

Speedster

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Overview of Lesson

In this activity students will collect data to compare their reaction time for catching a falling object or to an online stimulus to their classmates. Possible methods for collecting data include having students catch a ruler between their finger and thumb and convert the distance the ruler falls to a reaction time, or using a reaction time website. Students will collect data for their class, construct a graph to represent the data and then answer the question “How good are my reactions compared to other students?” The nature of the data collected and the variety of appropriate graphs make this activity suitable for investigations in grades 4 and 5.

GAISE Components

This investigation follows the four components of statistical problem solving put forth in the *Guidelines for Assessment and Instruction in Statistics Education (GAISE) Report*. The four components are: formulate a question, design and implement a plan to collect data, analyze the data by measures and graphs, and interpret the results in the context of the original question. This is a GAISE Level A activity.

Common Core State Standards for Mathematical Practice

2. Reason abstractly and quantitatively.
5. Use appropriate tools strategically.
6. Attend to precision.

Common Core State Standards Grade Level Content (Grades 4 through 5)

4. MD. 1. Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz; l, ml, hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit.
4. MD. 4. Make a line plot to display a data set of measurements in fractions of a unit.
5. MD. 1. Convert among different-sized standard measurement units within a given measurement system, and use these conversions in solving multi-step, real world problems.
5. MD. 2. Make a line plot to display a data set of measurements in fractions of a unit.

NCTM Principles and Standards for School Mathematics

Data Analysis and Probability Standards for Grades 3-5

Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them:

- design investigations to address a question and consider how data-collection methods affect the nature of the data set;
- collect data using observations, surveys and experiments;
- represent data using tables and graphs such as line plots, bar graphs and line graphs.

Select and use appropriate statistical methods to analyze data:

- describe the shape and important features of a set of data and compare related data sets, with an emphasis on how the data are distributed;
- use measures of center, focusing on the median, and understand what each does and does not indicate about the data set;
- compare different representations of the same data and evaluate how well each representation shows important aspects of the data.

Develop and evaluate inferences and predictions that are based on data:

- propose and justify conclusions and predictions that are based on data and design studies to further investigate the conclusions or predictions.

Prerequisites

Students should have prior experience collecting data, calculating the median and range, and constructing graphs.

Learning Targets

Students will produce and interpret a graph of reaction time data for their class, including identifying the observation(s) that represent their reaction time(s). They will make predictions concerning the reaction time of individuals with fast reaction times (e.g., race car drivers, athletes, video game players).

Time Required

One class period.

Materials Required

Graph paper and a copy of the Activity Sheet (pages 10 and 11). The data can be collected manually using a ruler marked in centimeters or using one of the following websites:

Census at School Reaction Time Test:

<http://www.amstat.org/education/cas/2.cfm>

The Online Reaction Time Test:

<http://getyourwebsitehere.com/jswb/rttest01.html>

Human Benchmark Reaction Time Test:

<http://www.humanbenchmark.com/tests/reactiontime/>

MathIsFun Reaction Time Test:

<http://www.mathsisfun.com/games/reaction-time.html>

Note: These sites all work pretty much the same way and are easy to use. They all require the user to click on a button or on the screen when a shape (circle or square) changes color. The Census at School test provides the reaction time after one trial. To run the test click on start and then on a separate button to stop when a box changes color. An example response time from this site is .422 seconds. The Online Reaction Time Test uses the image of a stoplight to run the test and has the advantage that the same button is used to start and stop the test. This site has slots for recording up to five reaction times and includes a running average time. The Human Benchmark Reaction Time Test also allows for the results of up to five reaction times to be

recorded but after the first trial only the most recent trial and the average are reported. This site has a link to all reaction times collected from individuals using that site plus tips for improving reaction time. The MathIsFun site also allows for five trials and reports the average of all five trials. For the last trial this site makes the circle that changes color very large, indicating that some people record their fastest time for this trial due to a “startle” reflex. Data from the Human Benchmark site is recorded in milliseconds (ms) while data from the other sites is in seconds.

