Lesson 2: How does being distracted affect whether you will avoid a collision?

Previous Lesson *We determined that the number of injuries and vehicle collisions has increased in recent years and developed models to try to explain how distracted driving and vehicle factors and features might contribute to those trends. We asked questions about the potential causes of these trends and developed ideas for investigation.*

This Lesson

Investigation

2 days

We analyze videos of two drivers encountering a sudden obstacle: one who is undistracted and one who is distracted. We make a plot for each driver to show how being distracted affects the motion of the vehicle over time, and thus the outcome of a potential vehicle collision.

Next Lesson *We will use mathematical models to generate data about how speed affects reaction distance based on average reaction times for distracted versus undistracted drivers. We will use what we have figured out from video data and mathematical modeling to identify design features that can decrease reaction distance to prevent collisions in the event of a sudden obstacle.*

BUILDING TOWARD NGSS

HS-ETS1-3, HS-PS2-2, HS-PS2-3, HS-PS2-1

What students will do

2.A Analyze videos of two drivers encountering a sudden obstacle by graphing change in distance over time in order to describe and predict how being distracted can affect the risk of a potential vehicle collision. (SEP: 4.1; CCC: 1.4, 7.2; DCI: ETS1.A.2)

What students will figure out

- We can plot the distance that a vehicle travels over time to learn more about how it is moving, including its speed.
- Distracted driving lengthens reaction time, which means that the driver has less distance over which to stop before hitting the obstacle.

Lesson 2 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		**NAVIGATE** Motivate watching videos of undistracted and distracted drivers with a quick Initial Ideas Discussion about how being distracted will affect a driver's ability to avoid a collision.	A	Distracted Driving Initial Consensus Model from Lesson 1
2	15 min		**COMPARE VIDEOS OF A CAR STOPPING AND ANALYZE THE UNDISTRACTED DRIVER (CLIP #1)** Watch both videos (clips #1 and #2) and elicit noticings about differences. Create a position-line for the undistracted driver (clip #1). Elicit ideas about how to calculate distance.	B-D	https://youtu.be/Z11esq-Zs2E?si=j5gSUw7dRqIqxSsL, https://youtu.be/D2-2L_e3bLU?si=2jZ57RdNLrrzgr4u, roll of receipt paper, tape, chart paper markers (at least 3 colors), meterstick, toy car
3	10 min		**ADD DISTANCES TO THE POSITION-LINE FOR THE UNDISTRACTED DRIVER (CLIP #1)** Calculate $\Delta X1$, $\Delta X2$, and $\Delta X3$ and add these to the position-line. Use a scaling ratio to calculate the actual distances and record these on the handout.	E	*Creating Position-Lines*, https://youtu.be/Z11esq-Zs2E?si=j5gSUw7dRqIqxSsL, meterstick, Scaling Ratio Poster, chart paper markers (at least 3 colors), Undistracted position-line (in progress), 3x3 sticky notes (optional)
4	15 min		**ANALYZE THE DISTRACTED DRIVER VIDEO (CLIP #2)** Make predictions about a distracted driver. Create a position-line for the distracted driver video. Compare position-lines and predictions for the undistracted and distracted drivers.	F-H	*Creating Position-Lines*, Undistracted position-line (in progress), toy car, roll of receipt paper, tape, meterstick, chart paper markers (at least 3 colors), https://youtu.be/D2-2L_e3bLU?si=2jZ57RdNLrrzgr4u
5	2 min		**NAVIGATE AND ASSIGN HOME LEARNING** Motivate analysis of timing by using a manipulative and assigning home learning.	I-J	*Distracted Driving Research*, toy car, Distracted position-line
					End of day 1
6	3 min		**NAVIGATE: REACTION TIME**	K-L	*Distracted Driving Research*

		Focus on the relationship between distraction and reaction time. Articulate our motivation to analyze timing. Add to the Personal Glossary.		
7	5 min	**CREATE A TIMELINE FOR THE UNDISTRACTED DRIVER (CLIP #1)** Create a timeline for the undistracted driver using the time code in the video.	M	roll of receipt paper, tape, meterstick, chart paper markers (at least 3 colors), https://youtu.be/Z11esq-Zs2E?si=j5gSUw7dRqIqxSsL, Undistracted position-line
8	20 min	**CREATE A POSITION VERSUS TIME GRAPH** Reorient the position-line and timeline for the undistracted driver to represent the axes of a graph. Plot the important points for each video on this graph.	N-T	loose-leaf paper, graph paper with three-hole punch, Whiteboard (optional), dry erase marker (optional), Undistracted position-line, Undistracted timeline, tape, meterstick, chart paper, chart paper markers, toy car
9	15 min	**GRAPH THE DISTRACTED SCENARIO IN PAIRS** Graph the distracted driver's collision in pairs. Debrief the graphing.	U-V	graph paper with three-hole punch, colored pencils (various), undistracted position versus time graph
10	2 min	**NAVIGATE WITH AN EXIT TICKET** Administer an exit ticket.	W	sheet of loose-leaf paper for exit ticket

End of day 2

Lesson 2 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • *Creating Position-Lines* • *Distracted Driving Research* • loose-leaf paper • graph paper with three-hole punch • colored pencils (various) • sheet of loose-leaf paper for exit ticket	• Whiteboard (optional) • dry erase marker (optional)	• Distracted Driving Initial Consensus Model from Lesson 1 • https://youtu.be/Z11esq-Zs2E?si=j5gSUw7dRqIqxSsL • https://youtu.be/D2-2L_e3bLU?si=2jZ57RdNLrrzgr4u • roll of receipt paper • tape • chart paper markers (at least 3 colors) • meterstick • toy car • Scaling Ratio Poster • Undistracted position-line (in progress) • 3x3 sticky notes (optional) • Distracted position-line • Undistracted position-line • Undistracted timeline • chart paper • chart paper markers • undistracted position versus time graph

Materials preparation (45 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make copies of the following handouts:

- *Creating Position-Lines* (1 per student)
- *Distracted Driving Research* (1 per student)

Three-hole-punch all images and handouts so they can be added to students' science notebooks.

