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# Systematic Snooker Skills Test to Analyze Player Performance Systematic Snooker Skills Test to Analyze Player Performance

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by

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# Systematic Snooker Skills Test to Analyze Player Performance

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#### ABSTRACT

The process of rigorous training and coaching is one that is essential to any sports player aiming to develop their abilities further. From the novice player through to professional athletes, it is vital to maintain and assess their level of performance in order to progress to a higher standard. However, traditional practice routines can often be non-strategic and devised with an "ad-hoc" approach. In order for a training regime to be beneficial to a player, methods to examine a player's performance are desirable and can offer quantifiable feedback that will help the player to understand their current weaknesses and provide a benchmark to improve upon.

This article focuses on the introduction of a systematic skills test. We assess the fundamental physics of snooker and from this we identify a set of key skills that characterises the basis of all snooker shots. We present 5 snooker tests that can be used to quantify the performance of these key skills. This allows us to analyse snooker players in an objective manner based on their level of ability for each key skill. The article concludes with a user study that assesses the performance of novice, intermediate and professional players when performing our proposed snooker skills test, which demonstrates the ability to make accurate comparison between players of different ability.

Key words: Ball Spin, Deterministic Model, Snooker, Physics, Skills Testing

# INTRODUCTION

The essence of the game of snooker is to strike the cue ball with accuracy and power to achieve the desired outcome of the shot. There are many possible desirable outcomes, depending on the situation presenting itself to the player.

Reviewers:

Christian Dawson (Loughborough University, UK) Trevor Ringrose (Cranfield University, UK)

- To pot a ball into a pocket
- To leave an opponent snookered
- To deliver the cue ball and/or object ball to a safe position
- To escape from a snooker or a difficult position
- To leave the cue ball in a favourable position for the next shot

Despite these many outcomes, the only control that the snooker player has is obtained during the very short contact between the cue tip and the cue ball. Many coaches, players and writers have explored what constitutes the skills that a snooker player must possess to play the game. At an introductory level, a common consensus is that players must have good command of the basic skills, namely the bridge arm, the cue arm, the grip and the stance. However, even at this level, it is evident that not all the top players use the same grip; various players at the top of the game use grips involving the thumb and two, three or four fingers in contact with the cue. Also, there are considerable variations in stance and bridge arm even amongst the best professionals. In common with many other sports, it is clear that snooker players can play successfully even without sticking rigidly to what some coaches describe as 'the basics'. Intermediate level skills in snooker include [1]:

- A good, straight and repeatable cue action
- A method and routine in preparation for every shot so that the player is in control
- Being able to pot balls into the pockets at distance and at various angles
- A reliable and effective break-off shot and safety game
- Being able to employ top spin, stun and screw to control the cue ball
- Using the rest for a variety of shots when necessary
- Using snookers to put your opponent in trouble

A common practice routine in snooker usually involves setting up a scenario on the table and consists of a player potting balls in the manner of a break. An example of the set-up for a typical practice routine is shown in Figure 1. Similarly, it is possible to set up scenarios in which the intention is to obtain a snooker or a good safety shot.



Figure 1. An example of a scenario-based practice routine The objective is to pot 15 reds and colours followed by the balls yellow to black.

In traditional coaching, the snooker coach has a one-to-one session with the player being coached. At a novice level, the coaching will introduce the areas of stance, grip, the bridge arm and the cue arm. As the player progresses to intermediate level, all snooker coaches will spend considerable time assessing and instructing the player on his/her cue action; this is a fundamental pre-requisite for successful snooker; the ability to deliver the cue repeatedly in a straight line is of over-riding and continuing importance at all levels of the game. At the intermediate level, it is, sooner or later, necessary to introduce the idea of cue-ball control. This is achieved by striking the cue ball at various positions; the cue tip can set the ball spinning to give various combinations of top spin, back spin and side spin. (Figure 2)



Figure 2. Striking the cue ball at various positions to produce back/top spin and side spin

The black cross indicates positions of cue striking.

