*Note: Supporting narrated video (NV) demonstrations, high-speed video (HSV) clips, and technical proofs (TP) can be accessed and viewed online at **billiards.colostate.edu**. The reference numbers used in the article help you locate the resources on the website. If you have a slow or inconvenient Internet connection, you might want to view the resources from a CD-ROM or DVD. See the website for details.*

This is the eleventh article in my series dealing with throw and English effects. If you are tired of reading about throw, don't despair ... I'm almost done. I'll conclude next month with my final article in the series. So far, I've looked at basic terminology, examples of where throw can help you or hurt you in game situations, the effects of cut angle and speed, the effects of follow and draw, spin-induced throw, the difference between inside and outside English, the combination of spin- and cut-induced throw effects, spin transfer, and the big picture of squirt, swerve and throw. If you want to refer back to any of my past articles, they are all available on my website (*billiards.colostate.edu*).

To refresh your memory, **throw** is change in **object ball (OB)** direction due to sideways forces between the **cue ball (CB)** and object ball during impact. **NV 4.15, 4.16, 7.5, 7.6, and A.21** show examples of both **cut-induced throw** (**CIT**) and **spin-induced throw** (**SIT**). When using English, in addition to understanding throw, it is also important to understand the effects of squirt (see **NV 4.13** and **NV A.17**) and swerve (see **NV 4.14** and **NV 7.12**). See the video demos and last month's article for illustrations and more information.

normal video

NV 4.13 – Squirt due to high speed English
NV 4.14 – English swerve due to an elevated cue
NV 4.15 – Using throw to make a partially blocked shot
NV 4.16 – Over-cutting a cut shot to compensate for throw
NV 7.5 – Frozen ball throw
NV 7.6 – Frozen cue-ball throw
NV 7.12 – Small-curve massé shot
NV A.17 – English deflection (squirt) vs. speed
NV A.21 – Bank shot using throw and spin transfer

In this article, I wish to summarize many of the conclusions and results from the past ten articles as a culminating reference. Because there is so much terminology in this article, I though I would first summarize definitions for many of the important terms:

cling: excessive friction and throw caused by non-ideal surface conditions at the point of contact between two balls (e.g., a chalk smudge).

cut-induced throw (CIT): throw caused by a cut angle.

English: sidespin imparted to the CB by hitting the CB left or right of center.

gearing outside English: the amount of outside English that results in no sliding between the CB and OB during contact. Instead, during contact, the CB rolls on the OB as if the two balls were like meshing gears. The result is no throw.

impact line (AKA **line-of-centers**): the imaginary line through the CB and OB centers at impact. The OB moves along this line after impact (unless there is throw).

inside English (IE): English created by hitting the CB on the side towards the direction of the shot (i.e. on the "inside" of the CB). For example, when the CB strikes an OB on the left side, creating a cut shot to the right, right sidespin would be called "inside English." Illustrations can be found in my January '07 article.

outside English (OE): English created by hitting the CB on the side away from the direction of the shot (i.e. on the "outside" of the CB). For example, when the CB strikes an OB on the left side, creating a cut shot to the right, left sidespin would be called "outside English." Illustrations can be found in my January '07 article.

percentage English: amount of sidespin applied to the CB, specified as a percentage of the maximum possible amount occurring on the verge of a miscue. For a well-chalked, well-shaped tip, the maximum amount of cue tip offset possible (before miscue) is about half the CB's radius. See my July '06 article for illustrations and for explanations of how this relates to "tips of English."

spin-induced throw (SIT): throw caused by CB English.

squirt (AKA **CB deflection**): angular displacement of the CB path away from the cue stick stroking direction caused by the use of English. The effect increases with the amount of English.

swerve (AKA **CB curve**): curve of the CB's path due to cue stick elevation and English.

throw: change in the OB direction (away from the impact line) due to sideways forces between the CB and OB during impact.