Make sure the Distracted Driving Initial Consensus Model from Lesson 1 is visible near the front of the room.

Look through *Making a Position-Time Graph* for an overview of how to create position lines and timelines. This information is summarized from the details in the *Teacher Guide* for quick reference.

Prepare the Scaling Ratio Poster. Create a chart that looks like the image at right. If you have multiple sections, you can use stickies to fill in this chart, rather than creating multiple versions.

In this lesson, you will project a video over a piece of receipt paper to mark the positions of a stopping vehicle. You will do this twice for distance, and twice to create timelines. Decide where you will make your position and timelines ahead of time, and prepare the receipt paper. Test out the video to make sure that the length of the receipt paper will not be too long to make into a graph in the next step, or too small for students to see, and consider resizing the video window.

After creating position lines and timelines, you will turn the position line vertically and attach it to the left side of the timeline to create a position versus time axis. You will then use chart paper to graph position versus time. Decide where you will create your graph, and make sure there will be space for the lines you create.

Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

This lesson focuses on some of the basic kinematic conventions and high school-level *computational thinking* that students will need in future lessons to figure out how force, momentum, and time are related. Lessons 2 and 3 are the only lessons in the course that focus on kinematics. Kinematics are not emphasized in the Next Generation Science Standards (NGSS), which is why many of the physics ideas in this lesson are not well aligned to high school Physical Science disciplinary core ideas (DCIs). Instead, the major standards-aligned ideas are concerned with engineering and identifying a major challenge with ramifications in communities, an important element of the DCI ETS1.A.

This lesson and the next are designed to coherently build ideas related to the following DCIs:

- **ETS1.A.2: Defining and Delimiting Engineering Problems.** Humanity faces major global challenges today, ~~such as the need for supplies of clean water and food or for energy sources that minimize pollution,~~ which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1)
- **ETS1.A.1: Defining and Delimiting Engineering Problems.** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account~~, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them~~. (HS-ETS1-1, secondary to HS-PS2-3)

Students identify a major challenge--that distracted driving is dangerous--and consider how the risks associated with driving might be mitigated. In Lesson 3, they will learn about a set of design solutions aimed at preventing distracted driving, and they will consider the constraints set by society on these solutions.

Students explore the differences between position versus time graphs for distracted and undistracted drivers. This lesson focuses on how being distracted affects the likelihood of a collision. In Lesson 3, students will use many of the same algebraic techniques to consider how the speed of a vehicle affects the likelihood of a collision. In Lessons 4-5, they will begin to apply their ideas about speed, distance, and time to think about the forces in a collision.

Students co-construct definitions for the following vocabulary during this lesson: *reaction time, reaction distance, braking distance.* Be prepared for them to add these phrases to their Personal Glossary. Students are also introduced to the following symbol: Δ (delta). **Do not** ask students to define or keep track of any words until after your class has developed a shared understanding of their meaning.

Where We Are NOT Going

Students do not consider the forces in a collision in this lesson; they think only about time and distance. They do not use vectors, and they will be thinking about speed rather than velocity until Lesson 4.

In this lesson, students “invent” position versus time graphs to analyze and compare two videos of a car stopping. Avoid presenting position versus time graphs in a decontextualized way or as “something we use in physics.” Instead, use student questions to motivate comparing the position of the car and the time, so it becomes clear why these representations are useful. Students may have used these graphs before, but it can still be productive to create a representation because it is needed to answer our current questions, not because it is a representation that we have used in the past or that may be useful for solving decontextualized problems.

LEARNING PLAN for LESSON 2

1 · NAVIGATE

3 min

MATERIALS: Distracted Driving Initial Consensus Model from Lesson 1

Motivate watching videos of undistracted and distracted drivers. Say, *We wanted to investigate the impact of distracted driving on a vehicle collision. We had some ideas about how drivers might behave differently when they are focused and undistracted to reduce the chance of getting in a collision in the first place.* Direct students' attention to the class consensus model to remind them of this. Then present **slide A**. Use the slide's prompts to elicit 1-2 initial ideas as shown in the table below. ✱

Suggested prompt	Sample student response
What does it mean to be "distracted"?	Texting or being under the influence of a substance.
How do you think being distracted may affect whether you will avoid a collision?	It might make it more dangerous because you won't see another car or a pedestrian.
Are all distractions as dangerous as texting or drinking? What are some other, maybe more common distractions? ✱	Talking to a friend. Eating a snack. Fixing your makeup in the mirror. Choosing a new song on your phone.
It sounds like everyone is distracted sometimes when they're driving, even if it's just for a moment. How could being distracted affect whether you will avoid a collision?	You'll brake slower if you're distracted.

Say, *I have videos of a car braking when the driver is undistracted and when the driver is distracted. Let's break them down to test our ideas about how being distracted affects whether you will avoid a collision.*

✱ ATTENDING TO EQUITY

Universal Design for Learning: The goal at this moment is to support *engagement* by encouraging students to draw connections to everyday distractions in their own lives. Not every distracted driver is breaking the law. Use the third question in the table above to push students to think beyond texting and drinking when it comes to distracted driving, and highlight the idea that everyone is distracted sometimes when they are driving.