Clearly, there are various degrees and combinations of spin available by altering the striking point on the ball and the cue speed at contact. As players progress to the advanced level, much of the subtlety in the game is produced by fine control of the power in the shot and the spin imparted to the cue ball. Traditional snooker coaching by experienced players and qualified coaches is very effective in developing the skills required in snooker players since the coach can give individual feedback and advice immediately, thus maximising the impact of the session. Experienced coaches know what to look out for and can spot errors easily, especially at the introductory and intermediate levels. The coaching sessions can be individually-tailored to concentrate attention on weaknesses and thereby making them effective and value-for-money. The disadvantages are that the sessions are time-consuming for the coach and he is restricted to dealing with just one player at a time. The coach needs to observe the player very carefully, taking in a myriad of detail about the stance, grip, cue action, drill, body and head movements, the result of the shot(s), the reason(s) for any failures as well as making a mental note of the advice he will give as feedback. The demands on the coach are therefore just as high as, if not higher than, those on the player. A major drawback is that the feedback provided by the coach tends to be subjective in nature due to the difficulty of observing and analysing fine levels of detail in long practice routines. Video recording has been used to assist in snooker coaching; this helps with reducing the demands

on the coach and enables the action to be replayed as many times as necessary and in slowmotion if required. Also, some biomechanical analysis can be introduced by the use of suitable video analysis software; for example [2].

Measuring the ability of a player is a desirable tool both as a player's point of view, for reviewing their own development within the game and also from a coaching perspective, for identifying strengths and weaknesses. Fundamentally, it allows us to analyse and compare the ability between players. There are several approaches to measuring performance within sport. McHale et al. [3] developed a rating system for soccer players known as the EA Sports Player Performance Index. Given a pre-defined set of stats (e.g., number of goals scored, successful passes etc.), they used regression analysis to derive a single score for each player. The problem with such a method is that it does not scale well within a coaching environment (i.e., outside a real match scenario) where such statistics are not generally well-defined or collected. A widely recognised set of snooker tests is provided by the World Professional Billiards and Snooker Association (WPBSA) [1] which are currently used and practised by many coaches worldwide. The system introduces a red to black ball (beginners to advanced) grading scheme consisting of 5 snooker tests with increasing difficulty that must be completed using 3 or less lives. Similarly, the Player Ability Test (PAT) by Hein [4] proposes a similar set of modular exercises to help players monitor their progress and diagnose their own performance. However, such tests appear to be designed in an 'ad-hoc' manner in which they do not justify their methods and provide no real insight as to what ability each test is assessing. This has led us to question the quality of the tests for assessing the performance of a player and its use for snooker analysis and coaching.

In this article, we develop a set of systematic snooker skills test to measure and analyse a player's performance. Based on the fundamental mechanics involved in snooker, we propose that each snooker skill, ranging from beginners (e.g., potting a ball) to more advanced skills (e.g., playing a cannon) can be decomposed as a series of key skill elements that characterises a snooker player. We describe an experimental design that allows us to objectively measure these elements. Quantifying such key skill elements is one approach for assessing the ability of a player. This work is undertaken in close collaboration with a world snooker coach and the head snooker coach of the Hong Kong Institute of Sport. We have found that our systematic skills test enables coaches to analyse a player's performance more effectively and in an objective manner over traditional coaching methods.

The remainder of the article is organised as follows. We summarise the mechanics of ball movement, snooker accuracy and ball positioning. We use this as our basis to devise a set of key skill elements that describe the principles of all snooker shots. Then, we propose a series of tests that allows us to measure these key skill elements. We perform a study to evaluate our testing scheme and report our findings.

#### FUNDAMENTAL MECHANICS OF SNOOKER

ANALYSIS OF THE CUE ACTION ON THE CUE BALL

Snooker is potentially open to analysis using the science of mechanics and dynamics. Figure 3 shows the forces acting on the snooker cue ball during the brief contact with the tip of the cue.

