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Part 4

Assessing normality when you have two repeated measures

The Wilcoxon signed-rank test

Assessing the assumption of normality

- Q-Q plots and Shapiro-Wilk test used

The difference between timepoint 1 and timepoint 2 should be normally distributed

Calculate a difference score for each participant and assess normality of this difference score

Research question

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Does day of the week affect how much fizzy drinks an individual consumes (Saturday vs Monday)?

Participants come into the lab for the day and are offered unlimited fizzy drinks. Does the amount of fizzy drink consumed (in ml) differ depending on the day of the week?

Same participants in each condition!

Participant	Saturday	Monday
1	630	46
2	810	21
3	630	542
4	740	745
5	416	411
6	226	226
7	468	304
8	753	23
9	274	177

Load in the data and calculate a difference score

Load in the data:

```
fizzy_drink_data <- read.csv("fizzy_drink_data.csv")
```

	Participant	Saturday	Monday
1	1	630	46
2	2	810	21
3	3	630	542
4	4	740	745
5	5	416	411
6	6	226	226
7	7	468	304
8	8	753	23
9	9	274	177

Calculate a difference score:

```
fizzy_drink_data$difference <- fizzy_drink_data$Saturday - fizzy_drink_data$Monday
```

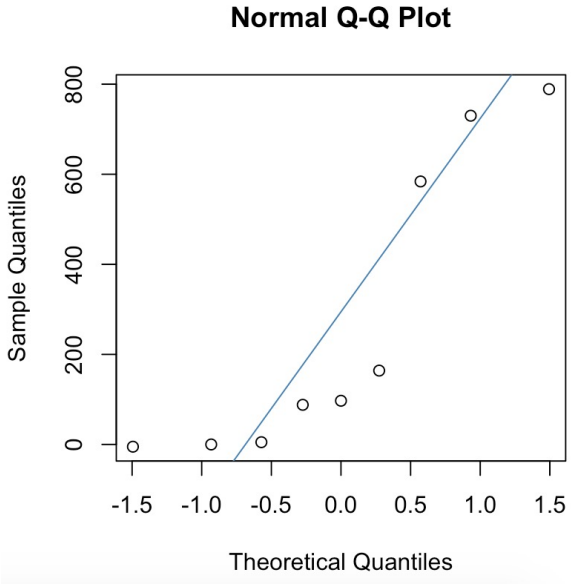
Code creates a new column “difference” which is the value of Saturday minus the value of Monday

	Participant	Saturday	Monday	difference
1	1	630	[illegible]	584
2	2	810	21	789
3	3	630	542	88
4	4	740	745	-5
5	5	416	411	5
6	6	226	226	0
7	7	468	304	164
8	8	753	23	730
9	9	274	177	97

Now produce Q-Q plot and run Shapiro-Wilk test on the **difference** column

Q-Q plot

```
qqnorm(fizzy_drink_data$difference)
qqline(fizzy_drink_data$difference, col = "steelblue")
```



Shapiro-Wilk test

```
shapiro.test(fizzy_drink_data$difference)
```

```
        Shapiro-Wilk normality test

data:  fizzy_drink_data$difference
W = 0.78211, p-value = 0.01274
```

Normality assumption violated

Wilcoxon signed-rank test

- Alternative to the related samples t-test
- Appropriate if you have a design with only two repeated measures (all participants contribute data at both timepoints)

The theory behind the Wilcoxon signed-rank test

Step 1: Calculate the difference between the conditions

Participant	Saturday	Monday	Difference
1	630	46	584
2	810	21	789
3	630	542	88
4	740	745	-5
5	416	411	5
6	226	226	Exclude
7	468	304	164
8	753	23	730
9	274	177	97

- Calculate the difference between the conditions
- If there is no difference (i.e. the conditions are equal), exclude these cases

Step 2: Note the sign of the difference (+ or -)

Participant	Saturday	Monday	Difference	Sign (+ or -)
1	630	46	584	+
2	810	21	789	+
3	630	542	88	+
4	740	745	-5	-
5	416	411	5	+
6	226	226	Exclude	
7	468	304	164	+
8	753	23	730	+
9	274	177	97	+

- Note the sign difference (+ or -)
  - Here:
    - + Saturday higher than Monday
    - - Monday higher than Saturday

Step 3: Calculate the ranks

Participant	Saturday	Monday	Difference	Sign (+ or -)	Rank
1	630	46	584	+	6
2	810	21	789	+	8
3	630	542	88	+	3
4	740	745	-5	-	1.5
5	416	411	5	+	1.5
6	226	226	Exclude		
7	468	304	164	+	5
8	753	23	730	+	7
9	274	177	97	+	4

- Rank as before
- Ignore whether the sign is positive or negative for now
- Ignore “Exclude” cases