Instructional Lesson Plan

The GAISE Statistical Problem-Solving Procedure

I. Formulate a Question

Begin the lesson by asking the students if they think they have a fast reaction time. Encourage them to consider situations when a fast reaction time is needed or useful (e.g., athletes at the start of a race, drivers of cars to avoid an accident). Explain that the class will conduct an investigation to record their reaction times.

Possible questions to ask:

1. What types of reaction times could we measure?
2. How can we measure reaction times?
3. Does reaction time depend on age or gender?
4. Can practicing improve reaction time?

II. Design and Implement a Plan to Collect the Data

Guide the students in creating an investigation to record and study their reaction times. Describe possible ways to collect the data. One way to record the data manually is to use a ruler marked in centimeters. The teacher, or another student, holds the ruler directly above the test student’s forefinger and thumb. The test student watches the ruler and when it is released attempts to catch it between his or her finger and thumb. To use this method have the students decide how far above the test student’s fingers the ruler should be held and where the reading on the ruler should be made (e.g., just above the test student’s finger and thumb, just below, or half way in between). Also have the students determine the appropriate orientation for the ruler (i.e., with the numbers increasing from top to bottom or from bottom to top). Show the students how to convert their catch distance to a reaction time using the table provided below. Table 1 provides the reaction time (in milliseconds) for a collection of possible catch distances.

Table 1. Catch distances converted to reaction times.

Catch Distance (cm)	Reaction Time (ms)	Catch Distance (cm)	Reaction Time (ms)
5	101	18	192
6	111	19	197
7	120	20	202
8	128	21	207
9	136	22	212
10	143	23	217
11	150	24	221
12	156	25	226

13	163		26	230
14	169		27	235
15	175		28	239
16	181		29	243
17	186		30	247

Note: If a catch distance is recorded that is not given in this table the reaction time can be calculated using

$$\sqrt{\frac{2 \times \text{cmdropped}}{980\text{cm/sec}^2}} \times 1000$$

This formula is based on the formula for determining how far an object will fall in t seconds. Let y be how far the object falls. Then $y = \frac{1}{2}gt^2$ where g is the gravitational constant (980 cm/sec^2). Solving for t for a given value of y and converting from seconds to milliseconds results in the above formula.

If a computer is available for classroom use one of the reaction time websites can be used instead. Have the students decide how many trials each student should record then perform the experiment and record the data. Regardless of the data collection method students should be given the opportunity to practice a few times before collecting and recording their reaction times.

After everyone has completed their reaction time trials and recorded their trials and median reaction time, collect and record the class data. If one of the websites was used that reports reaction time in seconds have the students convert their reaction times to milliseconds by multiplying by 1,000. Remind students that this is a census of the class because data is gathered from every student in the class. Ask them to review the data for patterns (e.g., do some students improve with each trial?) and to consider sources of variation (between students, within students). Why might some students have faster reaction times than others? Possible reasons could include ability to focus or concentrate, previous experiences with similar activities, etc. Ask the students how they might identify a “typical” value or range of typical values for their class. Ask them how they could find the median of the median reaction times. Have them order the median reaction times from smallest to largest and find the median of that list. Ask them to identify a “middle group” in the class data and to describe what this group represents. Possible ideas for identifying a “middle group” could be to identify the middle 50% or determining the range over which the distribution tends to cluster.

III. Analyze the Data

There are various ways to analyze the collected data. For example, the class can calculate measures of center and produce graphs that they have studied. The analyses can be repeated separately for the boys and girls in class. Table 2 provides some example class data in milliseconds.

Table 2. Example class data.

Student #	Student	Trial 1	Trial 2	Trial 3	Median (ms)
1	Amy	235	244	222	235
2	Bob	217	229	237	229
3	Carlos	242	253	241	242
4	Diana	233	234	231	233
5	Evan	261	255	251	255
6	Frank	221	218	228	221
7	Georgia	224	219	215	219
8	Hank	277	264	267	267
9	Ian	243	251	244	244
10	Jane	237	231	235	235

A plot of the example class data is shown in Figure 1.