Despite the simplicity of the force diagram, it is unfortunate that the forces on the diagram are unknown apart from the weight of the ball (W). It is unlikely that the unknown forces will be rendered measurable in the near future, at least, not in a way that would be unobtrusive. For this reason, coaches assess their players by observation of the subsequent motion of the cue ball. Any deficiencies are shown up by a missed pot, or the cue ball

finishing in the wrong position for example. The skill of the coach then becomes diagnosing this fault in terms of the key skill elements of the shot; for example, not enough cue power, or the cue not striking the right spot on the ball. In some ways, this is similar to the method of inverse dynamics in biomechanics [5], whereby the forces acting on a system are estimated from their effects on the motion of the system.



 $\bigotimes$  Cue ball centre of mass

Figure 3. The forces acting on the cue ball during contact with the cue  $\rm F_c$  and  $\rm F_r$  are the forces exerted on the ball by the cue tip and the table respectively



Figure 4. The cue ball before and after being struck by the cue. (a) at the ball centre, (b) just below centre and (c) well below centre  $E_r$  = rotational kinetic energy,  $E_t$  = translational kinetic energy, f = fraction of energy imparted by the cue that goes into translation

It may be advantageous to consider the effect that spin has on the kinetic energy of the cue ball similar to Shepard [6]. Figure 4 shows the cue ball being struck at several locations at or below the ball's centre and imparting a total energy E to the ball. A cue ball struck at its centre will roll on the cloth without sliding. In this case the cue power (or cue speed) imparts a kinetic energy of translation to the ball, of which  $\frac{1}{2}$  is translational kinetic energy and  $\frac{2}{2}$  is rotational kinetic energy. However, the cue can also be used to impart back spin or top spin. If the ball is struck below centre, for example, the cue ball can be pushed forwards and made to slide on the cushion without any rotation or even to spin backwards. In these cases, the friction between ball and cloth will eventually ensure that the ball rolls on the cloth, but this may be after collision with the object ball. It is clear that the commonly used term 'cue power' can be interpreted as a means of controlling the resulting motion of the cue ball, using a combination of linear translation and rotational motion.

#### ANALYSIS OF SNOOKER ACCURACY

The importance of accuracy in playing any snooker shot can be judged from the geometry shown in Figure 5. In order to project an object ball at the correct angle, the cue ball must travel an initial line displaced from the centre of the object ball.



Figure 5. Diagram showing the projected trajectory between two snooker balls both of radius r during collision.

The line intersecting through both ball centres at impact gives the final direction of the object ball [7]. In snooker, we refer to each collision type using the terms full ball contact ( $\theta = 0^{\circ}$ ), a half-ball contact ( $\theta = 45^{\circ}$ ), a quarter-ball contact ( $\theta = 67.5^{\circ}$ ) and a thin cut where  $\theta = 90^{\circ}$ . Based on the geometry shown in Figure 5 we have:

$$\sin\theta = \frac{x}{2r}$$

If the offset x is incorrect by an amount dx, then the error in the angle  $\theta$  will be:

$$d\theta = \frac{dx}{2r\cos\theta}$$

The challenge in obtaining exactly the correct offset x is increased when the distance Y between the cue and object balls is larger. Hence, if we consider the line of the cue ball is uncertain by a small angular amount  $d\phi$  then we have:



 $d\theta = \frac{Yd\phi}{2r\cos\theta}$ 

Figure 6: Graph showing the increase in angular error  $d\theta$  of the object ball (in degrees) as the distance (Y) between cue ball and object ball increases and as the final angle ( $\theta$ ) of the object ball increases.

#### UNDERSTANDING BALL POSITIONING

In a game of snooker, a common term used by many coaches is "good cue ball control". By this, it is generally used in conjunction of referring to the ability of a player to place the cue ball in a particular position from any given shot. This is well sought after, as it can make the next (or further subsequent) shots easier to play; for instance by reducing the distance between cue and object ball (as described in section 1.2). From a biomechanics view, in order to predict where the cue ball will finish, it is the combination of the use of cue power and understanding the path a ball takes after collision [8]. Let us first look at the effects of ball colliding along a cushion as shown in Figure 7. A cue ball struck without any side spin will bounce off a side cushion with the angle of reflection equal to the angle of incidence, at least in principle. One of the subtleties of the game of snooker is the use of side spin on the cue ball to change the angle of reflection to achieve a good position. Check side is used by applying side spin opposing the direction of bounce on the cue ball to reduce the angle of reflection and speed after contact with the cushion. In a similar way, running side can be imparted to widen the angle by striking the cue ball along the angle direction as shown in Figure 7. Mathavan et. al. describe a different approach by analysing the change in cue ball velocities during ball to cushion contact [9].

