Which Hand Rules?

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Student Handout

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Part I: Analyzing our Class Data

The time it takes for the eye to see, the brain to process what the eye sees, and the body to physically react, varies from person to person. It can also vary depending on whether you are using your right or your left hand. If you are right-hand dominant, you might suspect that you have quicker reaction times with your right hand than with your left hand. But do you really?

We are going to investigate the speed with which you can catch a falling yardstick by measuring the distance it drops before you catch it. The faster you are, the closer to the 0 centimeter mark you will grab the yardstick when it falls. We will refer to where you grabbed the yardstick as your "reaction distance".

Since averages are less variability than individual observations (we don't want any really extreme values to throw off our measurements), we are going to perform the experiment three times and average the distances the yardstick drops before you catch it. We are also going to randomly determine which hand you use first by flipping a coin.

For this activity, your dominant hand is the one with which you write.

Read through steps 1-4 before you conduct the experiment for the first time.
1. Flip a coin to determine if you will begin with your dominant (Heads) or non-dominant (Tails) hand. Record your result here:
2. Data Collection:
    a. You will rest your arm on a table with your wrist over the edge. Your partner will hold the yardstick between your index finger and thumb of the hand determined by the coin flip; the top of your finger should be at the 0 cm mark on the yardstick.
    b. You will let your partner know when you are ready. Then, within 5 seconds, your partner will release the yardstick and you will catch the yardstick as quickly as possible.
    c. Record the distance (to the nearest tenth of a centimeter) between the bottom of the yardstick and the top of your index finger in the chart below.
3. Switch hands and repeat the experiment. Record all distances.
4. Now, it's your partner's turn! Switch roles & conduct the experiment for each hand.

Which Hand? Dominant or Non-dominant?	Reaction Distance (centimeters)	Which Hand? Dominant or Non-dominant?	Reaction Distance (centimeters)

5. Next, calculate the following differences in your reaction distances:
    a. (**Non-Dominant, ND,** Reaction Dist.) – (**Dominant, D,** Reaction Dist.) = _____ cm
    b. (**Dominant, D,** Reaction Dist.) – (**Non-Dominant, ND,** Reaction Dist.) = _____ cm
    c. Compare your results in parts a. and b. with several classmates. What do you notice?

    d. If we switch the order in which we subtract our reaction distances, from (**ND – D**) to (**D – ND**), how will the two differences *always* be related?

6. Add your data to the class data sheet and copy it below.

ID	Reaction Difference, ND – D (cm)	ID	Reaction Difference, ND – D (cm)	ID	Reaction Difference, ND – D (cm)	ID	Reaction Difference, ND – D (cm)
1		9		17		25	
2		10		18		26	
3		11		19		27	
4		12		20		28	
5		13		21		29	
6		14		22		30	
7		15		23		31	
8		16		24		32	

7. Use the differences in reaction distances in the table above to answer the following questions.
    a. Create a well-labeled dot plot of the data.

b. Calculate the mean of the data. Illustrate the mean with a vertical line on the dot plot above.

$$\bar{x}_{\text{difference}} =$$

c. Interpret the information from the previous parts in the context of this problem. Does the data we collected suggest that people have a shorter reaction distance when they use their dominant hand? Explain your answer.

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Part II: Could this have happened by Chance?

Is the difference *suggested* by the calculations and dot plot above enough to conclude that people really are faster with their dominant hand than with their non-dominant hand? Could the differences between reaction distances have been obtained regardless of which hand we called "dominant"?

In order to investigate the claim that people are faster with their dominant hand, we will use a *matched pairs randomization test*.

8. If there really is no difference in the reaction distance for the two hands, then should we expect the differences in reaction distances to be close to zero, positive or negative? Explain your answer.

9. If it is true that people are faster with their dominant hand than with their non-dominant hand, then should we expect the differences in reaction distances to be close to zero, positive or negative? Explain your answer.

The above two questions are the basis of determining whether the differences we obtained provide strong evidence that people are faster with their dominant hand. If there really is no difference between reaction distances, then it really does *not* matter which hand we call "dominant". In this case we should obtain differences that are close to zero. (Check: how did you answer #8?)

If there really is a significant difference between reaction distances, then it *does* matter which hand we call "dominant", and we should obtain differences, **ND – D**, that are positive. (Check: how did you answer #9?) In fact, the further the differences are from zero, the stronger the evidence that one's dominant hand is faster.

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If the hand used has no effect on reaction distance, then the difference "**ND – D**" is just as likely to be larger than zero as it is to be smaller than zero. If there is no difference in which hand we use, calling one hand "dominant" within any pair of reaction distances is just as likely as calling the other hand "dominant". This idea is the heart of a matched pairs randomization test.

