	1.54	1.34	1.14	0.92	0.81	0.68	0.53
	1%	.05	7.76	4.74	3.66	3.13	2.81	2.59	2.43	2.31	2.21	2.13	2.01	1.89	1.75	1.61	1.54	1.45	1.36
	1%	.01	12.20	7.02	5.28	4.40	3.86	3.50	3.24	3.04	2.88	2.76	2.56	2.36	2.15	1.93	1.81	1.69	1.55
	pow	.50	7.58	4.04	2.92	2.29	1.90	1.63	1.52	1.36	1.24	1.13	1.05	0.87	0.74	0.61	0.54	0.46	0.37
	pow	.80	13.10	7.05	4.98	3.93	3.29	2.85	2.56	2.32	2.12	1.97	1.75	1.50	1.25	1.00	0.86	0.71	0.55
	5%	.05	17.88	9.64	6.89	5.45	4.64	4.09	3.70	3.41	3.17	2.98	2.71	2.43	2.15	1.87	1.72	1.57	1.42
	5%	.01	24.59	13.05	9.20	7.28	6.12	5.35	4.80	4.38	4.06	3.80	3.41	3.02	2.63	2.23	2.03	1.83	1.61
	pow	.50	17.37	8.79	5.92	4.63	3.74	3.15	2.73	2.41	2.25	2.04	1.72	1.47	1.13	0.87	0.74	0.59	0.42
	pow	.80	25.54	13.02	8.83	6.78	5.51	4.67	4.06	3.61	3.30	3.00	2.57	2.16	1.71	1.29	1.08	0.85	0.61
150	nil	.05	3.89	3.06	2.67	2.43	2.27	2.16	2 07	2.00	1.94	1.89	1.81	1.73	1.64	1.53	1.47	1.40	1.32
	nil	.01	6.80	4.75	3.92	3.45	3.14	2.92	2.76	2.63	2.53	2.44	2.30	2.16	2.00	1.83	1.73	1.62	1.49
	pow	.50	3.83	2.50	1.90	1.55	1.41	1.24	1.10	1.08	0.99	0.92	0.86	0.73	0.63	0.54	0.45	0.40	0.33
	pow	.80	7.90	4.R9	3.09	3.02	2.63	2.32	2.09	1.94	1.80	1.68	1.52	1.31	1.11	0.90	0.77	0.64	0.49
	1%	.05	8.61	5.01	3.86	3.28	2.92	2.66	2.49	2.36	2.25	2.17	2.03	1.90	1.76	1.61	1.53	1.44	1.34
	1%	.01	13.04	7.40	5.51	4.56	3.98	3.59	3.31	3.09	2.93	2.79	2.58	2.37	2.15	1.92	1.79	1.66	1.51
	pow	.50	8.26	4.42	3.09	2.40	1.98	1.78	1.56	1.40	1.27	1.15	1.06	0.88	0.74	0.61	0.51	0.43	0.34
	pow	.80	14.11	7.43	5.21	4.09	3.40	2.96	2.62	2.37	2.16	2.00	1.77	1.51	1.25	0.98	0.83	0.68	0.51
	5%	.05	20.52	10.86	7.64	6.06	5.11	4.48	4.03	3.69	3.41	3.20	2.88	2.57	2.24	1.92	1.75	1.59	1.41
	5%	.01	27.47	14.46	10.12	7.95	6.65	5.78	s 10	4.69	4.33	4.04	3.60	3.17	2.73	2.28	2.06	1.83	1.59
	pow	.50	19.73	10.24	6.86	5.19	4.19	3.52	3.04	2.67	2.48	2.25	1.90	1.61	1.23	0.93	0.75	0.59	0.41
	pow	.80	28.49	14.57	9.81	7.46	6.05	5.10	4,43	3.92	3.56	3.24	2.76	2.31	1.81	1.35	1.09	0.85	0.58

Column headers 1–120: *dfHyp*

MINIMUM F REQUIRED (APPENDIX B)

COMPARISON TO A NIL EFFECT

With a $DF_{hyp} = 1$ and $DF_{err} = 161$, the Authors need an F-value of 3.89 or more to obtain a significant effect.

