Olga (top) and Vova Galchenko practice in their juggling room.

By Pearl Tesler

A brother and sister take juggling to the limit.

Flipping Out

I can't juggle—not even three lousy balls—and to be honest, it never bothered me much. I thought juggling was just a silly circus act, like sword swallowing or breathing fire. Then I met Vova and Olga Galchenko.

You know you've met serious jugglers when you find out they have an entire room devoted to juggling in the middle of their house. The Galchenkos live in the hills an hour north of Los Angeles, and their juggling room is a huge atrium with a soaring ceiling. The view from the floor-to-ceiling windows is spectacular, but the real spectacle occurs indoors when Vova and Olga let fly an endless stream of whirling white clubs that encircle them like a flock of startled birds.

This brother and sister from Russia, now 20 and 17 years old, have almost by themselves transformed juggling from a sideshow act into an extreme sport. They started juggling for fun as kids. Since moving to the United States in 2003, they have won competition after competition while toppling four world's records. They're best known for their astonishing club-passing routines, in which they hurl as many as 12 clubs at each other with dizzying speed and accuracy. They bring an eerie intensity to their juggling while somehow making impossible tricks look easy.

That's the rub for top-notch jugglers like the Galchenkos. The timeworn tricks that amaze audiences again and again—taking bites from a juggled apple or tossing flaming torches or chain saws—actually take very little skill. Those crowd-pleasers are so easy, in fact, that serious jugglers don't bother with them. By contrast, the tricks the Galchenkos perform look magically effortless yet are so difficult that only a handful of people in the world can do them.

HIGH FLIERS

Scattered everywhere in the Galchenkos' house are the tools of their trade. Jugglers call those tools props, and they include balls, rings, and *clubs,* which look like bowling pins but are much lighter. The stone floor of their practice room is chipped from clubs dropped during daily four-hour practice sessions.

In the air, the props become what physicists call *projectiles*. A projectile is any object—a juggling club, a baseball, a bullet—that has been launched into the air and is not self-propelled.

As Vova expertly launches nine balls into the air, he assures me that anyone, even me, can juggle three balls, though it may take a week or so to learn. As the number of props increases, though, the difficulty soars. Maybe anyone can juggle three balls, and in 1996 someone briefly juggled 10 balls, but there's no one on Earth—yet—who can juggle 11. Why not?

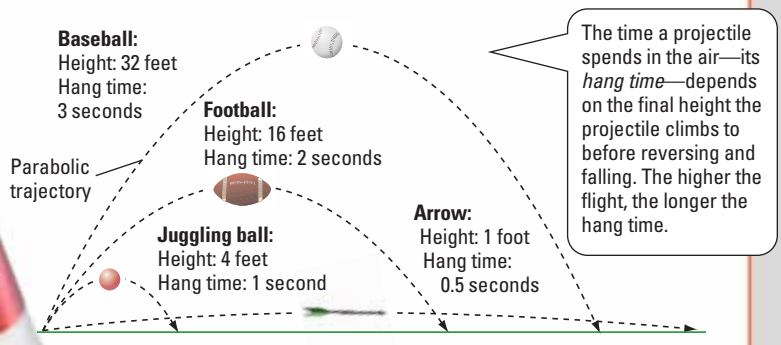
Juggling high numbers of props requires almost superhumanly fast hands. Keeping 11 balls in the air would mean tossing up a ball, then making 10 more tosses and catches before the first ball came back down to be caught and tossed again—requiring roughly eight tosses and catches each second!

One way jugglers buy time and reduce the number of throws they need to make each second is by throwing each prop higher. Higher throws help buy time because the time a projectile spends in the air—its *hang time*—depends on one thing only: the initial upward *velocity*. Velocity is a measure of the speed and direction of an object.

The greater the upward velocity of the projectile, the higher it travels and the longer it takes to come back

What Goes Up ...

A juggling club. A football. A baseball. An arrow. Any object thrown or launched into the air that doesn't have its own means of propulsion is a *projectile*. No matter what the object is, a projectile always follows a predictable *trajectory* (path through the air). That trajectory is an arc called a *parabola*.



Projectiles move in parabolic paths because of *gravity*—the force of attraction between objects. Earth's gravity gives projectiles a downward *acceleration*. Acceleration is a change in an object's speed or direction. The downward acceleration that gravity causes gradually slows the upward movement of the projectile until it stops. The projectile then reverses direction and heads down.

Let Fly!

Are you ready to start juggling? All you need is an open space, some perseverance, and three soft objects—try beanbags, tangerines, or tennis balls.

Most beginners attempt to juggle in a circle, a pattern called a *shower*. But an easier way to juggle three balls is in a sideways figure-eight pattern called a *cascade*. Here's how:

1. Start by throwing just one ball back and forth from hand to hand. The ball should rise to just about eye level.

2. Move on to *two-ball exchanges*. Start with one ball in each hand. Throw one ball, and just when it reaches its highest point, throw the other ball under the first. The rhythm is throw, throw, catch, catch.