Another collision type that needs to be understood is the paths taken during a ball-to-ball collision. During impact, a cue ball struck with centre ball will travel along a path that is perpendicular to the direction of the object ball. However, as snooker balls are not perfectly elastic, we find that the angle is not completely at right angles. By applying top spin to the ball, the rotational energy will force the cue ball to curve towards the path as shown in Figure 8, which is symmetrically identical under the effects of a screw back. A good snooker player will understand the effects of various spins during these two collision types and hence can apply the necessary spin in order to position the cue ball into a targeted area.



Figure 7. Diagram showing the effects of the angle  $\theta\,$  the cue ball takes off a cushion under various side spins



Figure 8. Diagram showing the paths of a ball to ball collision under top, no spin or back spin.

# **KEY SKILL ELEMENTS**

We propose that the following key skill elements can form a basis for testing the intermediate and advanced skills in snooker:

- Cue power control (or Cue speed)
- Cue alignment

- Use of top/back spin
- Use of side spin
- Angles

A deterministic model (Figure 9) [10] has been developed for a simple snooker potting shot, an intermediate level skill, leaving the cue ball in a good position for the next shot, another intermediate level skill. It provides an objective basis by which all important aspects of the snooker shot can be subjectively evaluated. The factors (blocks) of the deterministic model serve to describe the mechanical or mathematical relationships that govern the snooker shot. Similar models can be developed to encompass safety shots for example. It can be observed that the key skill elements are at the 5<sup>th</sup> level while the basic skills are at the 6<sup>th</sup> level in the model. The intermediate skills being tested are at the top level in Figure 9. Such



Figure 9. A deterministic model for a snooker potting shot leaving good position for the next shot

(A combination of two intermediate level skills.) In this diagram, the intermediate level skills are at the top, whereas the key skill elements are at the 5<sup>th</sup> level down and the basic skills are at the bottom (6<sup>th</sup> level).

models clearly reveal that most shots in snooker rely on combining many of the intermediate and advanced skills in order for success to be achieved. Expert players may use one or more advanced skills in executing a pot; for example, clearing a path for other balls to be potted if there are obstacle balls, and these could be analysed in a way similar to Figure 9.

We propose that the content of all snooker shots (see Figure 10) can be decomposed as a combination of key skill elements, some of which are intermediate skills and some of which are advanced skills.

Skills	Key Skill Elements of Snooker					
	Power Control	Angles	Top/Back Spin	Side Spin	Cue Alignment	
Potting	0				0	
Stun run through	О		0			
Safety	0	0		0		
Side spin avoidance					о	
Stun hold	0		0			
Cannon	0	0				
Snooker Escape		0				

Figure 10. Matrix showing the composition of snooker skills as a set of key skill elements

# METHOD

#### POWER CONTROL TEST

The ability to control the amount of power that is applied to the cue ball is perhaps one of the most fundamental skills in the game of Snooker. A novice player may concentrate purely on striking the cue ball so as to make contact with the target ball, but as they develop it is important to appreciate how the power can dramatically affect the outcome of the shot. Power can be used to control the final position of the cue ball. If a player takes a shot and applies too much or too little power, they are likely to be poorly positioned for the next shot. Likewise, the amount of power applied will also affect the result of any collisions with the other balls on the table. In order for a player to be able to maintain a high scoring break, it is crucial that they can position the ball as accurately as possible for the upcoming shot.

To assess power control, we devise a simple yet effective test that involves only the cue ball. The cue ball is placed on the brown spot to begin. The player must strike the cue ball down the table, aiming for the cue ball to stop as close to the bottom table cushion as possible as shown by the blue region in Figure 11. The distance from the cue ball to the bottom cushion is then measured. After performing the test a number of times, a mean result can be given to represent the performance of the player. The option of whether or not the cue ball is



Figure 11. Diagram showing the cue ball power test

allowed to make contact with the bottom cushion can also be introduced to provide a greater challenge.