Obtained F = 4.81

We have a significant effect

One Stop *F* Table

dfHyp

dfErr			1	2	3	4	5	6	7	8	9	10	12	15	20	30	40	60	120
90	nil	.05	3.94	3.10	2.71	2.47	2.32	2.20	2.11	2.04	1.98	1.94	1.86	1.78	1.69	1.58	1.53	1.46	1.39
	nil	.01	6.92	4.85	4.01	3.53	3.23	3.01	2.84	2.72	2.61	2.52	2.39	2.24	2.09	1.91	1.82	1.72	1.60
	pow	.50	3.86	2.53	1.93	1.66	1.43	1.26	1.21	1.10	1.01	0.94	0.89	0.81	0.70	0.59	0.54	0.46	0.40
	pow	.80	7.97	4.95	3.75	3.12	2.69	2.38	2.18	2.00	1.86	1.74	1.58	1.40	1.20	0.98	0.86	0.73	0.59
	1%	.05	6.97	4.37	3.48	3.00	2.71	2.52	2.38	2.26	2.18	2.11	2.00	1.88	1.76	1.63	1.56	1.48	1.40
	1%	.01	11.29	6.64	5.06	4.26	3.77	3.43	3.19	3.01	2.86	2.74	2.56	2.38	2.18	1.97	1.86	1.74	1.61
	pow	.50	6.86	3.74	2.66	2.18	1.83	1.58	1.47	1.33	1.21	1.12	1.03	0.87	0.79	0.65	0.55	0.49	0.40
	pow	.80	12.12	6.62	4.74	3.19	3.19	2.78	2.52	2.28	2.10	1.95	1.75	1.51	1.29	1.04	0.89	0.76	0.60
	5%	.05	15.17	8.31	6.02	4.88	4.15	3.70	3.37	3.12	2.93	2.77	2.54	2.30	2.07	1.83	1.70	1.58	1.44
	5%	.01	21.57	1.59	8.25	6.59	5.58	4.92	4.44	4.08	3.80	3.57	3.24	2.90	2.55	2.21	2.03	1.85	1.66
	pow	.50	14.87	7.58	5.14	3.92	3.29	2.78	2.41	2.14	1.92	1.82	1.55	1.34	1.09	0.85	0.69	0.58	0.45
	pow	.80	22.43	1.51	7.87	6.04	4.97	4.23	3.70	3.30	2.99	2.77	2.39	2.03	1.65	1.27	1.06	0.87	0.65
100	nil	.05	3.93	3.09	2.70	2.46	2.30	2.19	2.10	2.03	1.97	1.92	1.85	1.77	1.67	1.57	1.51	1.45	1.37
	nil	.01	6.89	4.82	3.98	3.51	3.21	2.99	2.82	2.69	2.59	2.50	2.37	2.22	2.07	1.89	1.80	1.69	1.57
	pow	.50	3.85	2.52	1.92	1.66	1.43	1.26	1.20	1.10	1.01	0.93	0.88	0.80	0.70	0.59	0.50	0.46	0.39
	pow	.80	7.95	4.94	3.73	3.10	2.67	2.37	2.17	1.99	1.84	1.72	1.56	1.38	1.18	0.97	0.83	0.71	o.57
	1%	.05	7.24	4.49	3.55	3.04	2.74	2.54	2.39	2.28	2.19	2.11	2.00	1.88	1.76	1.62	1.55	1.47	1.38
	1%	.01	11.60	6.76	5.13	4.30	3.80	3.45	3.21	3.02	2.87	2.75	2.56	2.37	2.17	1.96	1.84	1.72	1.58
	pow	.50	7.11	3.84	2.71	2.22	1.85	1.59	1.49	1.34	1.22	1.12	1.04	0.87	0.74	0.61	0.55	0.49	0.39
	pow	.80	12.45	6.76	4.82	3.83	3.22	2.80	2.53	2.29	2.11	1.95	1.75	1.50	1.26	1.01	0.88	0.74	0.58
	5%	.05	16.18	8.81	6.27	5.05	4.32	3.83	3.49	3.21	3.00	2.84	2.60	2.34	2.09	1.84	1.71	1.57	1.43
	5%	.01	22.59	2.08	8.57	6.82	5.76	5.06	4.56	4.18	3.88	3.65	3.29	2.94	2.58	2.21	2.03	1.84	1.64
	pow	.50	15.62	7.93	5.51	4.19	3.40	2.87	2.49	2.29	2.06	1.87	1.58	1.36	1.11	0.86	0.70	0.59	0.44
	pow	.80	23.49	2.03	8.22	6.30	5.14	4.36	3.81	3.43	3.10	2.83	2.43	2.06	1.67	1.28	1.06	0.86	0.63
120	nil	.05	3.91	3.07	2.68	2.45	2.29	2.17	2.09	2.01	1.96	1.91	1.83	1.75	1.66	1.55	1.49	1.43	1.35
	nil	.01	6.85	4.79	3.95	3.48	3.17	2.96	2.79	2.66	2.56	2.47	2.34	2.19	2.03	1.86	1.76	1.65	1.53
	pow	.50	3.84	2.51	1.91	1.56	1.42	1.25	1.11	1.09	1.00	0.92	0.87	0.74	0.64	0.54	0.50	0.43	0.36
	pow	.80	7.93	4.91	3.71	3.05	2.65	2.34	2.12	1.97	1.82	1.70	1.54	1.34	1.14	0.92	0.81	0.68	0.53
	1%	.05	7.76	4.74	3.66	3.13	2.81	2.59	2.43	2.31	2.21	2.13	2.01	1.89	1.75	1.61	1.54	1.45	1.36
	1%	.01	12.20	7.02	5.28	4.40	3.86	3.50	3.24	3.04	2.88	2.76	2.56	2.36	2.15	1.93	1.81	1.69	1.55
	pow	.50	7.58	4.04	2.92	2.29	1.90	1.63	1.52	1.36	1.24	1.13	1.05	0.87	0.74	0.61	0.54	0.46	0.37
	pow	.80	13.10	7.05	4.98	3.93	3.29	2.85	2.56	2.32	2.12	1.97	1.75	1.50	1.25	1.00	0.86	0.71	0.55
	5%	.05	17.88	9.64	6.89	5.45	4.64	4.09	3.70	3.41	3.17	2.98	2.71	2.43	2.15	1.87	1.72	1.57	1.42
	5%	.01	24.59	3.05	9.20	7.28	6.12	5.35	4.80	4.38	4.06	3.80	3.41	3.02	2.63	2.23	2.03	1.83	1.61
	pow	.50	17.37	8.79	5.92	4.63	3.74	3.15	2.73	2.41	2.25	2.04	1.72	1.47	1.13	0.87	0.74	0.59	0.42
	pow	.80	25.54	3.02	8.83	6.78	5.51	4.67	4.06	3.61	3.30	3.00	2.57	2.16	1.71	1.29	1.08	0.85	0.61
150	nil	.05	3.89	3.06	2.67	2.43	2.27	2.16	2 07	2.00	1.94	1.89	1.81	1.73	1.64	1.53	1.47	1.40	1.32
	nil	.01	6.80	4.75	3.92	3.45	3.14	2.92	2.76	2.63	2.53	2.44	2.30	2.16	2.00	1.83	1.73	1.62	1.49
	pow	.50	3.83	2.50	1.90	1.55	1.41	1.24	1.10	1.08	0.99	0.92	0.86	0.73	0.63	0.54	0.45	0.40	0.33
	pow	.80	7.90	4.R9	3.09	3.02	2.63	2.32	2.09	1.94	1.80	1.68	1.52	1.31	1.11	0.90	0.77	0.64	0.49
	1%	.05	8.61	5.01	3.86	3.28	2.92	2.66	2.49	2.36	2.25	2.17	2.03	1.90	1.76	1.61	1.53	1.44	1.34
	1%	.01	13.04	7.40	5.51	4.56	3.98	3.59	3.31	3.09	2.93	2.79	2.58	2.37	2.15	1.92	1.79	1.66	1.51
	pow	.50	8.26	4.42	3.09	2.40	1.98	1.78	1.56	1.40	1.27	1.15	1.06	0.88	0.74	0.61	0.51	0.43	0.34
	pow	.80	14.11	7.43	5.21	4.09	3.40	2.96	2.62	2.37	2.16	2.00	1.77	1.51	1.25	0.98	0.83	0.68	0.51
	5%	.05	20.52	0.86	7.64	6.06	5.11	4.48	4.03	3.69	3.41	3.20	2.88	2.57	2.24	1.92	1.75	1.59	1.41
	5%	.01	27.47	4.46	10.12	7.95	6.65	5.78	s 10	4.69	4.33	4.04	3.60	3.17	2.73	2.28	2.06	1.83	1.59
	pow	.50	19.73	0.24	6.86	5.19	4.19	3.52	3.04	2.67	2.48	2.25	1.90	1.61	1.23	0.93	0.75	0.59	0.41
	pow	.80	28.49	4.57	9.81	7.46	6.05	5.10	4,43	3.92	3.56	3.24	2.76	2.31	1.81	1.35	1.09	0.85	0.58

