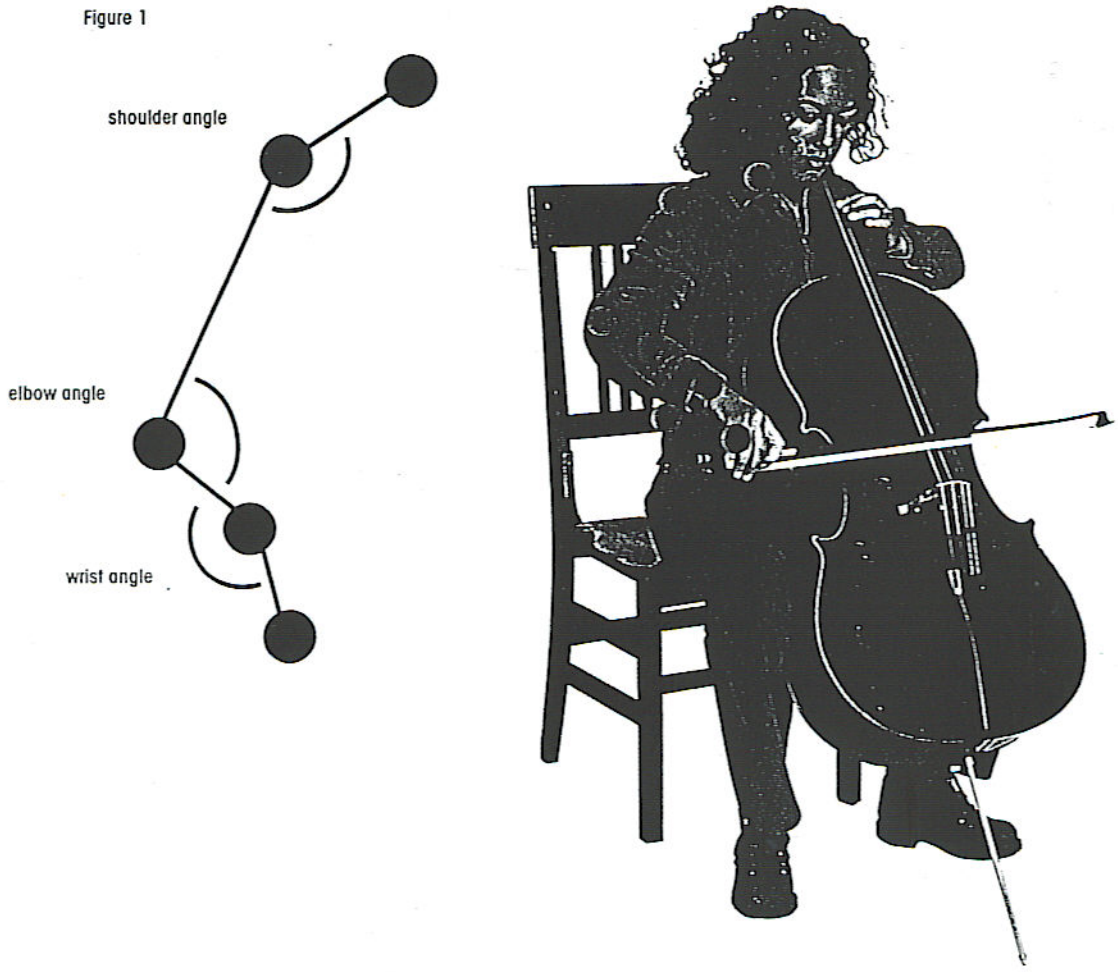



How *do* you play spiccato, and how do you teach it to someone else? **Helga Winold**, **Esther Thelen** & **Jing Feng** took eight cellists into a lab to investigate

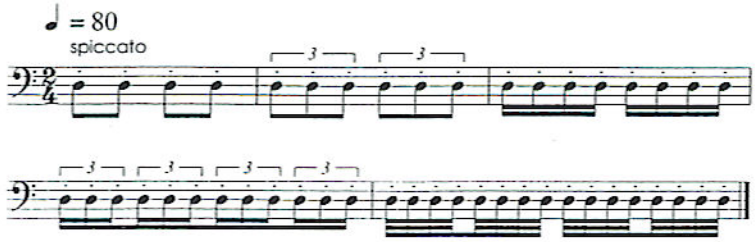
# On the rebound

**Spiccato is an off-the-string,** bouncing bowing that may occur at a relatively slow speed as in the accompaniment of a Haydn symphony, at a faster speed as in a Mendelssohn scherzo, or at a glittering virtuoso speed as in Popper's *Elfentanz*. The music calls for short but ringing sounds, which the performer creates by dropping the bow on to the string and letting it bounce off. The bow is made of elastic wood and tightened hair, which allows it to rebound easily if it receives the right impulse at a particular time and distance. This process happens about twelve hundred times during the few minutes it takes to perform the second movement of Elgar's Cello Concerto!