2 · COMPARE VIDEOS OF A CAR STOPPING AND ANALYZE THE UNDISTRACTED DRIVER (CLIP #1)

15 min

MATERIALS: science notebook, https://youtu.be/Z11esq-Zs2E?si=j5gSUw7dRqIqxSsL, https://youtu.be/D2-2L_e3bLU?si=2jZ57RdNLrrzgr4u, roll of receipt paper, tape, chart paper markers (at least 3 colors), meterstick, toy car

Watch the videos and identify differences. Present **slide B**. Project https://youtu.be/Z11esq-Zs2E?si=j5gSUw7dRqIqxSsL and https://youtu.be/D2-2L_e3bLU?si=2jZ57RdNLrrzgr4u. Play each clip twice. Although you can play these online, we recommend downloading them and using a video player to more easily move frame-by-frame.

Ask students what differences they noticed between the two videos. Accept all ideas, but highlight ideas about reaction time and reaction position, such as these:

- The distracted driver takes longer to stop.
- The undistracted driver brakes earlier (we can see the brake lights go on).
- The distracted driver moves more before they stop.
- The undistracted driver stops farther away from the obstacle.
- The distracted driver hits the obstacle.

Create a position-line for the undistracted driver. ✱ Present **slide C**. Tape a strip of receipt paper to the projection screen or whiteboard so the video is projected over the paper as shown in these images. Make sure the paper extends across the frame and is at the height of the car's bumper. (If you are using a monitor, you can tape the paper carefully to the edges and turn up the brightness to see the video through the paper.) Use the meterstick to create a line on the paper as shown.

✱ ATTENDING TO EQUITY

Universal Design for Learning: This lesson calls for the use of multiple colors in graphical representations. Create a key to track what colors, symbols, or letter or number codes represent different parts of the system. Although color coding is useful to quickly reference the parts of a model, letter or number coding helps ensure accessibility for any students who may be color blind. If color coding is used, consider a palette that uses orange, blue, black, or dark brown, as these colors are more universally distinguishable.

ADDITIONAL GUIDANCE

The position-line will eventually be displayed vertically as the *y-axis* of a position versus time graph. Keep this in mind as you choose what length to make your receipt paper. You may decide to make the video window on the screen a little smaller to ensure that the position-line will fit vertically on a whiteboard later. If your position-line is too long, you can use a wall for the graph instead, but you will need to use large sticky notes or chart paper to plot the points.

Identify and label important positions. For the first video (undistracted driver), elicit ideas about what positions are “important” to help analyze the way the car moves. You will mark these on the line, and mark the obstacle as well. Use probing questions to help students notice clues like the brake lights; for example, *Are there any changes to what we see when the car’s brakes go on?* Ask what clues we can use to consistently determine the moment the car stops; for example, the rotating of the front tire.

Be sure to mark the following positions on the line:

- Position 0: The car appears.
- Position 1: The obstacle appears.
- Position 2: The brake lights go on.
- Position 3: The car comes to a complete stop.

Once you have marked the important positions as shown in blue in this image, say, *Let's label and connect these positions so we can visualize the distance between them. What should we call each point?* Label the positions as students suggest, and then ask how we might abbreviate these to keep track. Students may suggest using X_1, X_2, and so forth. If you are short on time, briefly explain the convention of subscripting the letter X as a way to keep track of different positions, saying, *Let's label the first position with a little 1, and the second with a little 2, and so on, to tell them apart.*

Introduce *delta* and add to Personal Glossaries. Label each change in position as ΔX and ask the class what to call these intervals. Explain that scientists and engineers use a symbol called delta, Δ, when measuring change. Have students add this symbol to their glossary.

Introduce *reaction distance* and *braking distance* and add to Personal Glossaries. Point to the interval between the appearance of the obstacle and the brake lights, and ask, *What happens during this interval?* Listen for students to say that the driver sees the obstacle or reacts. Say, *Yes, this is the interval where the driver reacts. So let's call it the reaction distance.* Have students record this idea in their glossary. Do the same thing for the *braking distance*, which is the distance between when the driver begins to brake (or the brake lights go on in the video) and the car stops.

Measure and record the distances from point to point. Use a meterstick to measure the distances between the consecutive marked points on the line, starting where the car first appeared (X_0). These will likely be great enough that you won't need to use decimal places beyond the centimeter measurement. If students do want to use fractions of a centimeter, ask them to consider the error introduced by measurement. Record these distances on the timeline.

ADDITIONAL GUIDANCE	The conventions we use to describe kinematics are not always intuitive and require students to develop a new literacy. Consequently, we should think of the use of these conventions much as we think of the introduction of new vocabulary. As with vocabulary, it is best to motivate a need for a new convention before providing the convention itself, so it will be "earned." In the case of subscripts, for example, consider spending a moment asking what we could do to differentiate quickly between the positions. If students suggest using numbers or letters (i.e., 1, 2, 3; A, B, C), use their suggested representations. When we start to keep track of times as well, they will quickly see the need to add something to indicate whether we are referencing a position or a time. At that point, you can tell them that scientists use X and t to reference time and position, and subscript these letters with numbers.

Use a manipulative to reenact the video along the position-line. As a demonstration, briefly move the toy car in slow motion along the position-line from point to point, re-creating the video. Help students draw additional conceptual connections between the representation and the real-life phenomenon by asking, at each point that the toy car passes, *What happens when we get to this position?* Do not worry about the timings yet.

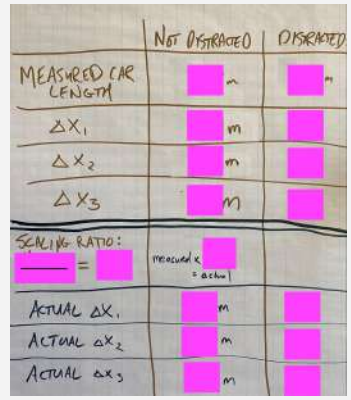
Elicit ideas about how to calculate the real-life distances. Present **slide D**. Have students share their ideas about how we could use scale to determine the distances that the car actually travels. Listen for ideas about wanting to know the real length of something in the video.

