David Alciatore ("Dr. Dave") **ILLUSTRATED PRINCIPLES**

"Throw – Part III: follow and draw effects"

***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. See the website for details.*

This is the third of a series of articles I plan to write concerning "throw" effects. Two months ago, I started with some basic terminology and some examples of where throw can help you or hurt you in game situations. Last month, we looked at the effects of cut angle and speed. To refresh your memory, **throw** is change in the object ball direction due to sliding friction forces between the cue ball (CB) and object ball (OB) during impact. **NV 4.15, 4.16, 7.5, and 7.6** show examples of both **cut-induced throw** (**CIT**) and **spin-induced throw** (**SIT**). See the video demos and the previous articles for more information.


normal video

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

Last month, we saw that:

- For small cut angle shots (i.e., fuller hits), the amount of throw does not vary with shot speed, but increases with cut angle.
- For larger cut angle shots (i.e., thinner hits), the amount of throw is significantly larger for slower speed shots as compared to faster speed shots.
- The amount of throw decreases some with larger cut angles.
- Maximum throw occurs at close to a half-ball hit (30º cut angle).

In this article, we will look at the effect of draw and follow on throw. **Diagram 1** shows what the theory (**TP A.14**) predicts about the comparison of draw, follow, and stun shots. **Diagram 2** shows two example shots from the graph to help you interpret the results. Shot "A" is a 30º cut angle (half-ball hit) stun shot, and shot "B" is the same cut with draw or follow. For shot "A," the amount of throw is abut 4.1º; and for shot "B", the throw is about 0.9º. The following trends are clear from the graph (**Diagram 1**):

- Throw is large for a stun shot.
- Both follow and draw reduce throw (as compared to stun), 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 (30º cut angle).
- The difference between the throw of stun and follow/draw shots is not as great at larger cut angles.