How do cellists use their right arm to generate this type of bowing and control it at any speed? What do they do differently when playing a slower or faster spiccato, and how do they change between different speeds? Playing spiccato with ease is difficult and teaching it is a challenge. Pedagogical texts by Maurice Eisenberg, Rudolf Matz, Gerhard Mantel and Louis Potter focus almost solely on the fingers and hand. However, few of these teachers look at the movement of the whole arm and none address the transition from a slow to a fast spiccato. We took a scientific approach to the problem, looking at

Photo: Interlochen Center for the Arts

**FIGURE 1** light-emitting diodes on the cellist's right side allowed scientists to analyse the angles created at the shoulder, elbow and wrist during spiccato playing




the movement of the arm and the interaction of its segments as the cellist plays spiccato, accelerating rhythmically from slow to fast.

There have been few studies on highly skilled movement that focus on the coordination of entire limb segment patterns. How do we select certain movements when, for example, we are faced with a task such as moving a fingertip a few inches? This can be achieved with an infinite number of combinations of knuckle, wrist, elbow and shoulder movements. Work by D.A. Rosenbaum and his colleagues describes how participants chose the segments of their arms to fit optimally with a given task. That is, they made fast, small movements with only the finger; slightly slower, wider ones with the hand; and slow, large ones with the forearm. They solved the tasks most comfortably by matching frequency and amplitude with their arm segments. An exercise such as moving a finger can be performed easily without much practice and with minimum use of energy. Playing spiccato cannot not be learned as rapidly or as easily.

When performing a spiccato stroke the bow comes from the air, touches the string and bounces off into the air. The bow describes an arc and contacts the string on the bottom of the half circle, approaching and leaving the string on a tangent, not vertically. Spiccato consists of a series of repetitive oscillating movements of the multi-jointed arm, which fling the bow bouncing on to the string. As the arm swings from the shoulder it forms a natural pendulum. We can use this property in two ways: to create a half circle at the bottom of the swing at the bow hand, and to create momentum. If the bow arm pendulum gets an impulse to swing away from the body it will return passively by gravity. Taking advantage of these properties is the basis for effortless playing.

When we look more closely at this swinging movement we see that the bow arm can generate three pendulums: the first as the whole arm swings from the shoulder, the second as the forearm swings from the elbow and the third as the hand swings from the wrist.

To play spiccato the arm is turned slightly inwards and the bow leaves the string on both up bow and down bow, changing direction in the air. Since the joints can be locked or mobile, the muscles involved can be tight or flexible. They absorb the impact of the hit and use it for a new impulse. The swinging away from the body, the down bow, can be the driving force, while the dropping back of the up bow is able to utilise gravity passively.

### Experimental study

In the motor laboratory of Indiana University Psychology Department, we closely examined the bow arms of eight cellists – two professionals and six advanced students – as they accelerated from a slow to a fast spiccato. Did they, like the participants in Rosenbaum's study, select different arm segments to fit optimally with the frequency and amplitude of the movement? We were also eager to see whether parts of the arm were immobile or some of the joints locked, and whether all the cellists solved the task in a similar way.

Each of the cellists performed the spiccato example (above left) five times. This required them to increase the speed of the spiccato from 4 to 6, 8, 12 then 16 strokes or bounces per bar, at a constant speed of ♩ = 80. Each trial took approximately eight seconds.

