Are Snakes Left-handed?

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Question 1

Do these creatures in general exhibit asymmetric coiling behavior? (Include a graphical display and an inference test to answer this question.)

Graph

Inference Test

Let $\mu =$ the true mean laterality index of cottonmouth snakes

$$H_0 : \mu = 0.5$$
$$H_a : \mu \neq 0.5$$
$$\alpha = 0.05$$

Test: 1-sample mean t-test

Checks

Normal: Central limit theorem, $n = 36 \geq 30$
Random: Reasonable to assume that SRS was used
10%: Reasonable to assume that $n \leq 0.1N$

Calculations

$$t = \frac{\bar{x}-\mu}{\sqrt{\frac{s^2}{n}}} = \frac{0.5184-0.5}{\sqrt{\frac{0.0566^2}{36}}} = 1.9468$$
$$p = P(t > 1.9468) = 0.0596 \text{ (with } df = 35)$$

Conclusion

Since our p-value (0.0596) is greater than α (0.05), we fail to reject our null hypothesis that cottonmouth snakes generally exhibit symmetric coiling behavior. Therefore, we do not have sufficient evidence to support the alternative hypothesis that cottonmouth snakes exhibit asymmetric coiling behavior.

Question 2

Which individual category (or combination of categories) of snake best exhibits/predicts asymmetric coiling behavior? (Explore different linear and multiple regression models. Chose the best fit. Include supporting documentation as to why you chose the model you did. No need to run an inference test.)

Models

Gender

```r
regres1 <- lm(Lat.Index ~ factor(Gender), data = snake_data)
summary(regres1)
```

```
##
## Call:
## lm(formula = Lat.Index ~ factor(Gender), data = snake_data)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.119444 -0.024319  0.008056  0.041722  0.101556
##
## Coefficients:
##                     Estimate Std. Error t value Pr(>|t|)
## (Intercept)          0.53644    0.01280  41.901   <2e-16 ***
## factor(Gender)Male -0.03617    0.01811  -1.998   0.0538 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.05432 on 34 degrees of freedom
## Multiple R-squared:  0.105,  Adjusted R-squared:  0.07871
## F-statistic:  3.99 on 1 and 34 DF,  p-value: 0.05382
```

Age

```r
regres2 <- lm(Lat.Index ~ factor(Age), data = snake_data)
summary(regres2)
```

```
##
## Call:
## lm(formula = Lat.Index ~ factor(Age), data = snake_data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.15072 -0.01525  0.00300  0.02375  0.09228
```

```
##
## Coefficients:
##                     Estimate Std. Error t value Pr(>|t|)
## (Intercept)          0.54572    0.01179  46.270   <2e-16 ***
## factor(Age)Juvenile -0.05472    0.01668  -3.281   0.0024 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.05004 on 34 degrees of freedom
## Multiple R-squared:  0.2405, Adjusted R-squared:  0.2181
## F-statistic: 10.76 on 1 and 34 DF,  p-value: 0.002397
```

Gender:Age

```r
regres3 <- lm(Lat.Index ~ factor(Gender) : factor(Age), data = snake_data)
summary(regres3)
```

```
##
## Call:
## lm(formula = Lat.Index ~ factor(Gender):factor(Age), data = snake_data)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.117889 -0.023889  0.005889  0.028917  0.070667
##
## Coefficients: (1 not defined because of singularities)
##                                         Estimate Std. Error t value Pr(>|t|)
## (Intercept)                             0.487667   0.015084  32.330  < 2e-16
## factor(Gender)Female:factor(Age)Adult    0.090889   0.021332   4.261 0.000168
## factor(Gender)Male:factor(Age)Adult      0.025222   0.021332   1.182 0.245777
## factor(Gender)Female:factor(Age)Juvenile 0.006667   0.021332   0.313 0.756676
## factor(Gender)Male:factor(Age)Juvenile         NA         NA      NA       NA
##
## (Intercept)                             ***
## factor(Gender)Female:factor(Age)Adult    ***
## factor(Gender)Male:factor(Age)Adult
## factor(Gender)Female:factor(Age)Juvenile
## factor(Gender)Male:factor(Age)Juvenile
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.04525 on 32 degrees of freedom
## Multiple R-squared:  0.4154, Adjusted R-squared:  0.3605
## F-statistic: 7.578 on 3 and 32 DF,  p-value: 0.0005767
```