MINIMUM F REQUIRED (APPENDIX B)

COMPARISON TO A 1% EFFECT

With a DF_{hyp} = 1 and DF_{err} = 161, the Authors need an F-value of 8.61 or more to obtain a significant effect.

Obtained F = 4.81

We do NOT have a significant effect

One Stop F Table

dfErr			1	2	3	4	5	6	7	8	9	10	12	15	20	30	40	60	120
90	nil	.05	3.94	3.10	2.71	2.47	2.32	2.20	2.11	2.04	1.98	1.94	1.86	1.78	1.69	1.58	1.53	1.46	1.39
	nil	.01	6.92	4.85	4.01	3.53	3.23	3.01	2.84	2.72	2.61	2.52	2.39	2.24	2.09	1.91	1.82	1.72	1.60
	pow	.50	3.86	2.53	1.93	1.66	1.43	1.26	1.21	1.10	1.01	0.94	0.89	0.81	0.70	0.59	0.54	0.46	0.40
	pow	.80	7.97	4.95	3.75	3.12	2.69	2.38	2.18	2.00	1.86	1.74	1.58	1.40	1.20	0.98	0.86	0.73	0.59
	1%	.05	6.97	4.37	3.48	3.00	2.71	2.52	2.38	2.26	2.18	2.11	2.00	1.88	1.76	1.63	1.56	1.48	1.40
	1%	.01	11.29	6.64	5.06	4.26	3.77	3.43	3.19	3.01	2.86	2.74	2.56	2.38	2.18	1.97	1.86	1.74	1.61
	pow	.50	6.86	3.74	2.66	2.18	1.83	1.58	1.47	1.33	1.21	1.12	1.03	0.87	0.79	0.65	0.55	0.49	0.40
	pow	.80	12.12	6.62	4.74	3.19	3.19	2.78	2.52	2.28	2.10	1.95	1.75	1.51	1.29	1.04	0.89	0.76	0.60
	5%	.05	15.17	8.31	6.02	4.88	4.15	3.70	3.37	3.12	2.93	2.77	2.54	2.30	2.07	1.83	1.70	1.58	1.44
	5%	.01	21.57	1.59	8.25	6.59	5.58	4.92	4.44	4.08	3.80	3.57	3.24	2.90	2.55	2.21	2.03	1.85	1.66
	pow	.50	14.87	7.58	5.14	3.92	3.29	2.78	2.41	2.14	1.92	1.82	1.55	1.34	1.09	0.85	0.69	0.58	0.45
	pow	.80	22.43	1.51	7.87	6.04	4.97	4.23	3.70	3.30	2.99	2.77	2.39	2.03	1.65	1.27	1.06	0.87	0.65
100	nil	.05	3.93	3.09	2.70	2.46	2.30	2.19	2.10	2.03	1.97	1.92	1.85	1.77	1.67	1.57	1.51	1.45	1.37
	nil	.01	6.89	4.82	3.98	3.51	3.21	2.99	2.82	2.69	2.59	2.50	2.37	2.22	2.07	1.89	1.80	1.69	1.57
	pow	.50	3.85	2.52	1.92	1.66	1.43	1.26	1.20	1.10	1.01	0.93	0.88	0.80	0.70	0.59	0.50	0.46	0.39
	pow	.80	7.95	4.94	3.73	3.10	2.67	2.37	2.17	1.99	1.84	1.72	1.56	1.38	1.18	0.97	0.83	0.71	o.57
	1%	.05	7.24	4.49	3.55	3.04	2.74	2.54	2.39	2.28	2.19	2.11	2.00	1.88	1.76	1.62	1.55	1.47	1.38
	1%	.01	11.60	6.76	5.13	4.30	3.80	3.45	3.21	3.02	2.87	2.75	2.56	2.37	2.17	1.96	1.84	1.72	1.58
	pow	.50	7.11	3.84	2.71	2.22	1.85	1.59	1.49	1.34	1.22	1.12	1.04	0.87	0.74	0.61	0.55	0.49	0.39
	pow	.80	12.45	6.76	4.82	3.83	3.22	2.80	2.53	2.29	2.11	1.95	1.75	1.50	1.26	1.01	0.88	0.74	0.58
	5%	.05	16.18	8.81	6.27	5.05	4.32	3.83	3.49	3.21	3.00	2.84	2.60	2.34	2.09	1.84	1.71	1.57	1.43
	5%	.01	22.59	2.08	8.57	6.82	5.76	5.06	4.56	4.18	3.88	3.65	3.29	2.94	2.58	2.21	2.03	1.84	1.64