To study the motion of the bow arm we monitored the upper extremities of the cellist and the bow using an OPTOTRAK 3-D Motion Analysis System. Three infrared-sensitive cameras tracked the movements of six infrared light-emitting diodes attached to right side of the cellist at the shoulder, elbow, wrist, fourth-finger knuckle, neck and waist (see figure 2). The data was collected at 150Hz, or 150 frames per second, which made it possible to ▸

**FIGURE 2** the moveme of the hand during spiccato. All eight cellists performed the task in a similar way, with the strokes becomir smaller as the spiccato accelerates

Figure 2

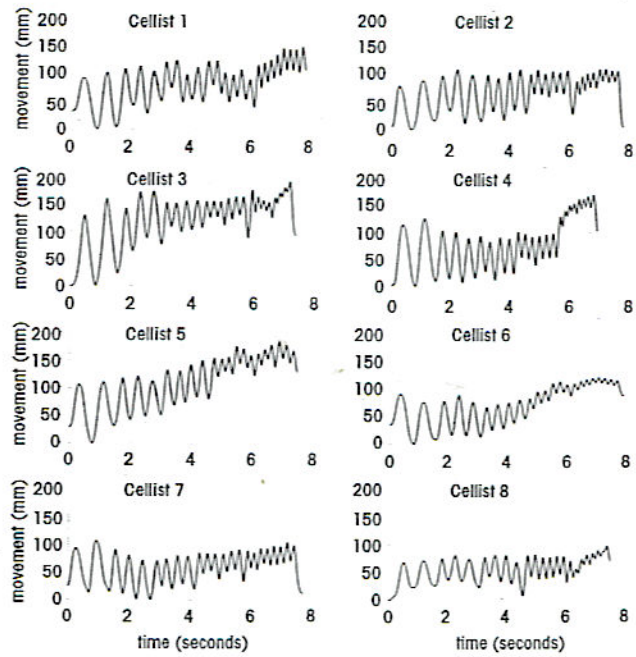


Figure 3: professional

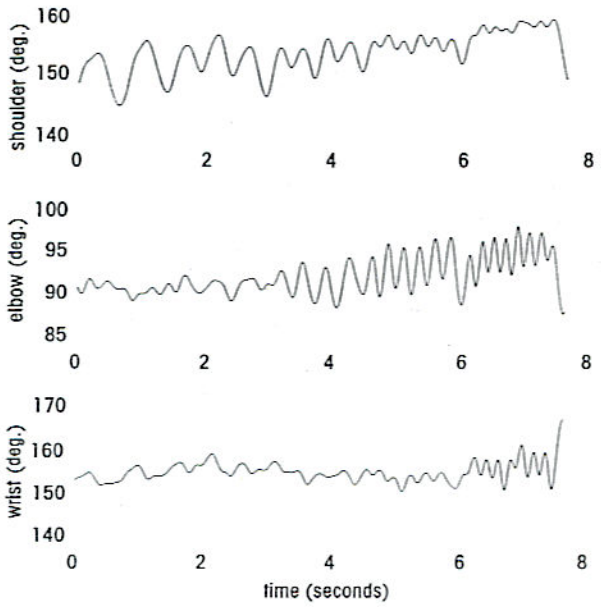
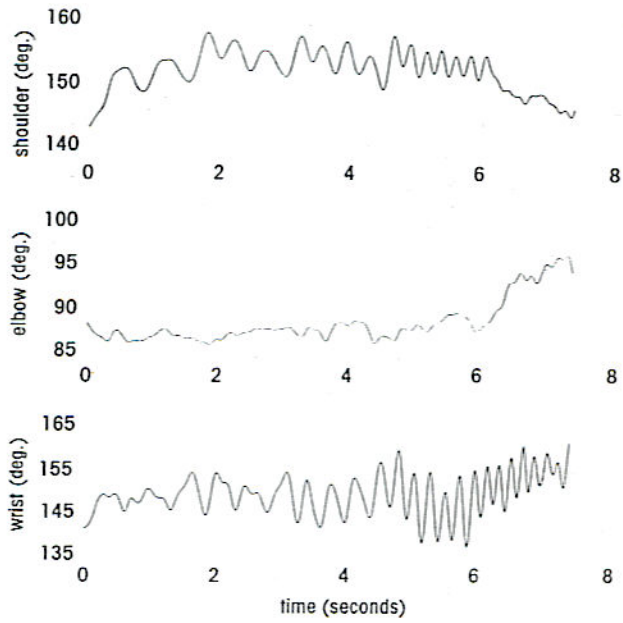



Figure 4: student




examine every aspect of the movements. All trials were video recorded for future examination.

Figure 2 clearly shows that, when we look only at the hand, the eight cellists performed the same task in a similar way. The curves represent the movement of the hand marker (the diode on the hand) as it swings back and forth, with down bows indicated by upward lines. We can see that the larger strokes become smaller and the wider spaces become closer as the spiccato increases in speed. All eight cellists reproduced the task reliably from trial to trial.