3 · ADD DISTANCES TO THE POSITION-LINE FOR THE UNDISTRACTED DRIVER (CLIP #1)

10 min

MATERIALS: *Creating Position-Lines*, https://youtu.be/Z11esq-Zs2E?si=j5gSUw7dRqlqxSsL, meterstick, Scaling Ratio Poster, chart paper markers (at least 3 colors), Undistracted position-line (in progress), 3x3 sticky notes (optional)

Calculate ΔX and create a Scaling Ratio Poster. Say, *We need a way to keep track of measurements that we make using what we see on the screen, as well as the actual distances they correspond to in real life. You can write the values on a handout, and I'll keep track of them for the class.* Reveal the Scaling Ratio Poster that you prepared before class.



If you teach multiple sections of this course, it may be convenient to use a single sheet of chart paper for all sections and add individual 3x3 sticky notes to the positions where you'll record values as shown in this image. Otherwise, write directly on the Scaling Ratio Poster

Present **slide E**. Distribute a copy of the *Creating Position-Lines* handout to each student. Say, *I looked up the length of this kind of car. It's 4.5 meters long.* Ask the class how we could use that known length of the car to find the actual distances in the video. Listen for ideas about finding the ratio of the actual car to the measured distances; this is called a scaling ratio. ✱

Explain that we will start with the columns marked "Undistracted"; the "Distracted" columns will be completed later. You will need to project video clip #1 again, and then pause it. Follow the directions on the slide (and the handout) as a class, demonstrating each step:

1. *Find the length of the car in the video clip at the scale that we watched it. Record this on your handout.*
2. *Find the length of each position interval that we identified (the lengths between the important positions) at the same scale. Record these on your handout.*
3. *Calculate a "scaling ratio" of the actual length of the car to the measured car length. Then use this ratio with the measured distances to calculate the actual distances in real life.*
4. *Label the actual distances we calculated on the position-line.*

✱ SUPPORTING STUDENTS IN ENGAGING IN USING MATHEMATICS AND COMPUTATIONAL THINKING

This is an opportunity to help students make connections to unit conversions in other contexts. For example, students who have completed Lesson 9 of *OpenSciEd Unit P.1: How can we design more reliable systems to meet our communities' energy needs? (Electricity Unit)* have done similar work in the context of batteries. Students who have traveled to different countries may have experienced converting amounts of money. To support this, explain along these lines: *When people travel to another country, they often need to think about converting units of money. A scaling ratio is useful in this context, too. For example, 1 US dollar is approximately the same as 20 Mexican pesos. If you know that a meal costs 75 pesos, you can use a scaling ratio to find the cost in dollars. Comparing the length of a measurement on the screen versus in real life is similar to comparing the cost of something in two currencies.*

4 · ANALYZE THE DISTRACTED DRIVER VIDEO (CLIP #2)

15 min

MATERIALS: *Creating Position-Lines*, Undistracted position-line (in progress), toy car, roll of receipt paper, tape, meterstick, chart paper markers (at least 3 colors), https://youtu.be/D2-2L_e3bLU?si=2jZ57RdNLrrzgr4u

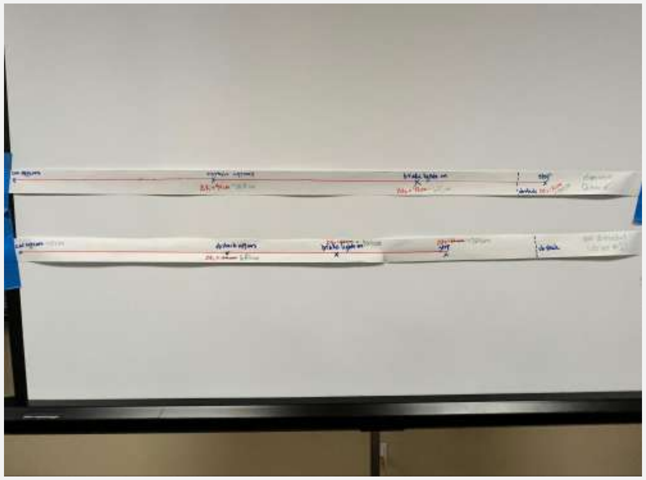
Make a prediction about a distracted driver. Present **slide F**. Use the prompt to engage students in making a prediction as shown in the table below.

Suggested prompt	Sample student response
Will the distances we calculated (reaction and braking) change if the driver is distracted? How?	Yes, the reaction distance would be longer, maybe twice as long. The braking distance would be the same, or shorter.

As students describe it, use a toy car to illustrate by driving it along the position-line you created, acting out the predictions. Revoice and record the predictions in words near the front of the room on a whiteboard; for example: "The reaction distance will be longer, but the braking distance will be the same. The car will take a longer distance to completely stop."

Create a position-line for the distracted driver. Present **slide G**. Label the first position-line as "Undistracted" and then move it above or below the path of the car to make room for another piece of receipt paper. Label this new strip of paper "Distracted".

Project clip #2 again and create a position-line for the distracted driver on the new piece of receipt paper. Move through the same steps as you did with clip #1 to create something that looks like these images. If you have time, students can independently calculate and record the actual distances using their handout. But to allow time for creating position versus time graphs, we recommend doing these calculations quickly with the class as for the undistracted driver video.



Compare the position-lines and predictions. Ask students to explain why the lines are different. You can annotate the position-lines as they describe their thinking, or underline the correct predictions on the whiteboard to emphasize that these were supported by the data.

Present **slide H**. Give students a minute of individual think time about the prompts. Then ask:

- *How did our predictions match the data?*
- *How were they different from the data?*

Accept all ideas.