Step 4: Add up positive and negative ranks separately

Participant	Saturday	Monday	Difference	Sign (+ or -)	Rank
1	630	46	584	+	6
2	810	21	789	+	8
3	630	542	88	+	3
4	740	837	-97	-	1.5
5	416	405	11	+	1.5
6	226	226	Exclude		
7	468	304	164	+	5
8	753	23	730	+	7
9	274	177	97	+	4

Sum of positive ranks = 6+8+3+1.5+5+7+4 = 34.5

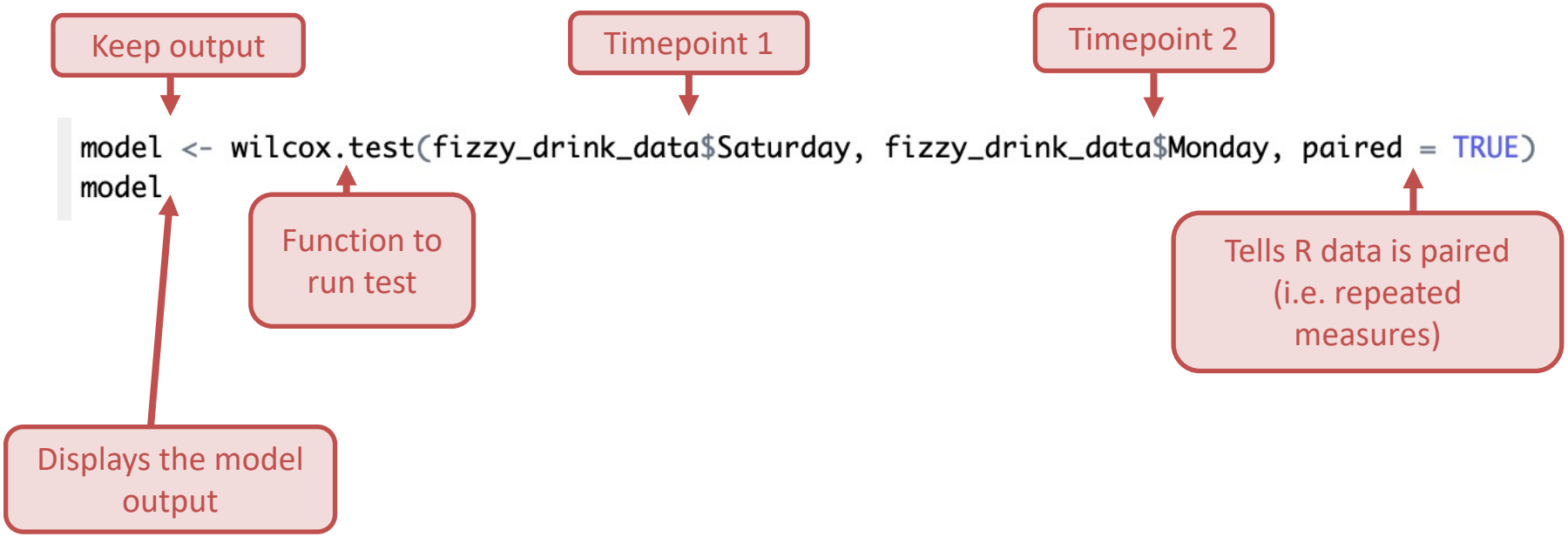
Sum of negative ranks = 1.5

If calculated manually, the test statistic (T) is the lowest sum of ranks

R outputs a different test statistic (V) which is equal to the sum of positive ranks

Running the Wilcoxon signed-rank test in R

Basic code to run the Wilcoxon signed-rank test



Output

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```
> model <- wilcox.test(fizzy_drink_data$Saturday, fizzy_drink_data$Monday, paired = TRUE)
Warning messages:
1: In wilcox.test.default(fizzy_drink_data$Saturday, fizzy_drink_data$Monday,  :
  cannot compute exact p-value with ties
2: In wilcox.test.default(fizzy_drink_data$Saturday, fizzy_drink_data$Monday,  :
  cannot compute exact p-value with zeroes
> model

        Wilcoxon signed rank test with continuity correction

data:  fizzy_drink_data$Saturday and fizzy_drink_data$Monday
V = 34.5, p-value = 0.02488
alternative hypothesis: true location shift is not equal to 0
```

What is V?

Sum of positive ranks =
6+8+3+1.5+5+7+4 = 34.5

Sum of negative ranks = 1.5

V = Sum of positive ranks

Does V differ depending on how I enter the variables into wilcox.test?

```
model1 <- wilcox.test(fizzy_drink_data$Saturday, fizzy_drink_data$Monday, paired = TRUE)
model1
```

```
        Wilcoxon signed rank test with continuity correction

data:  fizzy_drink_data$Saturday and fizzy_drink_data$Monday
V = 34.5, p-value = 0.02488
alternative hypothesis: true location shift is not equal to 0
```

```
model2 <- wilcox.test(fizzy_drink_data$Monday, fizzy_drink_data$Saturday, paired = TRUE)
model2
```

Yes – V is always the sum of positive ranks, but whether ranks are positive or negative will differ depending on the way you enter the variables into the 'wilcox.test' function

```
        Wilcoxon signed rank test with continuity correction

data:  fizzy_drink_data$Monday and fizzy_drink_data$Saturday
V = 1.5, p-value = 0.02488
alternative hypothesis: true location shift is not equal to 0
```

Is the difference significant?