When we look at the whole arm by observing the markers on the upper arm, forearm and hand, we see interesting differences. Figures 3 and 4 compare the eight-second trial of a professional cellist with that of a student. The professional moves every part of their arm throughout the trial, while the student sometimes locks different segments. Figure 3 shows that the professional's upper arm (shoulder marker) stays mobile and the excursions become smaller. The movement of the forearm (elbow marker) increases and the bow hand (wrist marker) becomes more articulated with the increase in speed.

In figure 4, however, we see that the student loses the shoulder action with the increase in speed. They do not use any distinct elbow action but articulate the wrist highly, even more so as the speed increases. When we look at the curves generated by all eight cellists we find that four of them keep all their joints free and mobile, while the others stiffen their shoulder or elbow while they activate the wrist.

Figure 5 shows the angles of the joints at the shoulder, elbow and wrist at 4, 6, 8, 12 and 16 strokes per bar. The results were averaged across the different trials of each cellist.

The movement of the upper arm (angle at the shoulder joint) decreases in six of the eight cellists. The movement of the forearm from the elbow joint stays strong or increases in four cellists but locks or hardly moves in the others. The movement of the hand (angle at the wrist) increases or stays strong. We see a dominant wrist movement especially when the shoulder or elbow joints are locked.

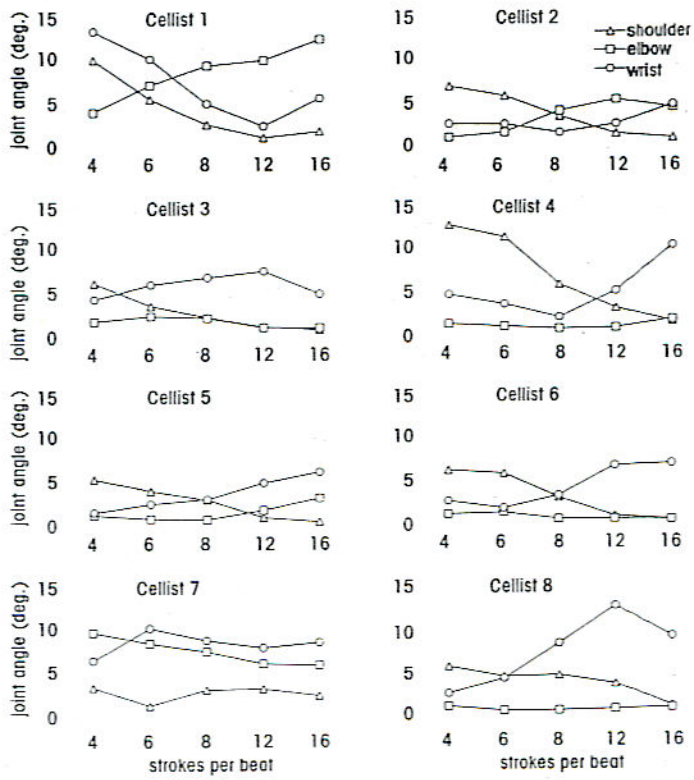
An interesting aspect of the movements is the generation of velocity in the angles of shoulder, elbow and wrist. Figures 6 and 7 compare the velocity graphs of a professional player and a student. The tips of the curves represent the fastest points, the middle of the stroke, where the bow hits the string. The bow changes occur at the crossing of the zero line, with the down bows above the line and the up bows below. Each bar is marked with a bracket.

As the strokes become faster the professional player increases both elbow and wrist velocity but decreases shoulder velocity. The student, however, first increases the shoulder movement and then stops it; the elbow is irregular and inactive while the wrist is enormously activated. Both players use higher velocity on the first note of each rhythmical group. Figures 6 and 7 both begin with two loops over the zero line (representing the first set of four strokes) then three loops (the next set of six strokes) then four loops et cetera, each set 'belonging together'. The graphs therefore depict the mental picture of the players' musical intention. That the down bows have slightly higher velocity than the upbows indicates that the cellists use more energy for the movement away from the body and let the bow return more passively, an energy-saving device. ▸

**FIGURES 3 AND 4**
a comparison of the arm movements of a professional player with those of a student. While the professional moves every part of their arm throughout the trial, the student's shoulder action diminishes, there is no distinct elbow action and the wrist is highly articulated