Conclusion

It appears that a combination of age and gender is the best way to predict a snake's asymmetric coiling behavior. The model using both age and gender had an r^2 value of 0.4154 and an $r^2(adj)$ value of 0.3605. The model using only gender and the one using only age had r^2 values of 0.105 and 0.2405, respectively, and $r^2(adj)$ values of 0.07871 and 0.2181, respectively.

Question 3

Do adults differ from juveniles in their asymmetric coiling behavior? Also, do males differ from females in their asymmetric coiling behavior? (Two separate inference tests are needed to answer this prompt.)

Adults vs. Juveniles

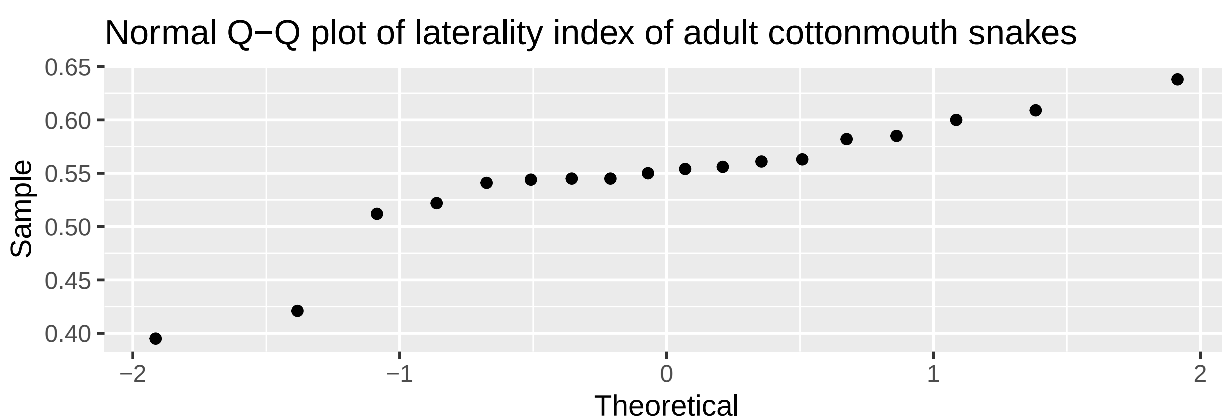
Let μ_a represent the true mean laterality index of adult cottonmouth snakes
Let μ_j represent the true mean laterality index of juvenile cottonmouth snakes

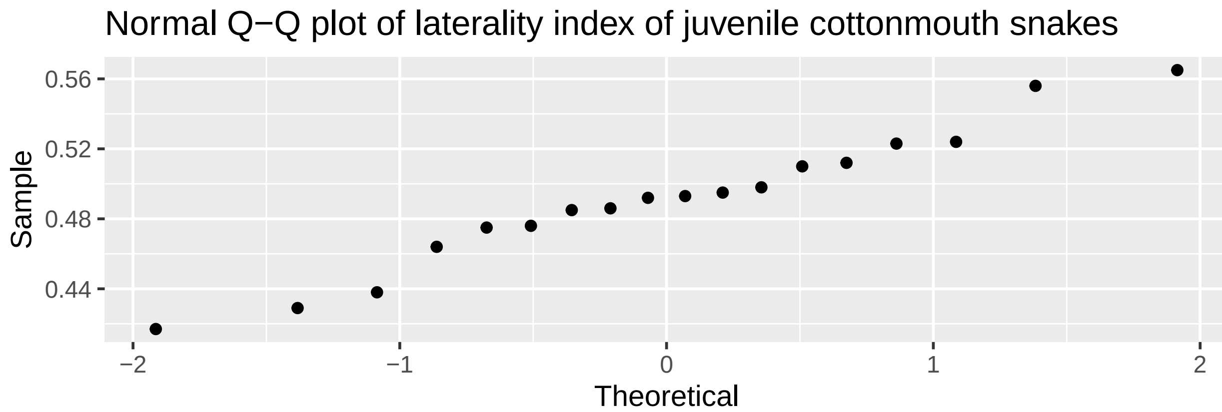
$$H_0 : \mu_a = \mu_j$$
$$H_a : \mu_a \neq \mu_j$$
$$\alpha = 0.05$$

