CHOKE UP ON THAT BAT!

Facilitator's Guide • Section 4.1

INTRODUCTION

It's a familiar baseball refrain. The pitcher winds up and delivers the ball, and the batter swings, but too slowly. Strike one. "Choke up on that bat!" says the coach. Most players know that this means they should slide their hands up higher along the bat handle, leaving a gap between their grip and the bottom end of the bat. But why? "Choke Up on That Bat!" explores the science behind this technique by introducing the concepts of inertia, force, and torque, though in somewhat more conceptual terminology. The poster starts with a discussion of what is required to take an object at rest and put it into motion. This is extended to investigate what is required to rotate an object. A simple example is given to illustrate how the motion resulting from a twisting action depends on where the action is applied. This is then used to connect to concept of "choking up" with reducing the rotational inertia of the bat, thus increasing the bat speed.

The primary points covered in the poster are:

- **A push** (that is, a force) is required to get an object moving.
- **Mass is a measure of an object's inertia** or resistance to changes in its motion. The more mass an object has, the larger the force that must be applied to set it into motion.
- **A twisting force** (torque) is required to rotate an object.
- **Rotating an object is easiest** when the twisting force is applied close to the point where most of the mass of an object is concentrated.
- **Choking up on a bat** moves the grip closer to the heaviest part of the bat, making it easier to swing.

BACKGROUND SCIENCE

Conceptually, every child knows that one needs to push on an object to get it to move, and that massive objects are the most difficult to set into motion. Newton's first and second laws of motion formalize and quantify this notion: An object at rest will remain at rest, and an object in motion will remain in motion (at constant velocity), unless a force is exerted to change that motion. This tendency to resist changes in motion is called inertia. The more massive an object is, the more inertia it has; mass is a measure of inertia. If a force is applied, the rate at which the motion changes is proportional to the size of the force, but inversely proportional to the mass; large forces cause large changes in motion, but if the same force is applied to two different objects, the change in motion will be greatest in the less-massive of the two.

This same idea applies to spinning motions. A twisting force, called a torque, is required to get an object to rotate, or to change its rotational speed. However, the tendency for an object to resist changes in its rotation depends on more than just its mass. It also depends critically on how far from the center of rotation the mass is located. This is easy to demonstrate. Simply take an ankle weight, or similar object (e.g., a heavy chain), wrap it around your wrist, extend your arm and try to swing it up and down (without bending your elbow). Now move

BACKGROUND SCIENCE (continued)

the weight is closer to your shoulder (which is the center of rotation). The total weight is the same, but its distribution is different; you have changed the rotational inertia (generally called the "moment of inertia").

The shape of a baseball bat concentrates most of the mass toward the top end. This makes it difficult to set into rotational motion. While it may seem like the center of rotation of the bat is the batter's body, the bulk of the rotation is actually centered on the batter's wrist. Thus, the farther the mass is distributed from where the batter is gripping the bat, the harder it will be to set the bat into rapid rotation. Sliding the grip a bit toward to top of the bat, which is known as "choking up" on the bat, brings the bulk of the mass closer to the rotation axis; it reduces the rotational inertia. For a given twisting motion, the batter is thus able to rotate the bat more quickly.

Major league pitchers throw with a variety of speeds (and with complicated motions induced by the spin on the ball—an interesting topic for another poster…), covering typical ranges of about 70 - 95 mi/hr (110 - 150 km/hr). The slower pitches take about 0.6 seconds to reach the batter. This is not a lot of time! But a high-speed fastball arrives even more quickly, taking just over 0.4 seconds to arrive. It is crucial for the hitter to get the bat around quickly! If the batter is facing a fast pitcher, he or she will often choke up on the bat a bit to increase the bat speed.

FUN FACTS

- Tightrope walkers often carry a long stick that extends horizontally, perpendicular to the tightrope. It may seem like this makes their job even more difficult, but it actually makes it easier! Because the stick provides mass that is located far away from the person, it is hard to rotate. If they tilt a bit to one side or the other, they have a relatively stable object to hold onto.

- The result of a large earthquake is often a "settling" of the Earth's crust, resulting in a tiny decrease in the radius of the planet. This decrease in its rotational inertia (because the mass is now slightly closer to the center of rotation) results in the planet spinning more rapidly, and thus a shorter day! The 2004 Sumatra earthquake resulted in a 6.8 microsecond decrease in the length of a day on Earth.