As we have seen throughout my throw series, the amount of throw for a given shot varies with cut angle, speed, the amount of top- or bottom-spin, and the type and amount of English. If you don't compensate your aim for squirt, swerve, and throw when playing pool (either consciously or sub-consciously), you will never be a great player. In **TP A.28**, I have created numerous plots that illustrate all of the effects related to throw. To be able to accurately compensate for throw, you must have knowledge and/or solid intuition of these effects. TP A.28 contains 36 different plots, but I will include here only a small collection that illustrates several important effects. **Diagram 1** shows how throw varies with cut angle for stun shots at various speeds. **Diagram 2** shows how throw varies with cut angle for follow or draw shots with 50% OE and various speeds. **Diagram 3** shows how throw varies with the amount of English for a full-ball hit at various speeds. And **Diagram 4** shows how throw varies with the amount and type of English for half-ball-hit follow or draw shots at various speeds.

 TP A.28 – Throw plots for all types of shots

technical proof

Below, I summarize many conclusions that can be drawn from the plots. Even if you have trouble understanding what all of the plots in **TP A.28** mean, look at them anyway. When you see how much everything varies with the type and amount of English and spin, speed, and cut angle, it will help you understand why this game can sometimes be so hard, and you can see why it takes so much practice and experience to build solid intuition for knowing how to adjust for everything.
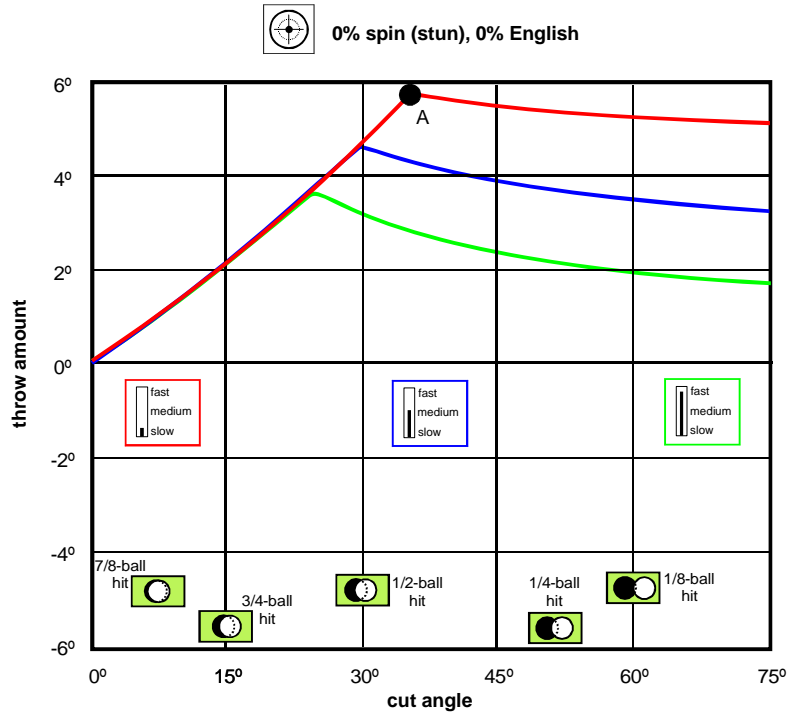
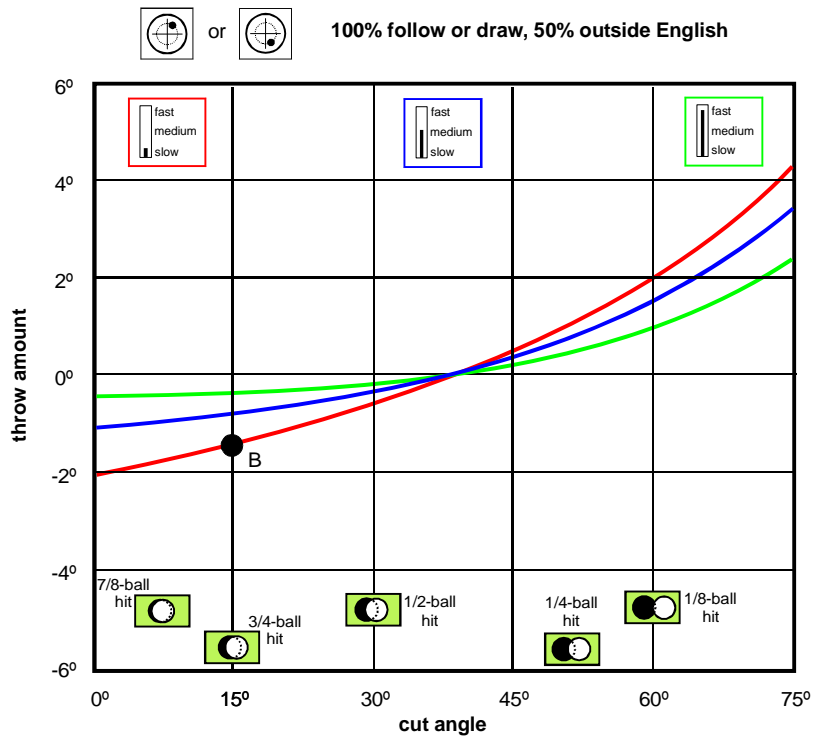**Diagram 1 Throw vs. cut angle for various speed stun shots**