Test: 2-sample difference of means t-test

Checks

Normal: $n_a = 18 < 30$ and $n_j = 18 < 30$, normal probability plots required





Since both Q-Q plots appear relatively linear, we will proceed with the test.
Random: reasonable to assume SRS was used
10%: reasonable to assume that $n_a \leq 0.1N_a$ and $n_j \leq 0.1N_j$

Calculations

$$t = \frac{(\bar{x_a} - \bar{x_j}) - (\mu_a - \mu_j)}{\sqrt{\frac{s_a^2}{n_a} + \frac{s_j^2}{n_j}}} = \frac{(0.5457 - 0.4910) - (0)}{\sqrt{\frac{0.0589^2}{18} + \frac{0.0392^2}{18}}} = 3.2808$$
$$p = P(t > 3.2808) = 0.002657 \text{ with } df = 29.568$$

Conclusion

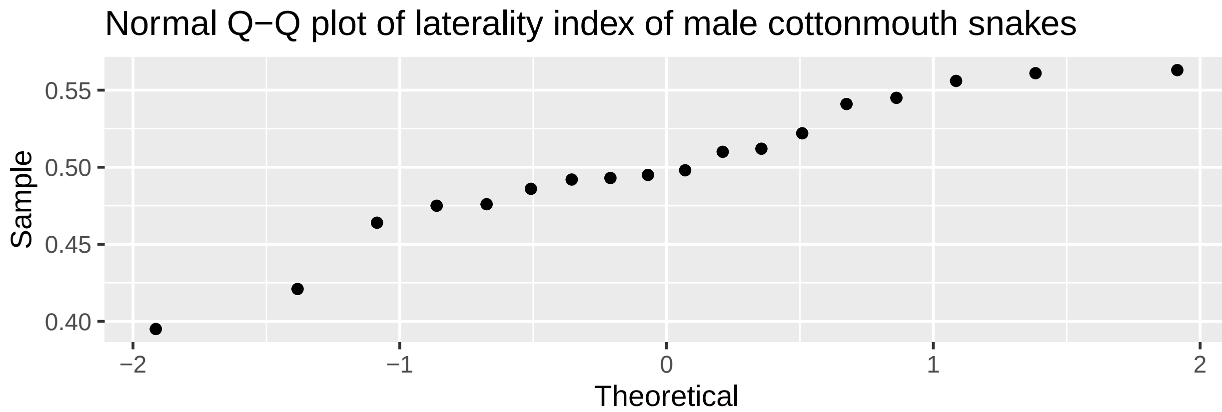
Since our p-value (0.002657) is less than α (0.05), we reject the null hypothesis that the true mean laterality indices of adult and juvenile cottonmouth snakes are equal. Therefore, we have sufficient evidence to support the alternative hypothesis that adults and juveniles have different mean laterality indices.