	pow	.50	15.62	7.93	5.51	4.19	3.40	2.87	2.49	2.29	2.06	1.87	1.58	1.36	1.11	0.86	0.70	0.59	0.44
	pow	.80	23.49	2.03	8.22	6.30	5.14	4.36	3.81	3.43	3.10	2.83	2.43	2.06	1.67	1.28	1.06	0.86	0.63
120	nil	.05	3.91	3.07	2.68	2.45	2.29	2.17	2.09	2.01	1.96	1.91	1.83	1.75	1.66	1.55	1.49	1.43	1.35
	nil	.01	6.85	4.79	3.95	3.48	3.17	2.96	2.79	2.66	2.56	2.47	2.34	2.19	2.03	1.86	1.76	1.65	1.53
	pow	.50	3.84	2.51	1.91	1.56	1.42	1.25	1.11	1.09	1.00	0.92	0.87	0.74	0.64	0.54	0.50	0.43	0.36
	pow	.80	7.93	4.91	3.71	3.05	2.65	2.34	2.12	1.97	1.82	1.70	1.54	1.34	1.14	0.92	0.81	0.68	0.53
	1%	.05	7.76	4.74	3.66	3.13	2.81	2.59	2.43	2.31	2.21	2.13	2.01	1.89	1.75	1.61	1.54	1.45	1.36
	1%	.01	12.20	7.02	5.28	4.40	3.86	3.50	3.24	3.04	2.88	2.76	2.56	2.36	2.15	1.93	1.81	1.69	1.55
	pow	.50	7.58	4.04	2.92	2.29	1.90	1.63	1.52	1.36	1.24	1.13	1.05	0.87	0.74	0.61	0.54	0.46	0.37
	pow	.80	13.10	7.05	4.98	3.93	3.29	2.85	2.56	2.32	2.12	1.97	1.75	1.50	1.25	1.00	0.86	0.71	0.55
	5%	.05	17.88	9.64	6.89	5.45	4.64	4.09	3.70	3.41	3.17	2.98	2.71	2.43	2.15	1.87	1.72	1.57	1.42
	5%	.01	24.59	3.05	9.20	7.28	6.12	5.35	4.80	4.38	4.06	3.80	3.41	3.02	2.63	2.23	2.03	1.83	1.61
	pow	.50	17.37	8.79	5.92	4.63	3.74	3.15	2.73	2.41	2.25	2.04	1.72	1.47	1.13	0.87	0.74	0.59	0.42
	pow	.80	25.54	3.02	8.83	6.78	5.51	4.67	4.06	3.61	3.30	3.00	2.57	2.16	1.71	1.29	1.08	0.85	0.61
150	nil	.05	3.89	3.06	2.67	2.43	2.27	2.16	2 07	2.00	1.94	1.89	1.81	1.73	1.64	1.53	1.47	1.40	1.32
	nil	.01	6.80	4.75	3.92	3.45	3.14	2.92	2.76	2.63	2.53	2.44	2.30	2.16	2.00	1.83	1.73	1.62	1.49
	pow	.50	3.83	2.50	1.90	1.55	1.41	1.24	1.10	1.08	0.99	0.92	0.86	0.73	0.63	0.54	0.45	0.40	0.33
	pow	.80	7.90	4.89	3.69	3.02	2.63	2.32	2.09	1.94	1.80	1.68	1.52	1.31	1.11	0.90	0.77	0.64	0.49
	1%	.05	8.61	5.01	3.86	3.28	2.92	2.66	2.49	2.36	2.25	2.17	2.03	1.90	1.76	1.61	1.53	1.44	1.34
	1%	.01	13.04	7.40	5.51	4.56	3.98	3.59	3.31	3.09	2.93	2.79	2.58	2.37	2.15	1.92	1.79	1.66	1.51
	pow	.50	8.26	4.42	3.09	2.40	1.98	1.78	1.56	1.40	1.27	1.15	1.06	0.88	0.74	0.61	0.51	0.43	0.34
	pow	.80	14.11	7.43	5.21	4.09	3.40	2.96	2.62	2.37	2.16	2.00	1.77	1.51	1.25	0.98	0.83	0.68	0.51
	5%	.05	20.52	0.86	7.64	6.06	5.11	4.48	4.03	3.69	3.41	3.20	2.88	2.57	2.24	1.92	1.75	1.59	1.41
	5%	.01	27.47	4.46	10.12	7.95	6.65	5.78	s 10	4.69	4.33	4.04	3.60	3.17	2.73	2.28	2.06	1.83	1.59
	pow	.50	19.73	0.24	6.86	5.19	4.19	3.52	3.04	2.67	2.48	2.25	1.90	1.61	1.23	0.93	0.75	0.59	0.41
	pow	.80	28.49	4.57	9.81	7.46	6.05	5.10	4,43	3.92	3.56	3.24	2.76	2.31	1.81	1.35	1.09	0.85	0.58