Diagram 2 Throw vs. cut angle for various speed, full-spin, 50% OE shots
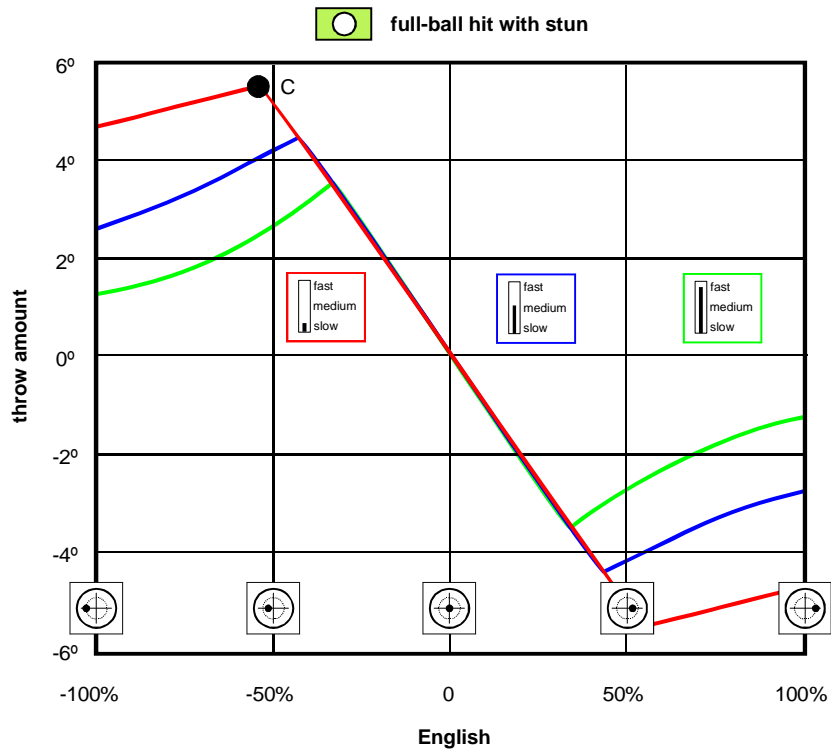
Diagram 3 Throw vs. English for various speed, full-ball hit stun shots
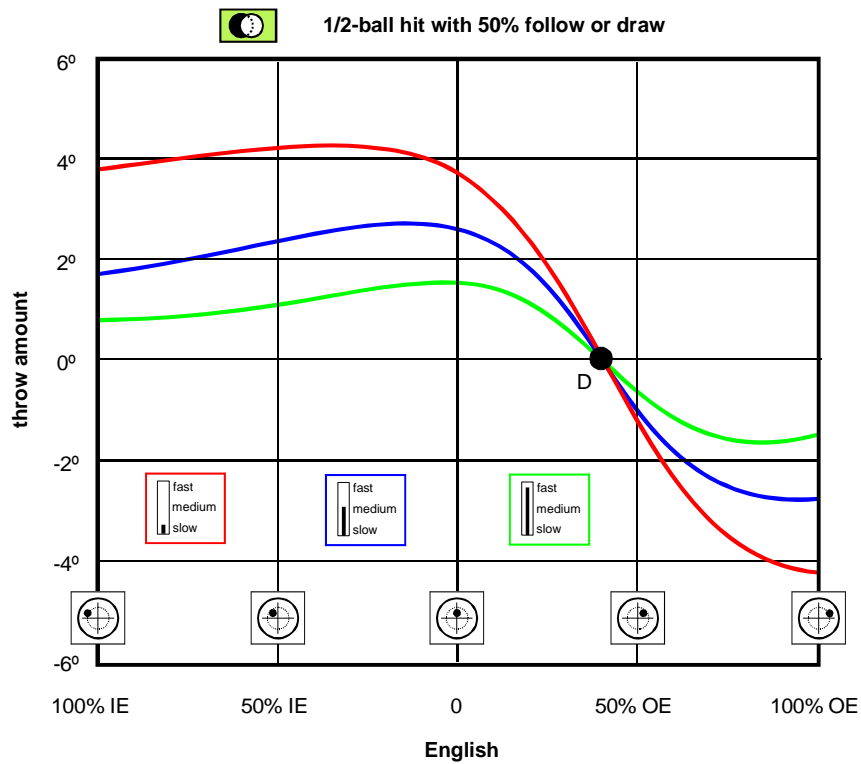