ALTERNATE ACTIVITY	If you have an additional day, consider giving students the opportunity to do the distracted driver analysis on their own. Each student (or student pair) will need a computer, a fine tip dry erase marker, and a transparency sheet. They should use tape to attach the transparency sheet to the monitor, and mark and label each car position with the marker. They can then measure the distance between the marks and go through the calculations on their own to determine the scale on their screens so they can convert into meters. Average the class's results to create a consensus position-time graph at the front of the room.

5 · NAVIGATE AND ASSIGN HOME LEARNING

2 min

MATERIALS: *Distracted Driving Research*, toy car, Distracted position-line

Motivate an analysis of timing. Use the toy car to "drive" along the line again, recreating the distracted scenario. Then present **slide I**. Use the slide's prompt and questions like those in the table below as a guide for discussion. Listen for students to identify speed or timing to motivate an analysis of the time intervals in the video.

Suggested prompt	Sample student response
What was different about how the distracted driver was driving that could explain why these distances were different?	They might be going faster.
How does this affect braking?	They might have to brake harder.
What does it mean to brake harder?	They might go the same distance, but they need to do it in less time.
Does everyone agree that the timing between these positions, as well as the distance, may be different for the distracted driver?	

Listen for them to think through the fact that the reaction time will be longer and the braking time will be either shorter or the same.

Present **slide J**. Say, *I heard ideas about speeding and about how fast the driver stops. These are related to the time it takes for the car to move and slow down and stop. But we've only been able to analyze this video based on distance. Let's take a closer look at the timing of the videos next time.*

Assign home learning. *Before our next class, let's read about the time it takes to react, and see whether that gives us some insight into the timing of the videos.* Give each student a copy of the *Distracted Driving Research* reading. The text has a Lexile score of 1010-1200 and is 843 words long.

End of day 1

6 · NAVIGATE: REACTION TIME

3 min

MATERIALS: science notebook, *Distracted Driving Research*

Consider the relationship between distraction and reaction time. Present **slide K**. Pose the prompts and additional questions like those shown in the table below to get students thinking about the difference between measuring distance traveled and time passed.

Suggested prompt	Sample student response
What insights did looking at distances give us into the system during our investigations of the videos?	It helped us calculate how far the car moved.
How did the article frame it--distance or time?	Time.
How much does the driver's being distracted impact the time it takes for the car to stop?	According to the reading, it could double the time it takes.
Doubling is a lot! Do you think this is true?	(Accept all ideas.)

Articulate our motivation to analyze timing. Present **slide L**. Pose the question to the class:

- *How could looking at the timing of each scenario (undistracted versus distracted) help us understand how distracted driving could change the outcome of a possible collision?*

Have students turn and talk briefly and then share out some ideas.

Add *reaction time* to Personal Glossaries. Say, *In the article, we read that the time it takes for you to hit your brakes when you see something you might collide with is called your reaction time. Let's keep track of that phrase, because it means something very specific.*

Give students a moment to add *reaction time* to their glossary. They may define it in terms of driving (i.e., the time it takes for a driver to hit the brakes when they see an obstacle) or biology (i.e., the time it takes for an animal or plant to react after sensing a stimulus).

ALTERNATE ACTIVITY	**Optional (requires an additional 15 minutes):** Ask, *How could we test to see whether being distracted impacts our reaction time?* Have students use https://www.justpark.com/creative/reaction-time-test/ to test their reaction times normally and when another student is distracting them; they will notice that being distracted does make

a difference. You can also give them something to unwrap, like a book wrapped in paper, to simulate someone who is trying to eat and drive.

Another way to measure reaction time is the ruler drop test. One person holds a ruler by the end and another person watches it and gets ready to catch it, trying to catch it as quickly as possible after it is dropped. Where on the ruler the second person catches it is an accurate measure of time because the acceleration due to gravity is constant on Earth's surface.

Say, *There's always a delay in how fast you can react to something. Researchers say being distracted doubles that time, and our test bears that out ... but we're talking about very short time periods here, like half a second versus a quarter of a second. How much of a difference do such small changes in reaction time make in avoiding a crash?*

7 · CREATE A TIMELINE FOR THE UNDISTRACTED DRIVER (CLIP #1)

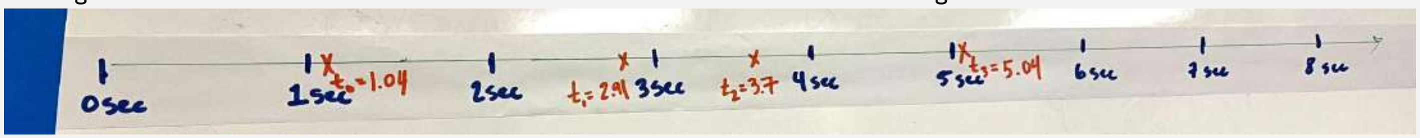
5 min

MATERIALS: roll of receipt paper, tape, meterstick, chart paper markers (at least 3 colors), https://youtu.be/Z11esq-Zs2E?si=j5gSUw7dRqIqxSsL, Undistracted position-line

Create a timeline for the undistracted driver. Present **slide M**. Use a new strip of receipt paper to construct a timeline. It does not need to be the exact length as the position-line but should be on the same scale, as you will eventually combine these lines to create the axes of a graph. You can do this on the projector screen again, or on a sturdier surface like a whiteboard or wall.

Start by creating tick marks for time, asking what unit we should use. The class should decide on seconds as the relevant unit. The videos are 6 seconds and 7 seconds long, respectively, so your line should go to about 7 seconds. In the example, the tick marks are 1 decimeter apart.

Use the time code in the video to figure out the time associated with each important position the class identified previously. Then determine the length of each time interval and add this information to the timeline as shown in this image. Label this timeline "Undistracted".