PART 2: BAYESIAN ANALYSES

A QUICK INTRODUCTION TO BAYESIAN STATISTICS

- Increasingly popular in psychology
- Models account for background knowledge *(not discussed in detail in this lab)*
- May allow us to overcome several limitations of NHSTs (e.g., the reproducibility crisis in psychology and reliance on large sample sizes)
- All common statistical analyses can be conducted in a bayesian framework (ANOVAs, regression, correlation, factor analysis, etc.)
- Interpretations are often more concrete than significance tests (clear probability statements)
- Today we will be calculating a statistic called a “Bayes factor”

Note: While bayesian analyses are on the rise and may overcome several limitations of frequentist methods, use of classical statistics has been argued for as well (e.g., this NY Times article from 2014: https://www.nytimes.com/2014/09/30/science/the-odds-continually-updated.html?_r=1)

RULES OF THUMB FOR BAYES FACTOR INTERPRETATIONS

Table 1. Evidence Categories for *p* Values (adapted from Wasserman, 2004, p. 157), for Effect Sizes (as proposed by Cohen, 1988), and for Bayes Factor BF_{A0} (Jeffreys, 1961)

Statistic	Interpretation
p value	
<.001	Decisive evidence against H_0
.001–.01	Substantive evidence against H_0
.01–.05	Positive evidence against H_0
>.05	No evidence against H_0
Effect size	
<0.2	Small effect size
0.2–0.5	Small to medium effect size
0.5–0.8	Medium to large effect size
0.8	Large to very large effect size
Bayes factor	
>100	Decisive evidence for H_A
30–100	Very strong evidence for H_A
10–30	Strong evidence for H_A
3–10	Substantial evidence for H_A
1–3	Anecdotal evidence for H_A
1	No evidence
1/3–1	Anecdotal evidence for H_0
1/10–1/3	Substantial evidence for H_0
1/30–1/10	Strong evidence for H_0
1/100–1/30	Very strong evidence for H_0
<1/100	Decisive evidence for H_0

Note: For the Bayes factor categories, we replaced the label "worth no more than a bare mention" with "anecdotal." Also, in contrast to *p* values, the Bayes factor can quantify evidence in favor of the null hypothesis.

Bayes factors are indices of *relative* evidence of one model (or hypothesis) over another

Evidence for alternative hypothesis (compared to null hypothesis)

Evidence for null hypothesis (compared to alternative hypothesis)

Wetzels et al., 2011
https://journals.sagepub.com/doi/abs/10.1177/1745691611406923

DATASET DESCRIPTION

A team of researchers analyzed if People's mental health after retirement was better or worse based on their sex and previous occupation.

- **sex:** participant sex. 1 = Female, 2 = Male
- **occupation:** Participant occupation prior to retirement. 1 = Professional, 2 = Manager, 3 = nonmanual worker, 4 = Skilled worker, 5 = semi-skilled worker, 6 = unskilled worker.
- **mental:** The participants score on a mental health measure. Higher scores indicate better mental health.

LET'S CODE!

LAST TUTORIAL OF THE SEMESTER! ☺

YOU ALL HAVE BEEN GREAT!

CREATE A NEW R-PROJECT AND R-NOTEBOOK!

Download the “retirement.csv” file from Canvas and save it into your R-project file

LOAD LIBRARIES

```
# Load libraries
```{r}
library(tidyverse)
library(psych)
library(BayesFactor)
```
```

READ IN THE retirement.csv

```
# read in retirement.csv
```{r}
retirement <- read_csv("retirement.csv")
```
```

```
-- Column specification ------------------------
cols(
  occupation = col_double(),
  sex = col_double(),
  mental = col_double()
)
```

```r
# Factor the categorical variables
```{r}
retirement <- mutate(retirement,
                     sex.f = factor(sex,
                                    levels = c(1,2),
                                    labels = c("Female", "Male")),
                     occupation.f = factor(occupation,
                                           levels = c(1,2,3,4,5,6),
                                          labels = c("Prof", "Manag", "nonmanual", "Skilled", "Semi-Skilled", "Unskilled")))
```
```

FACTOR CATEGORICAL VARIABLES

DESCRIBE DATA

```
# describe data
```{r}
describe(retirement)
```
```

Description: df[,13] [5 x 13]

	vars <dbl>	n <dbl>	mean <dbl>	sd <dbl>	median <dbl>	trimmed <dbl>	mad <dbl>	min <dbl>	max <dbl>
occupation	1	1910	3.15	1.25	3	3.09	1.48	1	6
sex	2	1910	1.61	0.49	2	1.64	0.00	1	2
mental	3	1910	3.79	0.91	4	3.84	1.48	1	5
sex.f*	4	1910	1.61	0.49	2	1.64	0.00	1	2
occupation.f*	5	1910	3.15	1.25	3	3.09	1.48	1	6