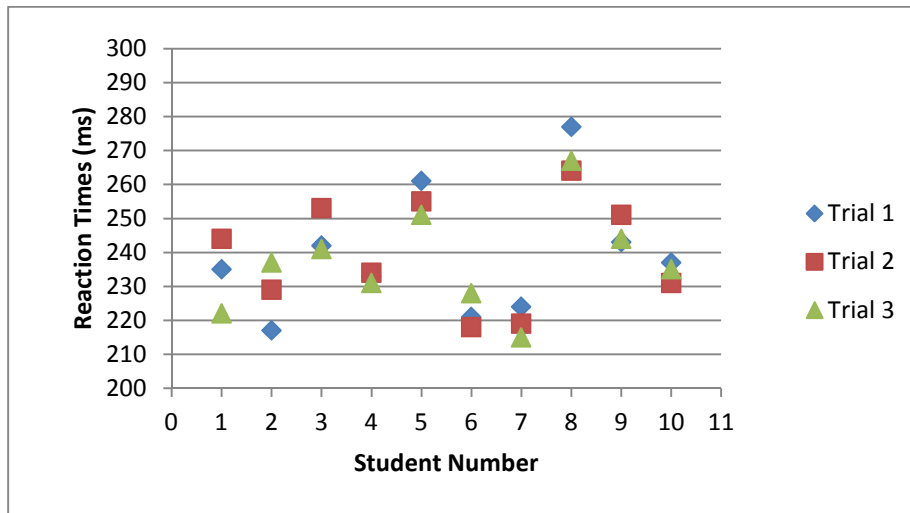


Figure 1. Plot for the example class data.

In this plot student 8 (Hank) can be identified as having the slowest reaction times overall while students 6 and 7 (Frank and Georgia) tend to have fast reaction times. The fastest trial reaction time was achieved by Georgia (215 ms) and the slowest trial reaction time was achieved by Hank (277 ms). The reaction times for student 4 (Diana) have the least amount of variability while student 1 (Amy) has the most variability. The range for Diana's responses is 3 ms while the range for Amy's responses is 22 ms. For several of the students Trial 3 is their fastest reaction time (students 1, 3, 4, 5 and 7).

A plot of the medians from the example class data is shown in Figure 2.

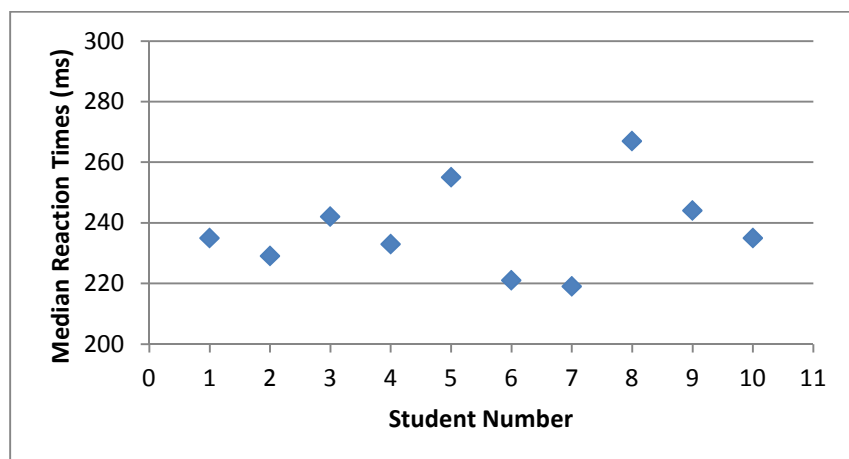


Figure 2. Plot of median reaction times for the example class data.

Student 7 (Georgia) has the fastest median reaction time while student 8 (Hank) has the slowest median reaction time. The range in median reaction times is $267 - 219 = 48$ ms.

The ordered list of medians is 219, 221, 229, 233, 235, 235, 242, 244, 255, 267. The median of this list is 235. A dot plot of the medians is shown below in Figure 3.