```
        Wilcoxon signed rank test with continuity correction

data:  fizzy_drink_data$Saturday and fizzy_drink_data$Monday
V = 34.5, p-value = 0.02488
alternative hypothesis: true location shift is not equal to 0
```

Yes, a significant difference in the amount of soft drinks consumed on a Saturday and a Monday

In what direction?

```
fizzy_drink_data %>%
  summarise(med_sat = median(Saturday), med_mon = median(Monday))
```

Calculates median for each timepoint

	med_sat	med_mon
1	630	226

Participants consumed significantly more fizzy drinks on Saturday

How is the p-value calculated?

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Options: The exact method and the normal approximation with continuity correction

Tells you there are tied ranks

Tells you some differences = 0

```
> model <- wilcox.test(fizzy_drink_data$Saturday, fizzy_drink_data$Monday, paired = TRUE)
Warning messages:
1: In wilcox.test.default(fizzy_drink_data$Saturday, fizzy_drink_data$Monday,  :
  cannot compute exact p-value with ties
2: In wilcox.test.default(fizzy_drink_data$Saturday, fizzy_drink_data$Monday,  :
  cannot compute exact p-value with zeroes
> model

        Wilcoxon signed rank test with continuity correction

data:  fizzy_drink_data$Saturday and fizzy_drink_data$Monday
V = 34.5, p-value = 0.02488
alternative hypothesis: true location shift is not equal to 0
```

Normal approximation with continuity correction used. If exact method was used, it would simply say “Wilcoxon signed rank test”

- By default, exact method is used unless there are tied ranks, there are some cases with a difference of 0, or there are 50 or more participants overall

What about effect size?

```
        Wilcoxon signed rank test with continuity correction

data:  fizzy_drink_data$Saturday and fizzy_drink_data$Monday
V = 34.5, p-value = 0.02488
alternative hypothesis: true location shift is not equal to 0
```

```
> qnorm(model$p.value/2)
[1] -2.243199
```

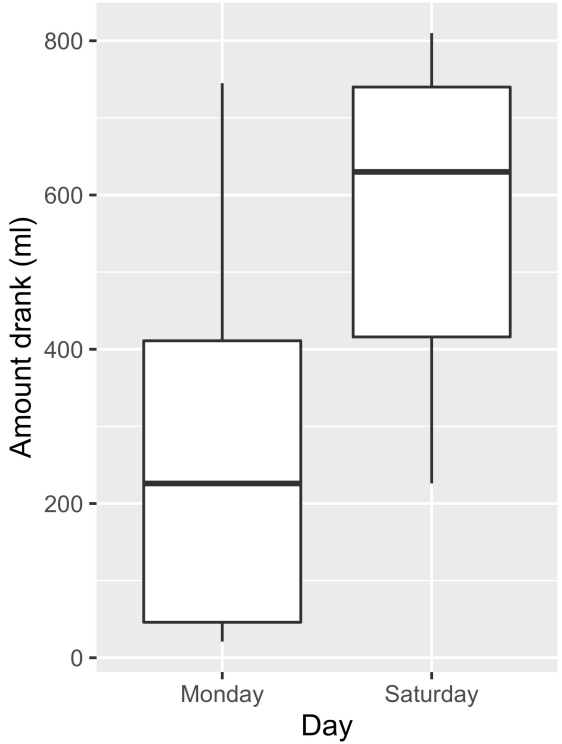
$$r = \frac{z}{\sqrt{N}} = \frac{-2.243199}{\sqrt{18}} = \frac{-2.243199}{4.24} = -0.53$$

Interpretation		
	Positive	Negative
Small	0.1 to 0.3	-0.1 to -0.3
Medium	0.3 to 0.5	-0.3 to -0.5
Large	0.5 to 1.00	-0.5 to -1.00

Note: *N* = total number of **OBSERVATIONS**, not participants

Large effect size

Reporting the results in APA format



A Wilcoxon signed-rank test revealed the number of fizzy drinks consumed was significantly higher on Saturday (Median = 630; Range = 226-810) than on Monday (Median = 226; Range = 21-745), $V = 34.5$, $p = .025$, $r = -.53$.

Lab preparation (~10 minutes)

- Please watch the short lab preparation video prior to your lab
- We will walk through an R script that runs a Wilcoxon rank-sum test and a Wilcoxon signed-rank test

Post-lecture activities

- Now live on Moodle

Thank you for listening!

Please post any questions on the discussion board or the anonymous Qualtrics link.