5 rows | 1-10 of 13 columns

RUN A NORMAL ANOVA

```
# Normal ANOVA
```{r}
anova(lm(mental~ sex.f*occupation.f, data = retirement))
```
```

```
Analysis of Variance Table

Response: mental
                     Df  Sum Sq Mean Sq F value    Pr(>F)    
sex.f                 1    0.21  0.2062  0.2558    0.6131    
occupation.f          5   45.93  9.1865 11.3962 7.439e-11 ***
sex.f:occupation.f    5    6.01  1.2021  1.4912    0.1894    
Residuals          1898 1529.99  0.8061                      
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

CALCULATE ETA^2 EFFECT SIZE

- Eta^2 = SSeffect / SStotal

```{r}
sex_eta    <-  0.21 / (1529.99 + .21 + 45.93 + 6.01)
occ_eta    <- 45.93 / (1529.99 + .21 + 45.93 + 6.01)
int_et     <-  6.01 / (1529.99 + .21 + 45.93 + 6.01)

sex_eta
occ_eta
int_et
```

```
[1] 0.0001327316
[1] 0.0290303
[1] 0.003798652
```

RUN BAYES FACTOR ANOVA, whichModels = “all”

```
# Bayes ANOVA: "all"
```{r}

m1 <- anovaBF(mental~ sex.f*occupation.f, data = retirement, whichModels = "all")
m1
```
```

```
  |=====================================================================================| 100%
Bayes factor analysis
--------------
[1] sex.f                                     : 0.05966566   ±0%
[2] occupation.f                              : 54417793     ±0.01%
[3] sex.f:occupation.f                        : 0.009737589  ±0.1%
[4] sex.f + occupation.f                      : 5049013      ±7.05%
[5] sex.f + sex.f:occupation.f                : 0.0006661466 ±2.5%
[6] occupation.f + sex.f:occupation.f         : 1620368      ±0.69%
[7] sex.f + occupation.f + sex.f:occupation.f : 112545.7     ±1.14%

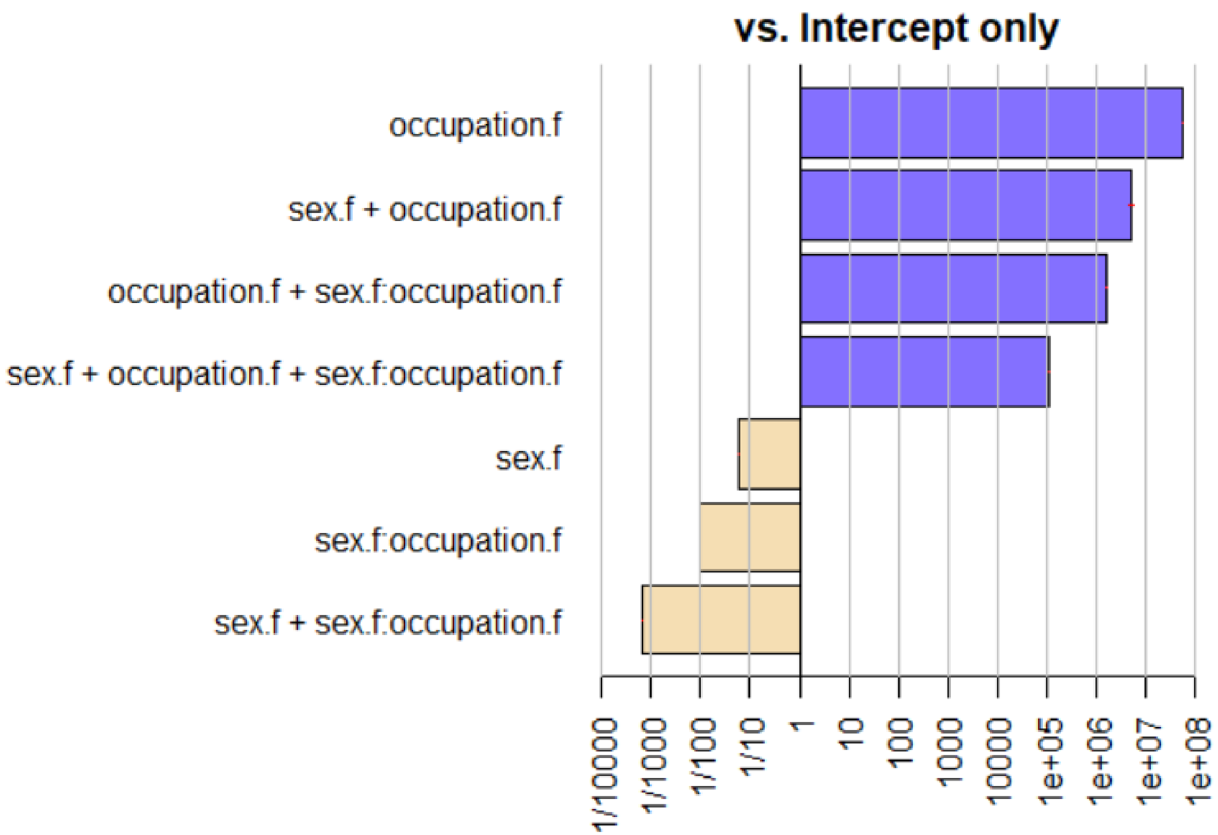
Against denominator:
  Intercept only
---
Bayes factor type: BFlinearModel, JZS
```

Shows Bayes factor for all possible models.

As can be seen: Any model with the inclusion of occupation.f main effect results in an extremely large Bayes factor!

PLOT BAYES FACTOR ANOVA, whichModels = “all”