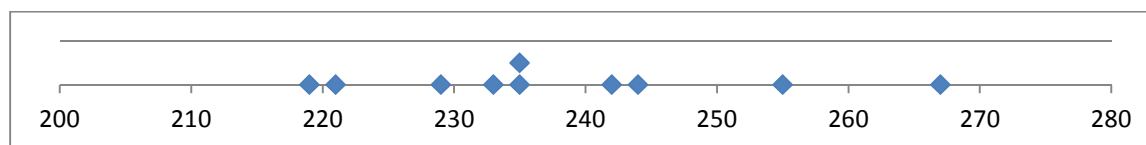


Figure 3. Dot plot of class median reaction times.

A “middle group” of median reaction times could consist of the middle 6 observations, from 229 to 244 ms. The two smallest and the two largest median reaction times appear to be separate from this middle group. The range of this middle group is $244 - 229 = 15$ ms.

IV. Interpret the Results

In addition to interpretive points made in analyzing the data, the students can be prompted to generate and answer further data analysis questions such as:

- Predict where the reaction time(s) for an athlete or racecar driver would be in the graph of the class data.
- If each student practiced more and was able to reduce their median reaction time by 5 ms how would this affect the appearance of the graph? Would the range in median reaction times be affected as well?

Assessment

Suppose that Jeremy's class produced the following results when performing this experiment:

Our Class Data: Reaction times					
Student Number	Student Name	Trial 1	Trial 2	Trial 3	Median (ms)
1	Karen	218	222	205	218
2	Joshua	267	257	259	259
3	Jamal	228	223	219	223
4	Trevor	233	236	230	233
5	Alicia	225	222	220	222
6	John	244	235	231	235
7	Bob	248	245	241	245
8	Barb	260	257	250	257
9	Kathi	288	275	279	279
10	Joannie	263	257	252	257
11	Mary	271	265	267	267
12	Lee	258	255	255	255
13	Jamie	227	220	215	220
14	Leilani	235	231	227	231
15	Reid	263	265	257	263

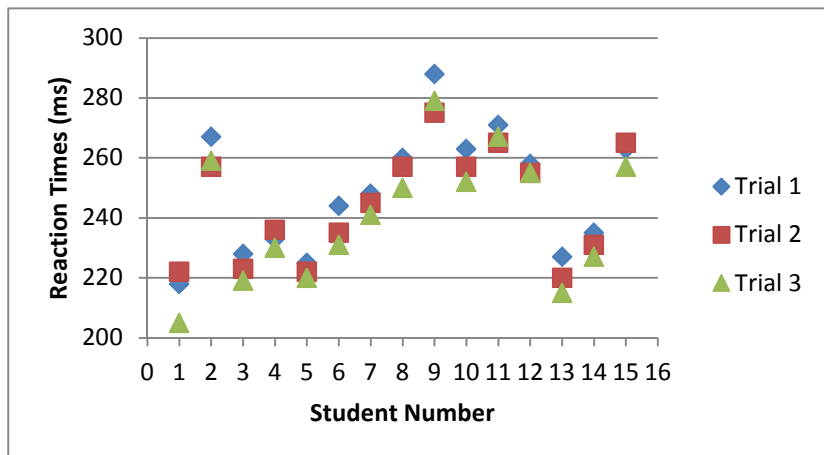
1. Produce a plot of the three trials. Identify the students with the fastest and slowest trial reaction times. Identify the student with the least variability in reaction times and the student with the most variability.

2. Produce a plot of the median reaction times. Identify the students with the smallest and largest median reaction times. Calculate the range of the median reaction times.

3. Order the median reaction times from smallest to largest and identify a “middle group” in this data. Justify your choice for the middle group.