8 · CREATE A POSITION VERSUS TIME GRAPH

20 min

MATERIALS: science notebook, loose-leaf paper, graph paper with three-hole punch, Whiteboard (optional), dry erase marker (optional), Undistracted position-line, Undistracted timeline, tape, meterstick, chart paper, chart paper markers, toy car

Motivate comparing our variables on a graph. Present **slide N**. Say, *We have two different ways to look at the events in the video: as time passes, and as the position of the car changes. What could we do to visualize what's happening here in both dimensions, time and position, and look for a relationship between these?* Give students a minute to consider this question with a partner, and then elicit their ideas. ✱

If students need more scaffolding here, use the prompts below to help them consider what they have done in the past, and if necessary, guide them to think about graphing specifically. ✱

Suggested prompt	Sample student response
What have we done in the past to compare two different variables and look for relationships between them?	Graphing on two axes.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING STABILITY AND CHANGE

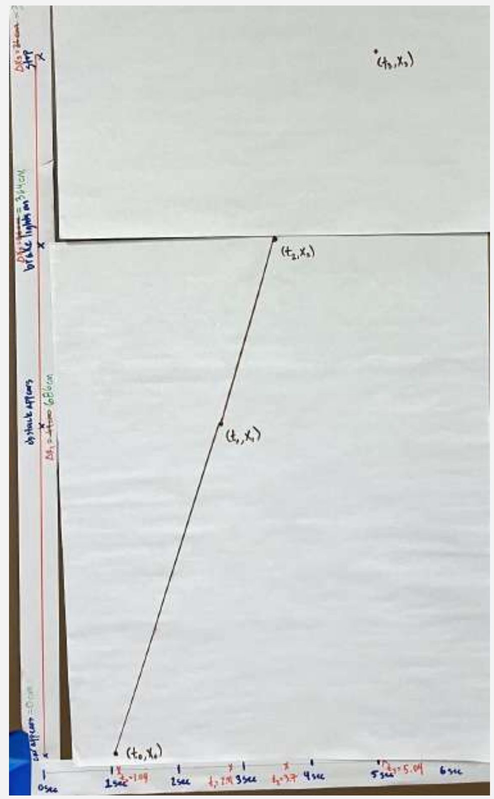
In this unit, students will develop a progressively deeper understanding around the following CCC element: *Change and rates of change can be quantified and modeled over very short or very long periods of time.* In this lesson, students "invent" position versus time graphs to answer their questions, motivating a quantification of a rate of

How can an x-y graph help us understand the relationship between two variables?	The graph tells us what y is given a value x.

Consider the relevant variables. Present **slide O**. Say, *The variable on the y-axis is usually the one that changes depending on the x-axis, so it's called the dependent variable. The variable that determines the dependent variable is called the independent variable.* Give students 30 seconds to discuss with a partner or think independently before eliciting ideas about the prompt in the table below.

Suggested prompt	Sample student response
Which of our two variables determines the other?	We can't change time, and time determines distance.

Designate the graph's axes. Say, *So, let's leave time on the x-axis. Let's put position on the y-axis. That way, we can visualize how position changes over time.*



Create the *y-axis* by repositioning the position-line. Move the Undistracted position-line up and sideways to be the *y-axis* with the timeline as the *x-axis as* shown in this image, joining the origins of each line at the bottom left corner. Add chart paper to be able to plot points using the axes.

If you want to move through the next several steps without projecting slides, to focus attention on the graphing, you can skip **slide P**; otherwise, use the slide to articulate the task for the class.

Determine the lines between points. Ask, *How do we represent the moment the car appeared, in both time and position, on this graph?* Help students see that we can graph this point, and use a meterstick to plot each point: (t_0, X_0), (t_1, X_1), (t_2, X_2), (t_3, X_3).

Ask, *What is the car doing between time 0 and time 1?* Listen for students to suggest that it is moving from position 0 to position 1. Connect these points with a line. Repeat for the other two intervals.

Copy the graph into science notebooks. Direct students to copy the plot the class makes onto a piece of graph paper with three-hole punch for their notebook, labeling the graph "Position vs Time".

change (speed) for the first time in the unit. Here, the time over which they think about rates of change is relatively long (several seconds). Later in the unit, they will model changes in a similar way but over very short periods of time (less than a second) to better understand the forces involved in the collision itself.

✱ SUPPORTING STUDENTS IN ENGAGING IN ANALYZING AND INTERPRETING DATA

If students need more support interpreting the graph, consider using the Identify and Interpret (I^2) sensemaking strategy. This breaks down an information-rich graph into smaller pieces to interpret. In the I^2 strategy, students first identify changes, trends, or differences. They draw an arrow to each observation and then write a "What I see" (WIS) comment. These comments should simply be what the student observes, such as a positive slope on a graph or increasing numbers in a data table. After they have made all their observations and written WIS comments, they interpret the meaning of their observations by writing a "What it means" (WIM) comment for each. Once they have mastered WIS and WIM comments, ask them to create a caption for the graph, figure, or table. A caption is a summary of all the information and helps show students' understanding.

Interpret the graph. Present **slide Q**. Have students turn and talk for a minute about the prompt:

- *What information do these lines give us about the motion of the car at that position and time?*

Bring the class back together and ask, *What does this first line tell us about how the car is moving?* Accept all ideas, but highlight any about speed. Guide students as needed with questions like the examples in the table below.

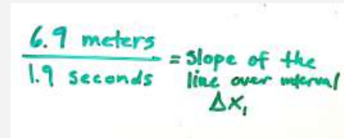
Suggested prompt	Sample student response
How far did the car need to move to get from X_0 to X_1?	About 6.9 meters (or 690 centimeters).
And looking at the x-axis, how long did it take the car to move from here to here?	About 1.9 seconds.