```{r}
plot(m1)
```



RUN BAYES FACTOR ANOVA, whichModels = "top"

```
#Bayes ANOVA: "top"
```{r}
m2 <- anovaBF(mental~ sex.f*occupation.f, data = retirement, whichModels = "top")
m2
```
```

```
  |===========================================================================================| 100%
Bayes factor top-down analysis
--------------
When effect is omitted from sex.f + occupation.f + sex.f:occupation.f , BF is...
[1] Omit occupation.f:sex.f : 41.26221    ±1.68%
[2] Omit occupation.f       : 6.41187e-09 ±8.88%
[3] Omit sex.f              : 14.37825    ±1.62%

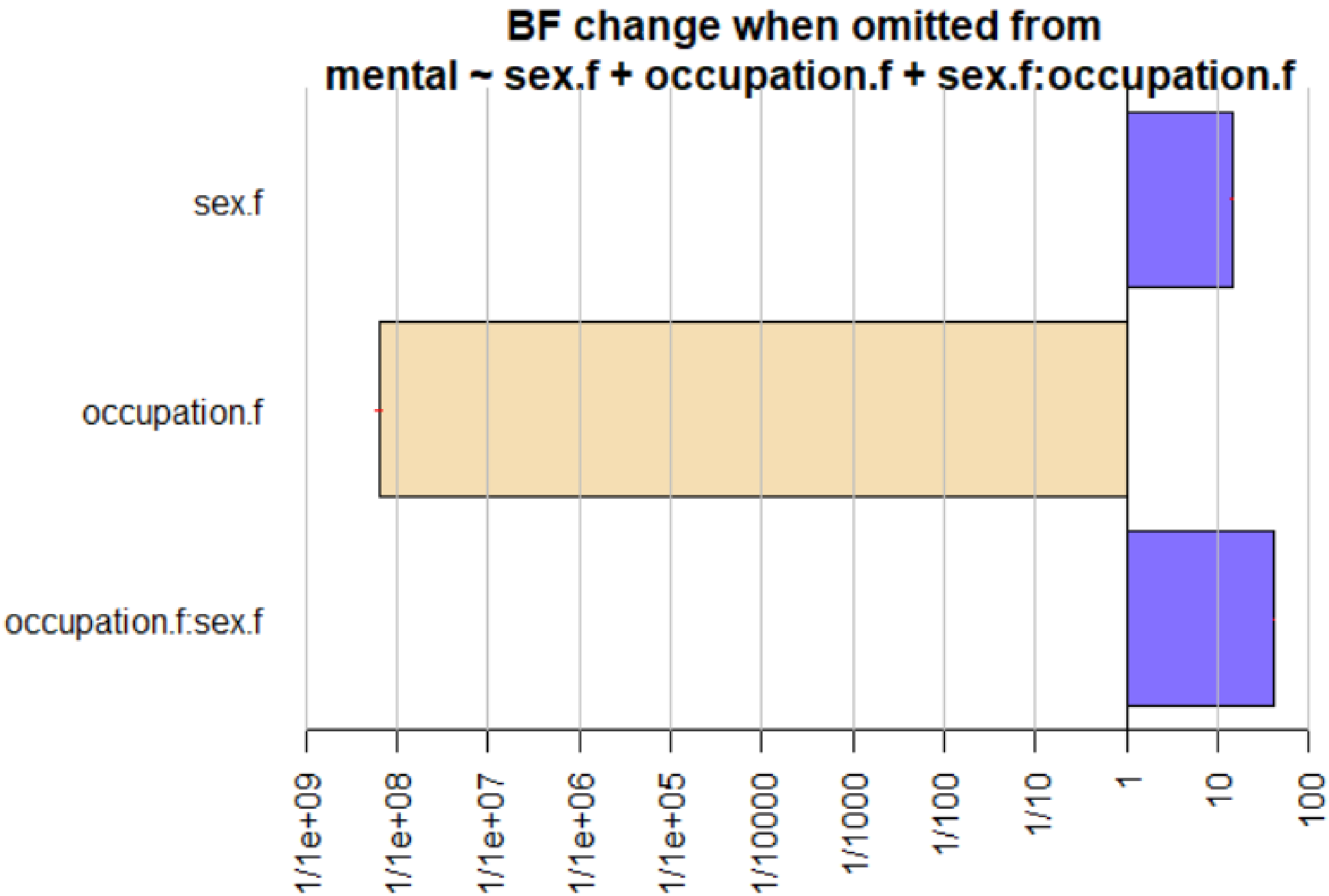
Against denominator:
  mental ~ sex.f + occupation.f + sex.f:occupation.f
---
Bayes factor type: BFlinearModel, JZS
```

Shows how the *omission* of a variable will affect the Bayes factor value

As can be seen: Any model with the *omission* of occupation.f main effect results in an extremely small Bayes factor!

PLOT BAYES FACTOR ANOVA, whichModels = “top”

```{r}
plot(m2)
```



RUN BAYES FACTOR ANOVA, whichModels = “bottom”

```
#Bayes ANOVA: "bottom"
```{r}
m3 <- anovaBF(mental~ sex.f*occupation.f, data = retirement, whichModels = "bottom")
m3
```
```

```
  |=================================================================================| 100%
Bayes factor analysis
--------------
[1] sex.f              : 0.05966566  ±0%
[2] occupation.f       : 54417793    ±0.01%
[3] sex.f:occupation.f : 0.009737589 ±0.1%