#### ANGLES TEST

Understanding the path of a ball as a result of ball or cushion collision is necessary in many aspects of snooker. In particular, knowing the angle an object or cue ball must take in order to (say) pot a ball or escape a snooker is a vital skill in a whole range of shots. Our angles test focuses on assessing the player's ability of judging the correct angle from a ball-to-cushion scenario. Such a setup is similar to, for example, when a player is escaping a snooker. Assuming that no intentional spin is applied to the cue ball, the key skill here is the ability to judge the correct contact point along the cushion such that the cue ball bounces and falls into the target pocket. This ideal contact point can be measured. Thus, any significant deviations between the observed bounce and ideal contact point will result in the cue ball missing the target pocket. We score the player's performance by measuring this distance and how far (if) the cue ball misses the pocket.

The whole scheme is shown in the Figure 12. To support measuring where the ball makes contact with the cushion more accurately, we propose to use a camera to record each shot. These can then be examined and annotated in order to extract the required distance.



Figure 12. Diagram showing the angles test

# TOP/BACK SPIN TEST

Top or back spin can be applied to the cue ball by altering the tip height during cue-to-ball contact, striking the cue ball above the centre point will generate top spin and striking below will generate back spin. The amount of spin generated is dependent on multiple factors; the distance between the cue tip and the centre point of the cue ball on contact (striking further from the centre point generates more spin), the amount of power applied to the shot, and the quality of the cue action of the player. We consider the number of full revolutions a cue ball takes before contact with the object ball as a good quantitative measurement for the amount of back or top spin applied. In a match situation, the use of top and back spin is extremely useful in positioning the cue ball where the player desires, ready for the next shot.

In order to assess a player's ability to apply top or back spin we devise the test shown in Figure 13. In the test, the cue ball is placed in line with both the blue and the yellow spots, and a red ball is placed on the blue spot. The objective of the test is to pot the red ball into the middle pocket and to apply top or back spin such that the cue ball is also potted into one of the middle pockets; if top spin is applied the cue ball should be potted into the same pocket as the red ball, otherwise it should be potted into the opposite middle pocket. The test is assessed both by counting the number of revolutions the cue ball undertakes (more revolutions is a better result) and by whether the player manages to pot the cue ball into one of the middle pockets. As it is not possible to count the number of revolutions using a standard cue ball, the test will require a special ball where one hemisphere is white and the other is black. The number of full revolutions can be used to estimate the amount of kinetic rotational energy that the player applies to the cue ball (see Figure 4).



Figure 13. Diagram showing a variation of Top/Back spin test

#### SIDE SPIN TEST

Using side spin is an extremely difficult shot to effectively use in practice. A ball struck to either the left or right from central (side spin) will immediately move in a direction opposite to the side of ball being struck instead of the linear path the cue ball would usually take. Naturally, the more power applied means the trajectory of the ball will be forced more off line, from which is evident in a novice or beginner as a common cause for missing pots as a result of unintentional side. However, side spin is vital in many advanced shots in order to gain better position for the next shot or even to swerve around object balls. Understanding the use of side spin enables a player to be able to force an angle which under normal conditions would not be possible (i.e., playing a dead ball shot with varying power). For instance, a player may apply side spin during a safety to shot to widen the angle of reflection the cue ball takes after cushion contact to avoid colliding with an obstacle ball.

In order to evaluate a player's side spin control, we use the test as illustrated in Figure 14. The player must play the cue ball from the yellow spot along the baulk line and pot the red placed 2cm away from the middle pocket off one cushion. By striking the ball with right hand side, the player can effectively create an angle from a relatively straight path to diverge towards the middle pocket. In order to quantify this skill, we measure the distance  $\alpha$  between the cushion contact point to the baulk line and record whether the red ball is potted or not. Taking  $\alpha$  enables us to see how well the player can compensate for the change in trajectory and the pot is used to measure how much side spin the player can apply. Should the cue ball collide with the red, we observe whether the contact was ±half ball (under-cut or over-cut)



Figure 14. Diagram showing the side spin test

or whether it was a full-ball contact. Due to experimental constraints, we will report the results of this test in a separate article.