- When you tug on a full roll of toilet paper, a sheet of paper can be torn off. Tugging similarly on a nearly-empty roll often just results in the whole roll spinning, dumping paper on the floor without ever tearing a piece off. This is because the rotational inertia is larger for the full roll, making it hard to rotate with a quick pull.

COMMON QUESTIONS OR MISCONCEPTIONS

- Students often regard objects being at "rest" as a natural state of motion where no forces are acting on a object. A book at rest on a table experiences the downward force of gravity. The table pushes upward on the book with an equal force. The TOTAL force on the book is zero. Newton's 1st Law explains that an unbalanced force is required to get the book to move. In addition, students usually understand that a stationary object will not move until you exert a force on it, but it is less obvious that a force is not required to keep it moving. Rather than understanding that friction or some other force acts upon an object to slow it down, students often think that the force that got it going "wears off."

- If choking up on a bat can increase bat speed, students might wonder if they should grip the bat a long way away from the end (i.e., choke way up). While choking up on a bat is appropriate for the reasons stated above, it shouldn't be taken to extremes. Laura Brenneman (MVP of the 2004 Women's Baseball World Cup, and also a PhD astrophysicist—so yes, some baseball players are scientists!) explains that choking up on the bat is "the easiest way to quickly increase your bat speed" but notes "I never choke up more than about an inch or so, to ensure that I haven't compromised my plate coverage or swing mechanics too much."

- Because gravity pulls harder on a body with more mass (i.e., it is "heavier"), students often think that if two balls are dropped simultaneously from the same height, the heavier one will reach the ground first. However, since it takes a smaller pull to get the smaller mass moving, these effects actually cancel out. The large tug of gravity on the massive ball and the small tug of gravity on the smaller ball will result in the two balls reaching the ground at the same time!

DEMONSTRATIONS AND ACTIVITIES

- **Timber!** You can demonstrate that it is easier to impose rotation on a mass that is close to the center of rotation than on one that is farther away by using a pair of meter sticks and a pair of identical weights. Tape one weight close to the top of the meter stick, and tape the other near the center of the other meter stick. Now stand both meter sticks on end, side by side, and tilt them slightly so that they are both leaning at the same angle. Let go of both simultaneously and let them topple over like falling trees. Because the stick with the mass located farthest from the rotation center has a larger rotational inertia, it will respond more slowly to gravity's torque; the stick with the mass closer to the rotation axis will hit the ground first.

- **Vegetables help you learn.** It is easy to give students a real "feel" for the concept of rotational inertia. This requires three meter sticks, some tape, four identical cans of vegetables, and two additional, but lighter, cans of vegetables. Tape a can of vegetables at both the 10-cm and 90-cm marks on a meter stick. On a second meter stick, tape identical cans at the 30-cm and 70-cm marks. Try to spin each meter stick by holding it at the 50-cm mark. Which is easier to spin? Now tape two smaller cans of vegetables on a third meter stick at the 10-cm and 90-cm marks. Compare the spin of this meter stick to the one with the larger cans at the same place.

DEMONSTRATIONS AND ACTIVITIES (Continued)

- **Putting a good spin on it.** A very familiar demonstration pertaining to rotational inertia is that of an ice skater pulling his arms in during a spin. By concentrating the mass near the rotation axis, it is easier for the skater to spin quickly. This can be simulated by having a student sit in a chair that can be spun around. Place weights in the student's hands and have her hold them out away from her sides. Spin her around in the chair, and then have her pull her arms in while she is spinning. As her rotational inertia is reduced, she will start spinning faster. Note that this is actually a better demonstration of the conservation of angular momentum, but it gets across the same basic point about rotational inertia.

- **How to lose a race.** When people run, they bend their knees as they bring them forward. This brings their feet closer to their hips, reducing the rotational inertia. How much difference does this make? Divide the students into pairs and hold footraces. One student runs normally, but the other must keep his or her legs straight while running. Not much of a contest, but a good lesson and a sure laugh!

- **Take me out to the ballgame.** The best way to demonstrate the main point of the poster is, of course, to play baseball! Have students experiment with gripping that bat at different locations to see how this affects their ability to rotate it quickly. Then play ball!

RESOURCES

http://www.youtube.com/watch?v=gO2CRb8FHLA

http://teachertech.rice.edu/Participants/louviere/Newton/