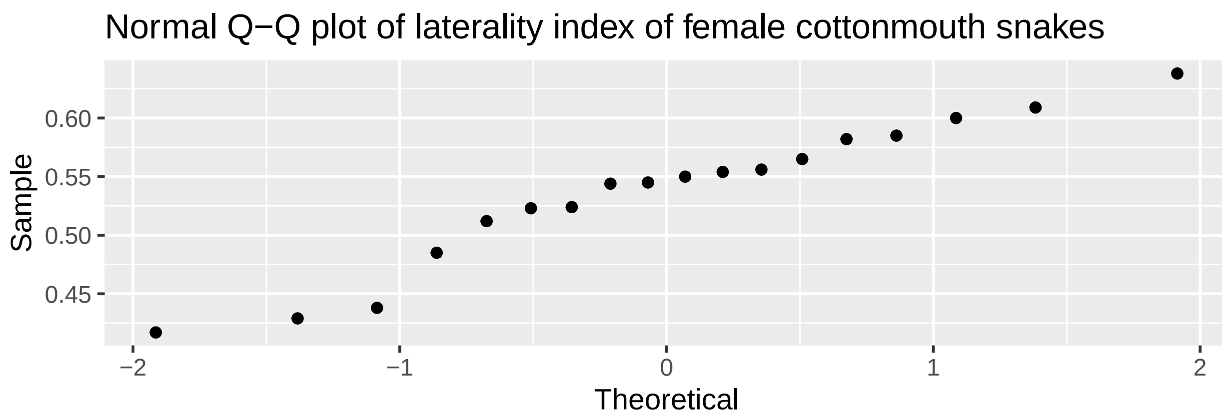
Males vs. Females

Let μ_m represent the true mean laterality index of male cottonmouth snakes
Let μ_f represent the true mean laterality index of female cottonmouth snakes
$H_0 : \mu_m = \mu_f$ $H_a : \mu_m \neq \mu_f$ $\alpha = 0.05$ Test: 2-sample difference of means t-test

Checks

Normal: $n_m = 18 < 30$ and $n_f = 18 < 30$, normal probability plots required





Since both Q-Q plots appear relatively linear, we will proceed with the test.
Random: reasonable to assume SRS was used
10%: reasonable to assume that $n_m \leq 0.1N_m$ and $n_f \leq 0.1N_f$

Calculations

$$t = \frac{(\bar{x_m} - \bar{x_f}) - (\mu_m - \mu_f)}{\sqrt{\frac{s_m^2}{n_m} + \frac{s_f^2}{n_f}}} = \frac{(0.5003 - 0.534) - (0)}{\sqrt{\frac{0.0456^2}{18} + \frac{0.618^2}{18}}} = 1.9975$$
$$p = P(t > 1.9975) = 0.05453 \text{ w/ } df = 31.278$$

Conclusion

Since our p-value (0.05453) is greater than α (0.05), we fail to reject the null hypothesis that the true mean laterality indices of male and female cottonmouth snakes are different. Therefore, we do not have significant evidence to support the alternative hypothesis that the true mean laterality indices of male and female cottonmouth snakes are not equal.

Conclusion

In conclusion, juveniles differ from adults in their coiling behavior, while males do not differ from females.

Question 4

Is there a difference in mean coiling laterality index per each categorical pairing of snake? (AF, JF, AM, JM) (Well, if you have been paying attention during the new learning from Semester II, this question should be easy for you to answer. State hypotheses, show all work with your calculations, confirm your calculations with an ANOVA summary table using R which you will copy and paste into your narrative/document, and write a conclusion.)

Inference test

Let μ_{af}, μ_{jf}, μ_{am}, and μ_{jm} represent the true mean laterality indices of adult female, juvenile female, adult male, and juvenile male cottonmouth snakes, respectively