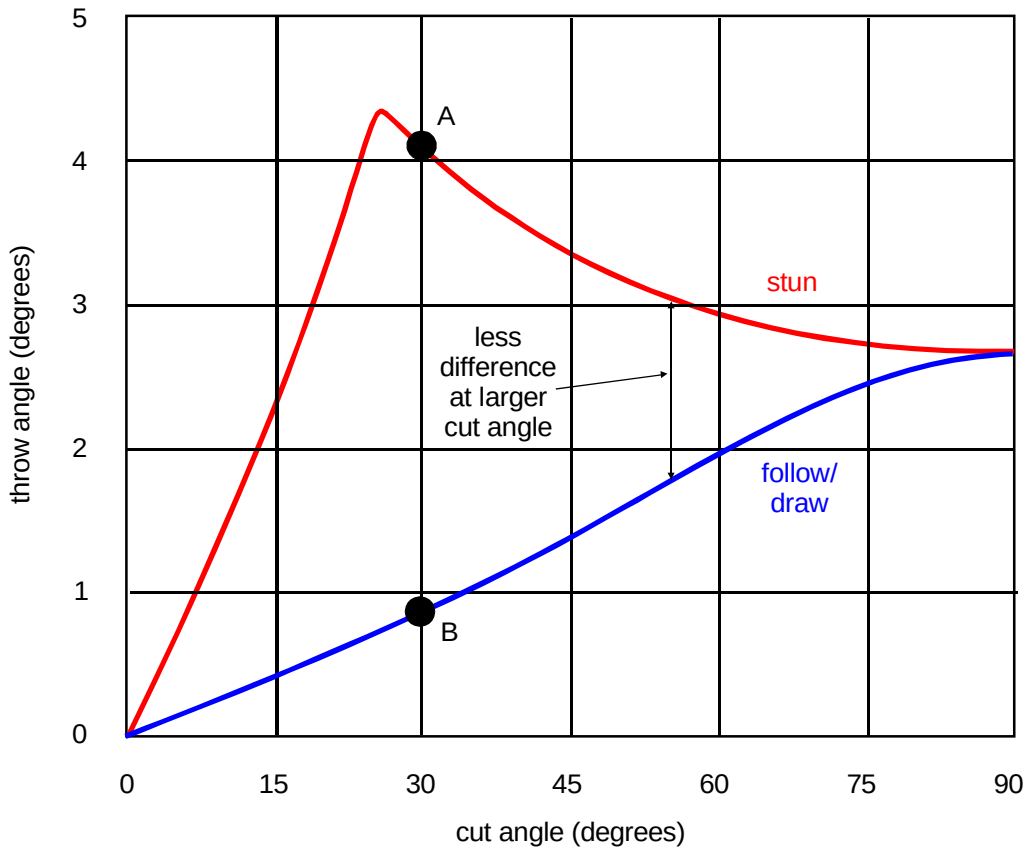

Diagram 1 **Throw angle vs. cut angle for stun. follow, and draw shots**

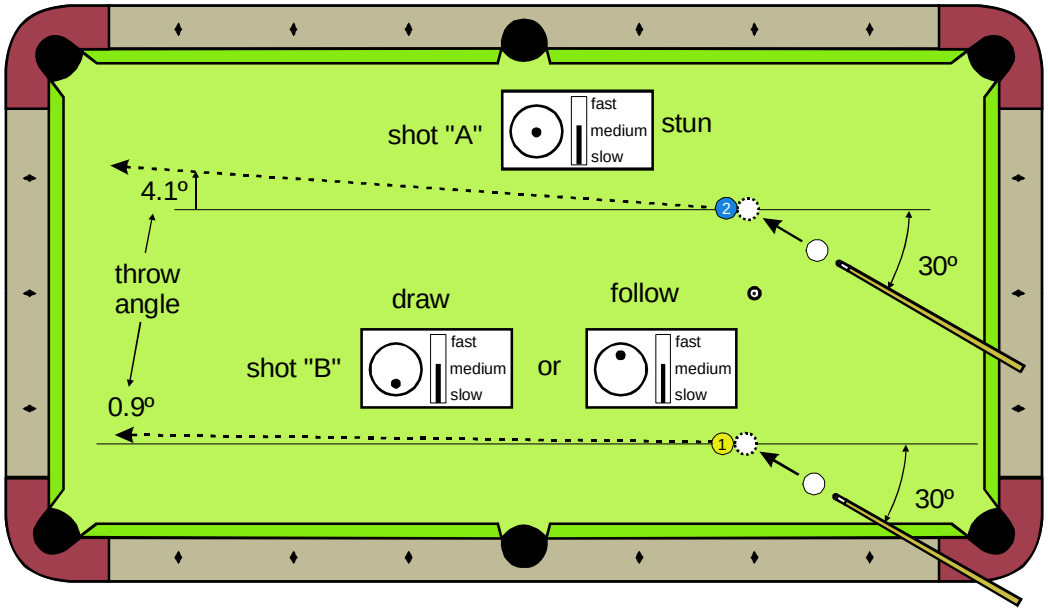

Diagram 2 **Example shots from Diagram 1**

technical proof

TP A.14 – The effects of cut angle, speed, and spin on object ball throw

To attempt to verify some of the conclusions and trends of the theoretical analysis, I decided to use and extend on an experiment proposed by Bob Jewett in his May '06 article. The setup for the extended experiment is shown in **Diagram 3**. There is a 1/4" gap between the CB and 1-ball, and the line through their centers is along the center of the table. The gap allows you to get a clean hit of the CB without a push or double hit. The idea of the experiment is to try stun, follow, and draw shots at each of the two cut angles to see how the amount of throw differs among the shot types. If you try this experiment yourself (which I highly recommend, even if you only try a few attempts of each type of shot), you should place adhesive hole-reinforcement labels ("little white donuts") for the CB and 1-ball and tap the balls into place to help ensure accurate placement for each shot attempt. Also, it is best if you can use a camera (or a trusty friend) to record where the 1-ball hits the head rail, so you can concentrate on your aim and stroke. The "rail ruler" under "templates" in the "Instructor and Student Resources" section of my website can help you get accurate results. The exact angles of the two shots aren't as important as making sure your aim is consistent for every attempt. You can place balls or pieces of chalk along the side rail to serve as aim points. I used the "cut angle template" (also on the website) to create 30º and 45º aiming lines. Although, because of the gap between the balls, the actual cut angles are slightly more (especially with the larger cut angle). But again, we don't care so much about exact cut or throw amounts. We care more about seeing the difference between stun and follow/draw, everything else remaining the same.