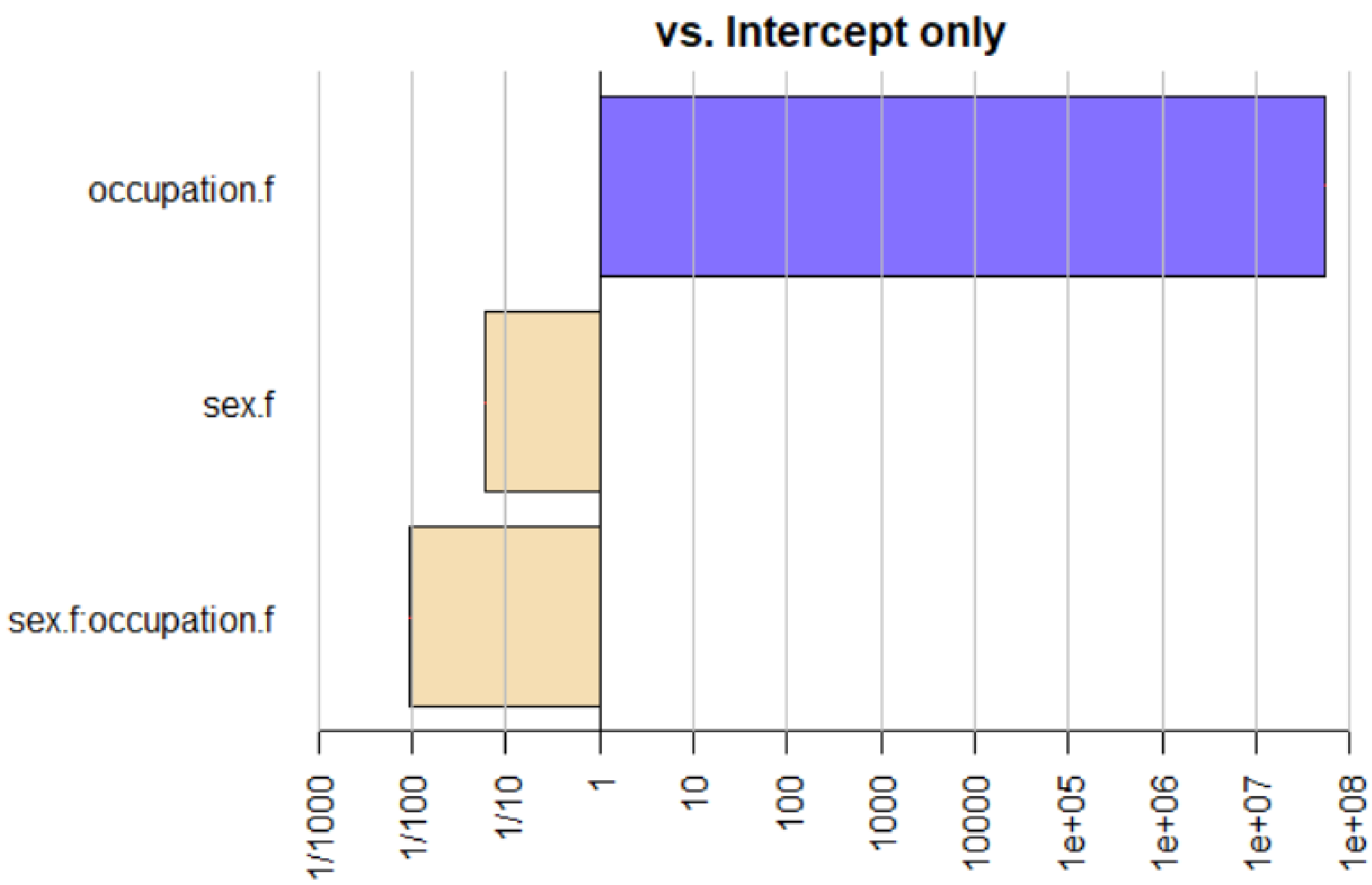
Against denominator:
  Intercept only 
---
Bayes factor type: BFlinearModel, JZS
```

Shows Bayes factor for *adding in* a variable

As can be seen: Any model with the addition of occupation.f main effect results in an extremely large Bayes factor!

PLOT BAYES FACTOR ANOVA, whichModels = “bottom”

```{r}
plot(m3)
```



ADDITIONAL RESOURCES ON BAYESIAN APPROACHES

An article by Etz & Vandekerckhove (2018) about basic bayesian inferences. It opens with a quote by Dumbledore, so you know you want to read it! https://link.springer.com/article/10.3758/s13423-017-1262-3

Helpful tutorials for learning bayesian analyses using the BayesFactor package: https://richarddmorey.github.io/BayesFactor/#fixed

More great tutorials for getting started with bayesian analyses, this time from the BayestestR package: https://cran.r-project.org/web/packages/bayestestR/vignettes/bayestestR.html

> *The accompanying citation for the BayestestR package can be found at: https://www.theoj.org/joss-papers/joss.01541/10.21105.joss.01541.pdf*

An example of using top down and bottom-up approaches with bayesian analyses: https://datascienceplus.com/bayesian-statistics-analysis-of-health-data/

An article by Krypotos et al. (2017) that calls for increased use of Bayesian approaches (and less NHST) in experimental psychology: https://journals.sagepub.com/doi/10.5127/jep.057316

THANKS FOR A GREAT SEMESTER!

- Once a student, always a student!
- Never hesitate to reach out in the future! - *ndyetz@gmail.com*
- I will keep all the YouTube videos up for your future reference

THANK YOU FOR BEING SUCH A WONDERFUL CLASS!

I enjoyed every minute of it!