$$H_0 : \mu_{af} = \mu_{jf} = \mu_{am} = \mu_{jm}$$

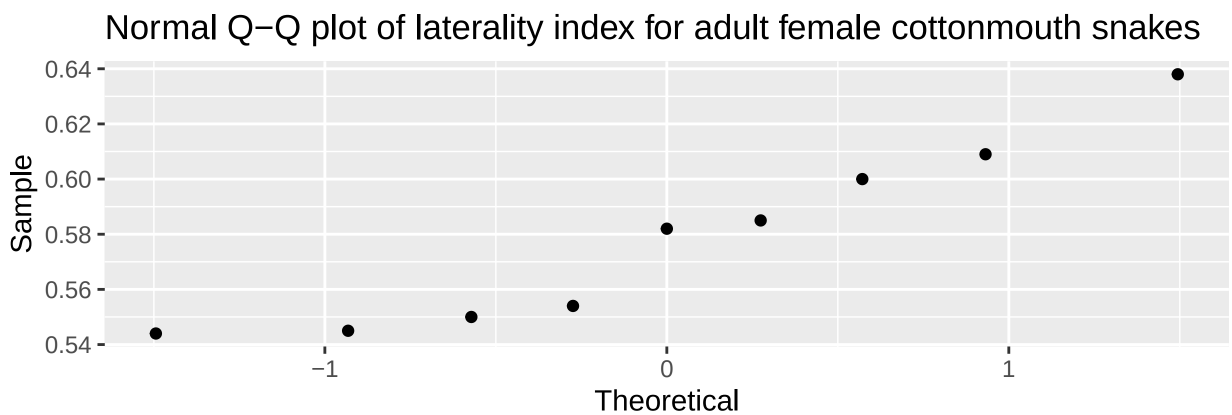
$$H_a : H_0 \text{ is false (i.e. at least one of the means is different from the others)}$$