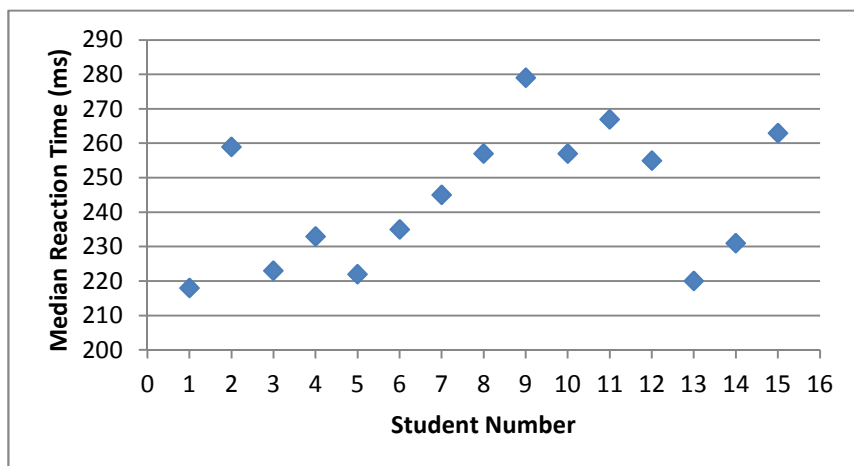
Answers

1. A plot of the three trials is shown below:



The fastest trial time was accomplished by Student 1 (Karen) at 205 ms and the slowest reaction time was accomplished by Student 9 (Kathi) at 288 ms. The student with the least amount of variability in their reaction time trials is Student 12 (Lee) with a range of $258 - 255 = 3$ ms. The student with the most variability is Student 1 with a range of $222 - 205 = 17$ ms.

2. A plot of the median reaction times is shown below:



The student with the fastest median reaction time is Student 1 (Karen) with a median of 218 ms. The student with the slowest median reaction time is Student 9 (Kathi) with a median of 279 ms. The range of the median reaction times is $279 - 218 = 61$ ms.

3. The ordered list of median reaction times is 218, 220, 222, 223, 231, 233, 235, 245, 255, 257, 257, 259, 263, 267, 279. The median of this list is 245 ms. A middle group could go from 231 to 259 (the middle 8 scores). This group is above the cluster of four lowest scores and below the three highest scores. The range of this middle group is $259 - 231 = 28$ ms.

Possible Extensions

1. Depending on the level of the class other graphs and statistics may be appropriate. For example, a histogram or box plot of the median reaction times could be produced instead of a dot plot. Students could calculate the mean of the trials instead of the median.
2. If a computer is available for collecting reaction times students could be asked to record their reaction times using a different site than the one used in class and then compare the results. Why might the results differ by website?
3. Students could be asked to collect data both manually and using one of the websites and then compare the results. Which method is better?
4. If a class of older (or younger) students is willing to collect reaction time data a comparison study could be done. Why might age have an effect on reaction time?

References

Adapted from the Speedster Census at School New Zealand activity created by Joanne Woodward, revised by Lindsay Smith: <http://www.censusatschool.org.nz/classroom-activities/speedster/>.

Speedster Activity Sheet – How good are my reactions compared to other students?

1. What are some questions we should ask to determine someone's reaction time?
2. Record your reaction time for the number of trials determined by your class. (If you used a website that recorded the data in seconds convert the data to microseconds.)

Trial 1 _____ ms

Trial 2 _____ ms

Trial 3 _____ ms

Trial 4 _____ ms

Trial 5 _____ ms

Median _____ ms

3. Record the results for the class (in ms) in the following table:

Student Number	Name	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Median

4. Look through the table of data. What do you notice?
5. Which student has the fastest reaction time? _____.
6. Which student has the slowest reaction time? _____

7. Construct a plot of the trial reaction times and a plot of the median reaction times.

8. Find yourself in the graphs you produced. Describe your position. How many students have a faster reaction time than you? How many are slower? Describe the variability in your trials. What is the range of your trial reaction times? Are there students with more variability in their reaction times? With less variability?

9. Add a point to your plot of the median reaction times that would represent a racecar driver (use a different color or plot symbol). Why have you plotted their value there?

10. If everyone practiced and improved their reaction times by 10 ms how would this affect the plot of the median reaction times that you produced?

11. Why do you think some students have faster reaction times than others?

12. Rewrite your reason for question 11 as a question to investigate (e.g., Does eye color effect a student's reaction time?)

13. What extra data would you need to collect to test your question?

14. You are now ready to answer the question we asked at the beginning of the worksheet. Remember to give reasons based on what you learned through this investigation:

How good are my reactions compared to other students?