3. Now you're ready to try a *three-ball flash*. Put a third ball in one of your hands, and throw it when the second ball reaches eye level. You'll make three throws and three catches. As the three-ball flash gets easier, you'll be able to add more throws and catches. You're juggling!

Olga juggles in the empty hot tub at her home.

down. To get one second of hang time, you have to throw a ball 1.2 meters (4 feet) into the air. For two seconds, you have to throw it 5 meters (16 feet) high. Three seconds? Try 11 meters (36 feet). Now it's clear why the Galchenkos need a room with such a high ceiling.

Of course, juggling more and more props isn't as simple as just chucking them higher and higher into the air. There's also the matter of aim. "The higher you throw, " explains Vova, "the harder it is to make it accurate. You just have to find a happy medium where you still have time, but you can also still throw them accurately."

Poorly thrown props will land outside of arm's reach or collide with the other props in the air. "With seven clubs, there's a lot of stuff in the air that has to fit in a pretty narrow corridor, so each throw you make has to be just right," says Vova. "If one is off, the next one goes *boom*, and you're done."

Spend any time around serious jugglers and you'll hear them talking in what seems to be secret code: "I nailed the 6-4" or "I'm working on the 9-7-5-3-1." What are they talking about?

Juggling is a form of aerial sculpture with an endless number of possible patterns—a repeating series of throws and catches, some of them mind-bendingly complex. Describing all the various patterns would be nearly impossible if it weren't for an ingenious mathematical tracking system called a *siteswap*. A siteswap is a sequence of numbers that describes a juggling trick. Each number in the sequence stands for a throw in the pattern. The higher the number, the higher the ball is tossed into the air. Odd numbers are balls that cross from one hand to the other. Even numbers are balls that are tossed and caught by the same hand.

Vova demonstrates one of his favorite siteswap tricks, the 9-7-5-3-1, which creates a surprising vertical stack in midair as the five balls reach the top of their arc at the same time. The trick works because, as the numbers suggest, each ball is thrown a little lower than the preceding ball.

TRADING PLACES

Scientist and world's-record-holding juggler Bruce Tiemann invented the siteswap system in 1985 as a way of coming up with new and unusual tricks. He even went so far as to use a computer program to generate new siteswaps. The resulting flood of tricks revolutionized juggling.

"It isn't necessarily true that the balls have to land in the order that they're thrown," says Tiemann. "What if you throw the first one higher, so that it lands later, and throw the second one lower, so it lands earlier? Now they've switched places. That's why I called them siteswaps."

Tiemann's favorite siteswap trick is the Five-Ball Disaster, a complicated series of 11 throws: 6-6-6-7-1-6-6-8-1-4-4. It looks like a juggler flailing in complete chaos, but somehow the balls magically land in his hands at just the right time. "Here's this juggler who's throwing the balls to all these crazy heights all over the place," he says. "Some of them cross; some of them don't. Some of them are low; some are high. It's a complete disaster, totally incomprehensible, and yet it keeps going, it works."

It's a totally cool trick. But there's an even better way to appreciate juggling—and juggling disasters—alike: Pick up a few balls and try it yourself! **CS**

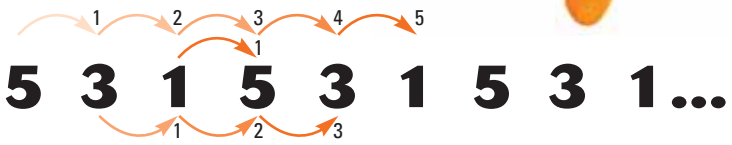
A Numbers Game

Even if you don't know how to juggle, you can invent juggling tricks of your own. Use a mathematical tracking system called a *siteswap*. Pick a sequence of numbers—try just three to start—to describe your trick. Then submit your sequence to two tests.

Each number in your series describes a different type of throw.

Test One: Add the numbers in your sequence; then find their average. If the answer is a *whole number*—a number without a fraction or a decimal part—it passes the test. For example, the sequence 5-3-1 passes the test because its average is 3, a whole number. The average also tells you how many balls you'll need to juggle the pattern. If the average is 3, you'll need three balls.

Test Two: Write your sequence a few times in a row. For example, if your sequence is 5-3-1, write 5 3 1 5 3 1 5 3 1 5 3 1. For each number in the pattern, count forward that many places to find out where in the series the ball will land. The sequence passes this test only if no two balls land in the same place.



5-3-1 is OK: The balls land at different times.

3-2-1 is a disaster: The balls land at the same time!

If your sequence of numbers passes the two tests, then it's a valid trick. Try juggling it—or let a computer-animated juggler do it for you by visiting **http://jugglinglab.sourceforge.net/**.

Try these patterns:
5-3-1, 6-4, 5-3-1-3, 7-7-1, 4-4-1-3, 9-7-5-3-1
Do they pass the tests?

Shutterstock