ADDITIONAL GUIDANCE	Encourage students to round to a single decimal point throughout these calculations. If they have learned about significant figures in math or in previous science classes, you can scaffold this move by reminding them that measured numbers always have a limited number of significant figures. For multiplication, the **least** number of significant figures in any number of the problem determines the number of significant figures in the answer. Because we used 4.5 meters (the given length of the car) to determine our distances, and that number has two significant figures, we need to stick to two significant figures.

Calculate the speed of the car before braking. Write 6.9 meters/1.9 seconds on the board at the front of the classroom. Say, *In math terms, we call this the slope of the line, or how much the y-axis changes every time the x-axis changes.* Label the fraction as "slope of the line over interval ΔX_1". Then say, *Let's take a closer look at what this slope is telling us.* Guide students as needed as shown below.

Suggested prompt	Sample student response
6.9 meters per 1.9 seconds, that's meters per second. Where else have we heard "distance over time"?	Meters per second is a speed. We have learned that distance over time is speed in math.
So, what do we need to do to determine how fast the car is going on average in this period?	Divide the numerator by the denominator.

Go through the calculations as a class. You should find that the car was initially moving at about 3.6 meters per second. (Optionally, type this into Google to convert, or do the calculations with the class to figure out what this means in miles per hour; 1 meter per second is 2.2 miles per hour.) Then repeat these calculations for the second time interval. You should find that the car was moving at about 4.6 meters per second after the obstacle appeared but before braking. Have students record these times in their notebooks, as they will need them for Lesson 3.



ADDITIONAL GUIDANCE

The car is going approximately 4 meters per second in the clip before braking, but students should get slightly different values for the average speeds of intervals 1 and 2. If students are puzzled by this, explain that in real life a car's speed is always changing, and that these values represent averages.

Articulate the relationship between slope and speed in a quick assessment moment. Present **slide R**. Pose the first prompt to the class as shown in the table below.

Suggested prompt	Sample student response
Based on the work we just did, what can the slope of a line in a position versus time graph tell us about how the car is moving?	It tells us the speed.

Then ask students to respond to the slide's prompts A-C on a sheet of paper. Collect these papers before the end of class to check their interpretations of this kind of graph.

A. *What does a steeper slope mean about the motion of the object?*
B. *What would it mean about the motion of the object if the slope were zero (a flat line)?*
C. *What would it mean if the slope were negative?*

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- (Prompt A) When the slope is steeper, the object is moving faster. (CCC: 1.4, 7.2)
- (Prompt B) When the slope is zero, the object isn't moving. (CCC: 1.4, 7.2)
- (Prompt C) When the slope is negative, the object is moving backward. (CCC: 1.4, 7.2)

What to do: Do not use this assessment moment to assign a score, but rather to decide whether the class needs more practice interpreting position versus time graphs. Consider reaching out to a math colleague to find out what students are expected to know about change over time in their math classes. If only a few students are struggling, consider meeting with them one-on-one to analyze the graphs and videos in detail before the next class. As the lesson goes on, students will use this change-over-time thinking to interpret the videos and describe factors that affect risk.

Building toward: 2.A.1 Analyze videos of two drivers encountering a sudden obstacle by graphing change in distance over time in order to describe and predict how being distracted can affect the risk of a potential vehicle collision. (SEP: 4.1; CCC: 1.4, 7.2; DCI: ETS1.A.2)

Add a horizontal line after time 3. Present **slide S,** and explain that we will add a line to the graph to show how the car was moving after time 3.

Use questions like those in the table below to motivate drawing a straight horizontal line after time 3.

Suggested prompt	Sample student response
What is the car doing after time 3?	It is stopped.
So, what is its speed?	Zero meters per second.
As the speed gets slower and slower, how does the slope change?	It gets less steep.
So, what do we think this line is going to look like if the car is not moving at all? How will its position change over time?	It will look like a straight line. The position won't change over time. (Add this line to the graph.)

Consider the line representing braking. Point to the second prompt on the slide: *Is there anywhere on the graph where we need to adjust the slope of the line to better show how the car was moving?* Look fro students to suggest the line representing braking. If they do not, say, *A straight* *line between two points indicates that the speed is constant over that time. Is that true of the car? Is the speed constant between these two points, for example?*

Point to t_3. Quickly do the following calculation on the board: (3.6 m/1.3 s) = 2.8 m/s. Alternatively, consider asking students to do their own calculations on a small whiteboard or in their notebook.

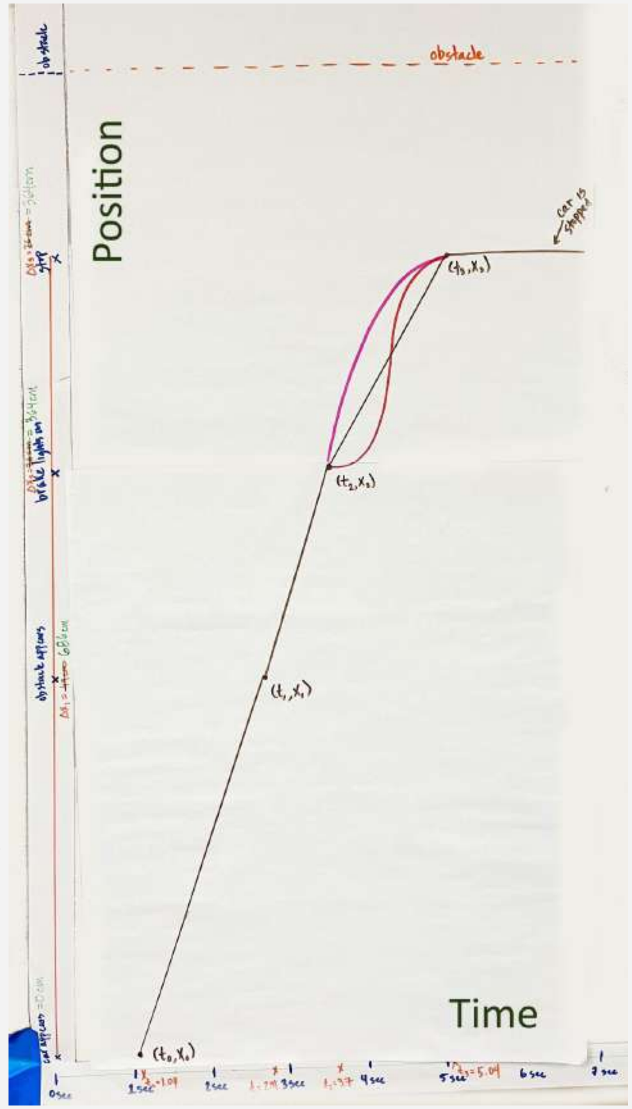
Ask, *But is the car really going that speed the whole time?* Students may need some individual think time before sharing out. Listen for them to recognize that the car starts at about 4 meters per second and then slows down to zero. Use the toy car to help them clarify their thinking, perhaps by asking them to demonstrate how the car in the video is moving between these two points.