Diagram 4 Throw vs. English for various speed, 1/2-ball hit, 50% draw or follow shots

To help interpret the results in Diagrams 1 through 4, **Diagram 5** illustrates the data for the four example points (A, B, C, D) shown. Shot "A" (from Diagram 1) is a 35⁰ cut-angle stun shot with no English, resulting in 5.8⁰ of throw to the right. If you don't adjust your aim to account for throw with a slow stun shot like this, you will usually miss the shot, sometimes very badly. Shot "B" (from Diagram 2) is a 15⁰ cut-angle, 100%-follow shot with 50% OE, resulting in 1.6⁰ throw to the left. Here, the OE more than compensates for the CIT effect, resulting in SIT in the opposite direction (see my January '07 article for more information). Also, as we saw in my October '06 article, follow and draw reduce the amount of throw. Shot "C" (from Diagram 3) is a 0⁰ cut-angle (full-ball hit) stun shot with 55% left English, resulting in 5.6⁰ of throw to the right. If you want to achieve maximum throw with a full-ball hit, a slow-speed stun shot with about 50% of maximum English results in the most throw. Shot "D" (from Diagram 4) is a half-ball hit (30⁰ cut angle) shot with 50% follow and 45% OE, resulting in absolutely no throw. In this case, the OB will head exactly in the impact line (line of centers) direction. The amount of OE used here is called the "gearing" amount, because it results in the CB rolling (instead of sliding) along the OB during contact, as if the balls were gears meshing together. The amount of OE required to eliminate throw is different for every cut angle (see my January '07 article for more information)
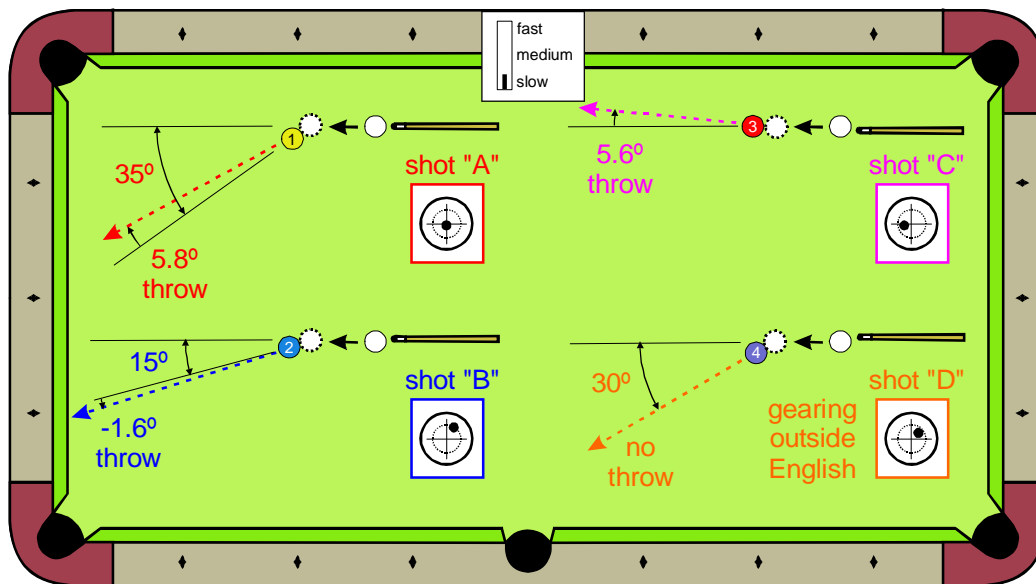