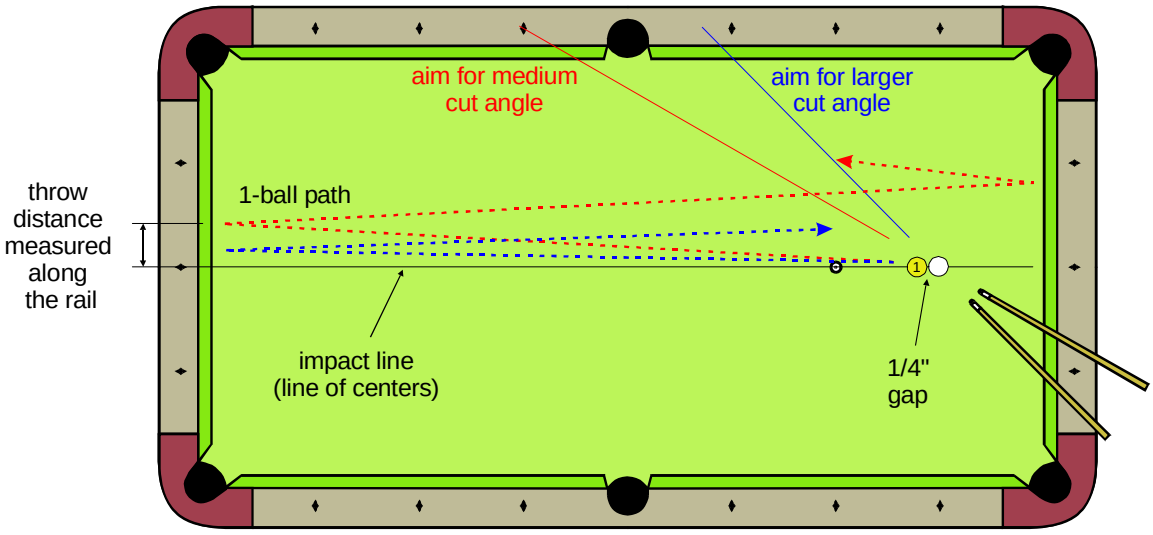

Diagram 3 Experiment to measure differences among stun, draw, and follow shots

Table 1 summarizes the results from my run of the experiment. The throw distance numbers for each "set" represent an average of four good attempts. For each set, I shot the stun, draw, and follow shots for each cut angle. If the speed of an attempt was off, or if I felt my stroke or aim was not good, I would redo the attempt. So **Table 1** represents lots of shot attempts. **Diagram 3** shows the amount of OB (1-ball) travel I strived for on each shot attempt to ensure consistent speed. The travel distance is less for the larger cut angle because the OB picks up less speed from the CB for the same stroke speed. If the final 1-ball location were off by more than about a foot, I would redo the attempt. As we saw last month, shot speed can have a dramatic effect on the amount of throw. If you try this experiment, you must be very careful with cue tip placement. Any slight unintentional and inconsistent side English can corrupt your results. Also, you should

be consistent with the amount of draw or follow you apply. I used close to maximum tip offset (with the cue tip center aimed at the red circle on an Elephant Practice Ball) on every shot.

My results for the medium cut shot agree with the theory and with the conclusions Bob presented in his article. The amounts of throw for the follow and draw shots were practically identical and much less than that observed for the stun shot. The larger cut angle shot helped verify the other trend in **Diagram 1** concerning how the throw amounts change at larger cut angles. The data agrees with the trend in the graph: the difference between the throw for stun vs. follow/draw shots was not as large at the larger cut angle. The results were also very repeatable for all shots (i.e., the numbers did not change much from one set of shots to another).

Again, the point of this experiment is not to measure exact throw angles (as with the experiments I described last month), but to see the difference between stun, follow, and draw shots. Because of the gap between the balls, the actual throw values aren't so useful because the CB is being cut to the left some, and by different amounts for each cut angle. However, the comparison between stun and follow/draw is still clear and supports the theoretical results.

Tabel 1 Throw distances (inches) for stun, draw, and follow shots

set	medium cut angle			larger cut angle		
	stun	draw	follow	stun	draw	follow
1	3.9	0.9	0.8	1.7	0.6	0.4
2	3.7	0.7	0.9	1.2	0.6	0.6
3	3.4	0.7	0.8	1.4	0.5	0.5
4	4.0	0.7	0.7	1.5	0.5	0.5
5	4.5	0.7	0.7	1.8	0.4	0.5

I hope you are enjoying and learning from my series of articles dealing with throw. If you have been missing some slow cut shots (especially with stun), and have been more accurate with faster follow and draw cut shots, throw effects might be part of the explanation. Next month, we'll look at spin-induced throw (SIT) in detail.

Good luck with your game,
Dr. Dave

PS:

- If you want to refer back to any of my previous articles and resources, you can access them online at ***billiards.colostate.edu***.

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