Say, *So, near this third point, the line should be almost flat, because it doesn't go straight from 4 to 0--it changes over time.* Extend the flat line from beyond the third point to before the third point just a tiny bit. Then ask, *What do you think the line looks like between the second two dots?*

Encourage students to make predictions and offer supporting arguments. Have a few volunteers come up and draw what they think the line will look like. Use a different color to indicate these predictions. If there are competing ideas, give each student a different color so you can differentiate between their predictions.

Add the obstacle to the graph. Present **slide T**. Say, *In this video, the car avoided a collision. How can we represent the obstacle in our plots to show why the car did not hit it? What if the obstacle had been closer to the car? How would the plot look different?* Give students a moment to turn and talk. Then ask a volunteer to come up and add the position of the obstacle to the graph. Ask the class if they agree or disagree, and adjust as necessary. The obstacle should be represented as a line, or a mark on the Y-axis, approximately just above the line indicating where the car is stopped.

Update the graph in science notebooks. Give students a moment to record the lines we added to the Position versus Time graph in their notebook.



9 · GRAPH THE DISTRACTED SCENARIO IN PAIRS

15 min

MATERIALS: science notebook, graph paper with three-hole punch, colored pencils (various), undistracted position versus time graph

Graph the collision for the distracted driver. Present **slide U**. Say, *Let's figure out what this line would look like if the driver were distracted.*

Have students work with a partner to go through the same steps as previously, but for the distracted driver. They can plot the points using the same axes as for the undistracted driver on their Position versus Time graphs, as long as they use a different color. Alternatively, they can create a separate graph on a new piece of graph paper. Make sure the position versus time graph that the class made for the distracted driver is clearly visible.

ALTERNATE ACTIVITY	If there is time, come together as a class and graph the distracted driver on the same axes as for the undistracted driver. You can move the position-line that the class created for the distracted driver to the left of the vertical position-line for the undistracted driver. Use another color and/or pattern, and create a key to distinguish between the two lines.

Debrief the graphing. With 5 minutes left in the period, have students share what they noticed. Present **slide V**. Pose the prompt:

- *What differences did you notice that could explain why being distracted increases the likelihood of a vehicle collision?*

ASSESSMENT OPPORTUNITY	**What to look for/listen for in the moment:** Look for students to correctly analyze the distracted driver video by graphing position versus time for clip #2. Then in the debrief, listen for them to explain that: ● The graphs reveal a pattern for the distracted driver that looks different than the pattern in the undistracted driver data. (CCC: 1.4) ● The graphs show that the distracted driver moved farther during the time between the appearance of the obstacle and the brake lights. (CCC: 7.2) ● This suggests that being distracted increases the time it takes to react to something (reaction time). (DCI: ETS1.A.2) ● A longer reaction time means that the car travels farther before braking (reaction distance) and is more likely to hit the obstacle. (SEP: 4.1) **What to do:** ● As students graph, move around the classroom and support those who are struggling. Point to the steps they moved through to plot the first series of points for the undistracted driver. Use probing questions to help them articulate the steps we took as a class and why: *What did we do when we did*

this together? What were we trying to figure out when we did that?

- To get ideas flowing during the debrief, you can hold up two graphs, point to easily observed differences, and ask what those differences mean. Have students point to evidence on their graphs to support their reasoning as they share ideas.

Building toward: 2.A.2 Analyze videos of two drivers encountering a sudden obstacle by graphing change in distance over time in order to describe and predict how being distracted can affect the risk of a potential vehicle collision. (SEP: 4.1; CCC: 1.4, 7.2; DCI: ETS1.A.2)

10 · NAVIGATE WITH AN EXIT TICKET

2 min

MATERIALS: sheet of loose-leaf paper for exit ticket

Assign the exit ticket. Say, *It seems like a shorter reaction time is key for preventing accidents*. Present **slide W**. Distribute a sheet of loose-leaf paper to each student. Instruct them to respond to the slide's prompt as an exit ticket:

- *What else could increase a driver's reaction time other than whether the driver is distracted?*

If there is time, ask students to share out. Otherwise, collect the exit tickets and read through them so you can summarize students' ideas at the start of Lesson 3.

Additional Lesson 2 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH	**The Number System** **CCSS.MATH.CONTENT.HS.A-CED.2 Creating Equations:** Create equations that describe numbers or relationships. Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. In this lesson, students graph position on a number line and then graph time on a number line. They decide that in order to get a sense of the relationship between the two quantities, they will graph them together with those lines as axes.