Diagram 5 Example shots for the points in Diagrams 1-4

As I described in last month's article, the amount of throw can vary significantly with ball conditions, so all of the numbers in the plots and diagrams in this article might not be the same as with the equipment you use. I've tried to use typical numbers consistent with typical conditions, but the only way to know is to shoot some test shots and calibrate your adjustments for the playing conditions (I'll discuss this further next month). Before playing important games on any equipment, you should always first get a feel for the equipment (i.e., gage the speed of the cloth, the rebound characteristics of the cushions, and the maximum amount of throw for the balls). New, clean, and smooth balls (e.g., top tournament-condition balls) will exhibit less throw than old, dirty, beat-up balls (e.g., typical bar, home-room, and pool-hall balls). Also, as described last month, balls can sometimes cling (e.g., when a chalk smudge happens to appear right at the contact point between the CB and OB).

I want to conclude this article with a summary of all of the important conclusions from all of my recent articles and from all of the plots in **TP A.28**:

- For small cut angle shots (i.e., fuller hits), the amount of CIT does not vary with shot speed, but increases with cut angle.

- For larger cut angle shots (i.e., thinner hits), the amount of CIT is significantly larger for slower speed shots as compared to faster speed shots.

- The amount of CIT decreases some with larger cut angles, but not by much (especially for slower speed shots).

- Maximum CIT occurs at close to a half-ball hit (30⁰ cut angle).

- In general, throw is larger at slower speeds, and for stun shots.

- Both follow and draw reduce throw, and they do so by the same amount.

- The largest discrepancy between throw values for stun and follow/draw shots occurs close to a half-ball hit (30⁰ cut angle).

- The difference between the throw of stun and follow/draw shots is not as great at larger cut angles.

- More English gives you more SIT only up to a point. Additional English beyond that point actually reduces the amount of SIT (i.e., more English doesn't always give you more throw).

- SIT is largest for a slow stun shot with about 50% of maximum English.

- The amount of throw can increase significantly as a small amount of English is added, especially for a stun shot.

- SIT is independent of speed (i.e., the throw is the same at all speeds) for small amounts of English.

- "Gearing" OE results in absolutely no throw. The amount of English required for "gearing" increases with cut angle. At a half-ball hit, the amount of English required is about 50%.

- At very small cut angles, IE and OE create similar amounts of throw (although, in opposite directions).

- For large cut angles, a small amount of OE can result in more throw than shots with no English.

- For large cut angles, IE results in less throw than shots with no English.

- IE increases throw at small cut angles, but actually reduces the amount of throw at larger cut angles.

- OE can cause throw in either direction depending on the amount of English and the cut angle.

- Even for large cut angle shots (thin hits), excess OE (more than the "gearing" amount) can be applied to throw the OB in the SIT direction.

- The amount of throw with IE can be much more consistent than with OE if the amount of English varies a little. In other words, the amount of throw varies more with tip placement for OE vs. IE. This might explain why some people prefer using IE on cut shots ... because they can better anticipate and adjust for the amount of throw.

Please refer to my recent articles for more information and to see examples of how all of this knowledge (and/or intuition built by years of successful experience) can be useful in your game. I hope you've been enjoying my series of articles on throw and English effects. Next month, I'll conclude the series by looking at how you might calibrate yourself for different playing conditions,

and I'll try to simplify some of the throw results a little to make it easier for you to use in your game.

Good luck with your game,
Dr. Dave

PS: I know other authors and I tend to use a lot of terminology (e.g., squirt, throw, cling, stun, impact line, 30 degree rule, etc.), and I know not all readers are totally familiar with these terms. If you ever come across a word or phrase you don't fully understand, please refer to the glossary in my book. For convenience, an expanded electronic copy is posted online in the "Instructor and Student Resources" section of my website.

Dr. Dave is a mechanical engineering professor at Colorado State University in Fort Collins, CO. He is also author of the book, DVD, and CD-ROM: "The Illustrated Principles of Pool and Billiards."