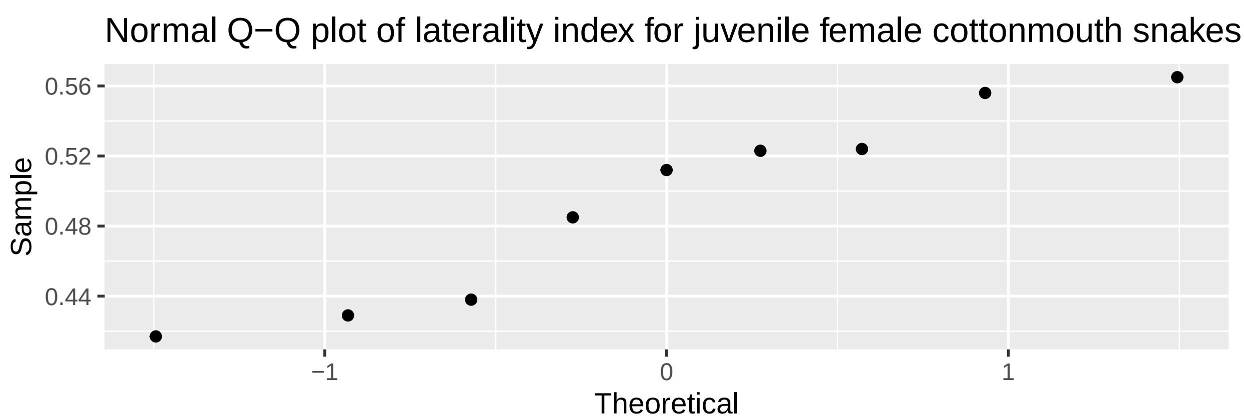
$$\alpha = 0.05$$

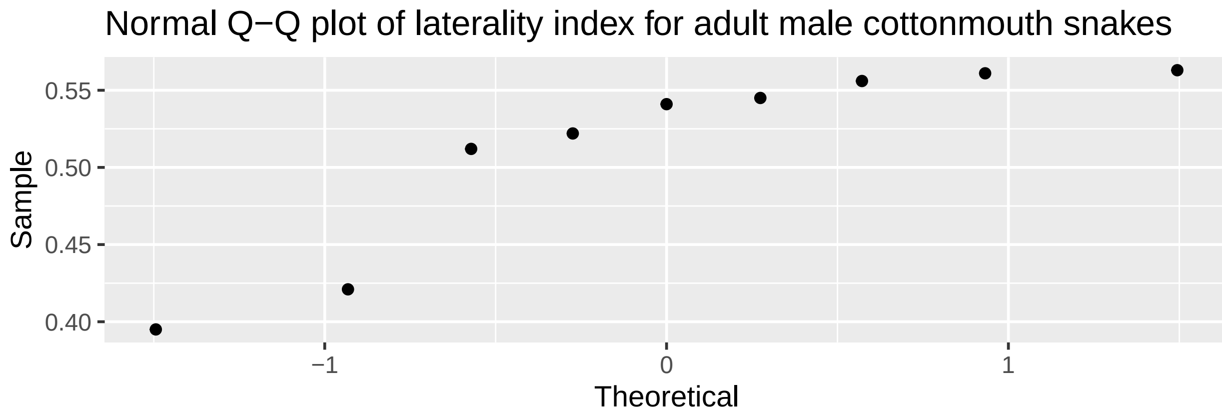
Test: One-Way ANOVA

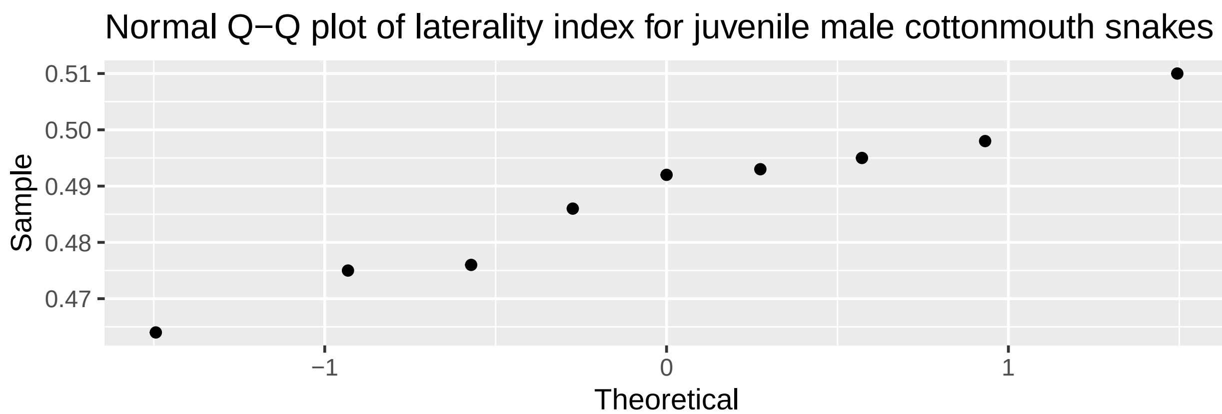
Checks

All populations approximately normal:









Since the normal Q-Q plots are all approximately linear, we will proceed with the test.
Standard deviations approximately equal: largest standard deviation is no more than twice the smallest
$s_{smallest} = 0.014 < 2s_{largest} = 2 \times 0.062$ Check failed, proceeding with caution anyways
Random: reasonable to assume SRS was used

Calculations

$$SSTr = \sum n_k(\bar{x}_k - \bar{\bar{x}})^2 = 0.0466$$
$$SSE = \sum (n_k - 1)s_k^2 = 0.0655$$
$$MSTr = \frac{SSTr}{k-1} = \frac{0.0466}{4-1} = 0.0155$$
$$MSE = \frac{SSE}{N-k} = \frac{0.0655}{36-4} = 0.0020$$
$$F = \frac{MSTr}{MSE} = \frac{0.0155}{0.0020} = 7.5781$$
$$p = P(F > 7.5781) = 0.0005767 \text{ w/ } df = \frac{3}{32}$$

Conclusion

Since our p-value (0.0005767) is less than α (0.05), we reject our null hypothesis that all of the true means are different. Therefore, we have enough evidence to support the alternative hypothesis that at least one of the true means is different from the others.

ANOVA table

```
## Analysis of Variance Table
##
## Response: Lat.Index
##           Df   Sum Sq   Mean Sq F value    Pr(>F)
## Cat.Pair   3 0.046555 0.0155184  7.5781 0.0005767 ***
## Residuals 32 0.065529 0.0020478
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```