To run a matched pairs randomization test, first imagine all possible rearrangements of which hand we call dominant in the class data set, keeping pairs of reaction distances for each person together. We could create all possible rearrangements of the class data, calculate the mean difference for each rearrangement, create a dot plot of all such means, and then compare our original mean difference to the distribution of mean values from the rearrangements. For a class data set of 20 reaction distances, we would be making 2^{20}, or over 1 million, such arrangements!

In the next part of the activity, each pair of students is going to find several rearrangements as described above and calculate the mean of each one.

To find the first randomization, we will flip a coin to determine which hand we call "dominant". If we obtain a tail, we will keep the original assignment of "**D**" and "**ND**" from our collection of data. If we obtain a head, we will switch the assignment of "**D**" and "**ND**".

10. If we switch the assignment of "**D**" and "**ND**", what happens to the sign of our original difference **ND – D**? Hint: consider your answers to #5.

11. Perform the randomization described above: For each ID, flip a coin, and record the new difference in reaction distances in the table below. Remember, keep the original assignment of hands if you flip a "tail" and change the assignment if you flip a "head".

ID	Heads or Tails?	ND – D (cm)	ID	Heads or Tails?	ND – D (cm)	ID	Heads or Tails?	ND – D (cm)	ID	Heads or Tails?	ND – D (cm)
1			9			17			25		
2			10			18			26		
3			11			19			27		
4			12			20			28		
5			13			21			29		
6			14			22			30		
7			15			23			31		
8			16			24			32		

12. Use the randomized differences in reaction distances in the table above to calculate the mean of the data.

$$\bar{x}_{\text{rearrangement\_1}} =$$

Recall that we said we needed to find <u>all</u> such rearrangements. We are going to find only three per group. Then we will pool all mean differences and count how many times we obtained means as extreme (farther from zero) as that of our original mean reaction distance.

13. Run a re-randomization on your original differences two more times. Calculate and record the mean difference for each re-randomization.

ID	Heads or Tails?	ND – D (cm)	ID	Heads or Tails?	ND – D (cm)	ID	Heads or Tails?	ND – D (cm)	ID	Heads or Tails?	ND – D (cm)
1			9			17			25		
2			10			18			26		
3			11			19			27		
4			12			20			28		
5			13			21			29		
6			14			22			30		
7			15			23			31		
8			16			24			32		

$$\bar{x}_{\text{rearrangement\_2}} =$$

ID	Heads or Tails?	ND – D (cm)	ID	Heads or Tails?	ND – D (cm)	ID	Heads or Tails?	ND – D (cm)	ID	Heads or Tails?	ND – D (cm)
1			9			17			25		
2			10			18			26		
3			11			19			27		
4			12			20			28		
5			13			21			29		
6			14			22			30		
7			15			23			31		
8			16			24			32		

$\bar{x}_{\text{rearrangement\_3}} =$

14. Add your three mean differences ($\bar{x}_{\text{rearrangement\_1}}$, $\bar{x}_{\text{rearrangement\_2}}$, $\bar{x}_{\text{rearrangement\_3}}$) to the class dot plot. Sketch a well-labeled dot plot below.

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15. What does each dot on the dot plot represent?

16. Describe the shape, mean, and standard deviation of the resulting dot plot. Use correct statistical language!

We plotted all of our randomized mean differences on the dot plot above. (Check: how did you answer #15?). Why did we do this? We are trying to see whether the results from the data collected by our class was due to chance alone or whether there is evidence there actually was a difference in reaction times. If a dominant hand is faster than a non-dominant hand, then we should expect to see few randomized differences like the ones in our experiment. If our results are not that unusual (and the dominant hand is not faster than the dominant hand), then we should expect to see many randomized differences like the ones in our experiment.

17. Recall that we calculated the mean of the original data in #7b, $\bar{x}_{\text{difference}}$. Draw and label a vertical line on the dot plot in #14 representing $\bar{x}_{\text{difference}}$.

18. How many $\bar{x}_{\text{rearrangement}}$'s from the randomization process are at least as extreme (farther from zero) as the vertical line representing the original mean difference? These dots represent mean differences where the dominant hand was faster than the non-dominant hand by more than our original mean difference.

The value p, the p-value, of a randomization test is **the proportion of observations from the process that are at least as extreme (farther from zero) as our original mean difference**. In general, if this proportion is less than 5%, the test provides strong evidence that reaction distances for dominant hands are less than those of non-dominant hands.

19. Estimate p using the pooled data from the class dot plot.

20. Based on the estimated p, what can you conclude about reaction distances between dominant and non-dominant hands?