**FIGURE 5** the angles at the shoulder, wrist and elbow during spiccato playing. A dominant wrist movement is more likely to occur when the shoulder is locked

Figure 5




**FIGURES 6 AND 7** the generation of velocity in the angles of shoulder, elbow and wrist. As the strokes become faster the professional player decreases shoulder velocity, while the student eventually stops it, making the wrist enormously active. In both players the highest velocity is on the down bow (above the line) and on the first note in each bar

Figure 6: professional

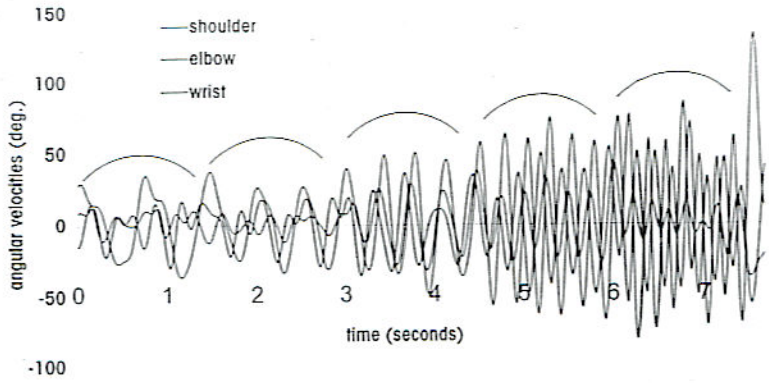
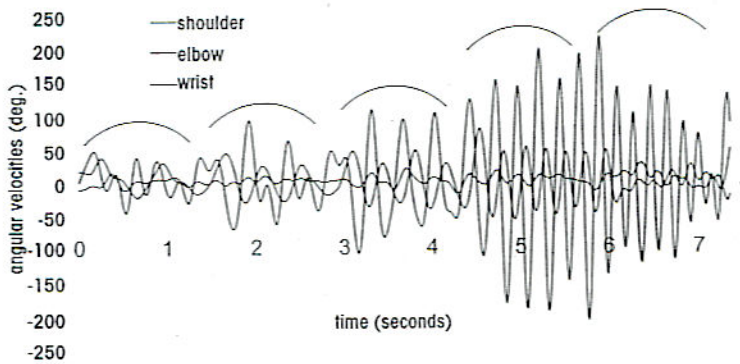



Figure 7: student




Figures 8 and 9 present composite pictures of an entire spiccato trial, with the shoulder angles plotted versus the elbow angles. The professional player transforms vertical shoulder loops into wider, almost horizontal elbow loops, and finally into smaller horizontal elbow loops. The student transforms vertical shoulder loops into smaller loops and uses no elbow loops for the rest of the trial. These graphs may give us a glimpse into the intricate planning of the entire movement series as spiccato is generated and accelerated.

### Players' solutions

Some of the above solutions to spiccato production are common to all cellists and some are different for individual players. Rosenbaum et al. showed that people choose certain arm segments to fit different tasks, but in their set-up the participants could choose to move only one segment – the finger, the hand or the arm. In our experiment the players were free to use every part of the arm. Some made perfect use of the principle of the 'kinematic chain' (Guiard, 1988). According to this principle the proximal motor, the shoulder, affects the more distal motor, the elbow, which in turn affects the most distal motor, the wrist. The cellists who did not block the movement in their shoulder or elbow joints did not co-activate muscle groups to stop their joints from moving.

Every cellist accomplished the speed-ups but only half used all their arm joints at all speeds. The others locked their shoulder or elbow joints when 'switching gait' to the new, faster spiccato. All eight cellists took advantage of the pendulum principle. That is, they lifted the arm sideways for the down bows and let the up bows rebound passively using gravity. The down bows had more velocity than the up bows and the graphs show smooth curves, which means that the players did not stop the ▸

motion anywhere, neither on the string nor in the air between strokes. The acceleration of the spiccato stroke shows a planned movement strategy mirroring the players' intentions: each new group of 4, 6, 8, 12 and 16 notes was initiated by a stronger and faster down bow, while the remaining notes followed with no visible effort until a new, faster group was initiated with another strong down bow.

The main difference between players occurred in the transitions from slower to faster spiccato. The cellists who blocked the mobility of their shoulder or elbow joints activated their wrist disproportionately. This could exert an extraordinary amount of strain on the wrist. In a task as formidable as playing the second movement of the Elgar Concerto or Popper's *Elfentanz*, this strain could render countless hours of practice futile.

**Practising tips**

The following suggestions for practising spiccato on one string with one bounce per bow are based on the principle that spiccato is a series of pendulums.

Hold the bow with the least amount of pressure so that the hand can be sensitive to the elasticity of the bow stick. Any pressure from the thumb and fingers will stiffen the wrist and prevent the arm movement from travelling undisturbed into the hand.

**Medium-slow spiccato** Swing the whole arm from the shoulder while it is slightly turned inwards and bent as if you were playing in the lower third of the bow. Choose a tempo where you can feel the momentum carry the arm back and forth. The impulse comes from the shoulder muscles as if you were kicking your elbow sideways. The bow will touch the string in the first third of the bow with a relatively broad stroke, and there is no stop in the air. You can increase the speed of this stroke by diminishing the arm movement and moving the contact point of the bow on the string towards the balance point of the bow. Practise groups of two, three and four pendulums, each consisting of a down bow and an up bow at around ♩= 60. When playing the groups of two, feel the impulse on the down bow swing and the release in the dropping of the arm during the up bow. For the groups of three think two triplets and swing the arm a little more on the down bow of the first triplet and the up bow of the second triplet. When playing groups of four the swing of the arm should be roughly half as wide as for groups of two and the elbow should be slightly further away from the body.

**Fast spiccato** It is impossible to practise fast spiccato slowly. Suspend the upper arm and let the forearm hang slightly turned inward. If you push the forearm it will swing passively back to you with a much smaller and faster pendulum than that of the whole arm. You will see only a very small movement in the elbow joint and a minute forward action in the upper arm. Drop the bow on the string and let it rebound near the middle of the bow. Feel the ease and speed of the pendulum while the bow bounces and rebounds. Practise in groups of two, three and four pendulums, taking time in between and not forcing the bow to jump faster than it will easily do. If you initially let the bow jump quite high, this will slow down the process so that the hand can feel the elasticity of the bow. For faster spiccato the bow will stay closer to the string.

**Very fast spiccato** If you shake your whole arm as if you were shivering, your hand will swing from the wrist creating an even smaller and faster pendulum. The arm should rotate inward slightly and the hand should swing forward and backward equally. The bow will barely leave the string.

In his Essay on the Fingering and Bowing of the Violoncello (p.156), Jean-Louis Duport writes: 'I have always perfectly felt these movements when playing on the violoncello, but I should be nearly as much embarrassed to analyse them as to describe the movements of my tongue when I speak.' All we teachers can do is try to verbalise our muscular sensations and hope that students will be able to transfer the images into movements that fit their physical make-up and their own musical intentions. ■

Figure 8: professional

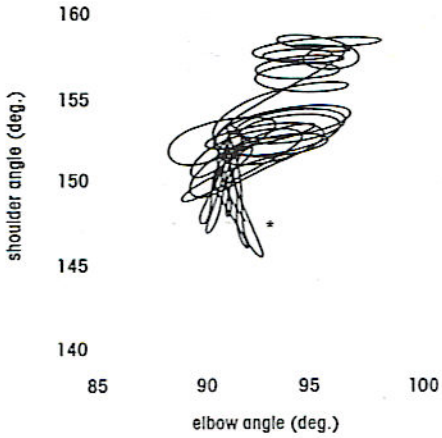
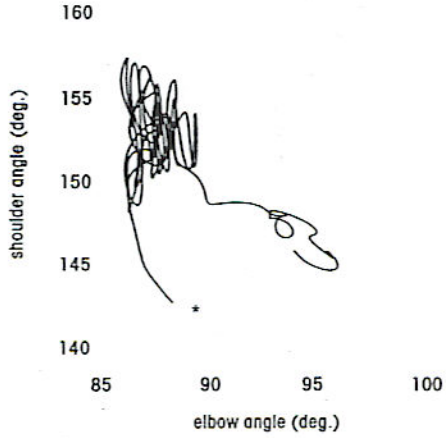



Figure 9: student




**FIGURES 8 AND 9** composite pictures of the spiccato trial. The professional player transforms vertical shoulder loops into wider, horizontal elbow loops; the student begins with vertical shoulder loops then uses no elbow loops for the rest of the trial