#### CUE ALIGNMENT TEST

We associate cue alignment with the ability to deliver the cue through the ball straight. Fundamentally, this is one of most basic and important aspects for a snooker player as it enables them to consistently perform shots such as potting or safety. By having good cue alignment, the trajectory variation of a repeated shot can be minimized which often corresponds to unintentional spin applied onto the cue ball when the cue is not delivered straight. Coaches would generally analyse the path the cue takes during the player's addressing stage (when the player is swinging the cue forwards and backwards) and study whether the cue and player's face are aligned. Any swinging motion to the left or right of the player shows a good indication that the cue ball will not follow the intentional trajectory. We measure the variance of this swinging off-set as a way to assess the player's alignment.

The test we use to evaluate this key skill is through the double kiss spin avoidance test as shown in Figure 15. The cue ball is played centre-ball from the brown spot down towards the blue which will then make a second contact roughly around the pink spot. We measure the player's alignment score by  $\alpha$ , which is computed by taking the distance between the position where the blue collides with the bottom cushion and the mid-point of this table edge. Additionally, we present a scoring system such that 1 is given if the double kiss is full-ball, 0.5 if the contact is half-ball and 0.25 for a quarter-ball. Measuring the angle of collision will enable us to determine the contact type. However, due to the limitations with standard

measuring tools and our focus on making the test feasible, this will be judged either by the player and/or an examiner. With experience, this can often be observed easily by eye. A half or quarter ball contact can be the result of two things, a)  $\alpha$  is small and the white ball is delivered straight, or b) the blue hits near the mid-point of the bottom cushion ( $\alpha \approx 0$ ) and there has been some unintentional side on the white. The study of the cue alignment test will be the focus of our future work.



Figure 15. Diagram showing the cue alignment test

# **USER-STUDY**

# PARTICIPANTS

There were a total of 18 participants. The sample included six novice players, six intermediate players and six experts aged between 11 to 55 years old. Players were classified into the following groups based on their maximum break: Novice with a break less than 30, Intermediates scoring between 31 and 70 with Experts regularly making breaks of 71 or higher. The lead researcher contacted the participants to explain the study and potential risks along with providing written informed consent; parental consent was obtained where players were less than 18 years of age.

# EXPERIMENTAL DESIGN

In this article, we report our findings for three tests: Power test, Angles test and Back Spin test. The study involved the 18 participants to repeat each test a total of 10 times. The complete data set was collected over a 2-year period in which a large proportion of time was spent acquiring the expert players' data due to their limited availability and expensive cost. Under approval, the base for where we conducted the experiment was in Terry Griffiths' Matchroom and Creigiau Golf Club where we set up the following apparatus. For the Angles test, we placed a metre ruler

along the corresponding table edge with video footage recording the expected contact point along this cushion. A high-speed camera (200 fps) was used for the Back Spin test and a specialist half-white, half-black cue ball. Distances were measured in cm using a tape measure.

# RESULTS

We present and describe results for the power control test, the angles test and the back-spin test. Due to time constraints and availability of players, data on the remaining two tests: Cue Alignment and Side Spin is still in working progress. The results of these tests will be reported in a separate paper as part of our future work. For all tests, novice players are level 1, intermediate players are level 2 and expert players are level 3. Equations [1] - [3] have been developed in a somewhat arbitrary manner according to our experience and to generate a meaningful statistic by which to measure performance. The coefficients used may be subject to change as more is learnt about snooker player performance.

#### POWER CONTROL

Figure 16 illustrates the results for distance from the cushion from the power control test (3.1) with Figure 17 providing the players score in the same test, calculated according to

$$SCORE = 1 / (1+Distance from Cushion).$$
 [1]

distance in cm.

A numerical summary of the means and standard deviations for the players performance are provided in Table 1.

Table 1. Statistical data showing the performance of each participant in the power test. The skill level (novice, intermediate and expert) are indicated by 1-3 respectively. The means and standard deviations are taken over 10 separate tests.

Player ID	Skill	Mean Distance (cm)	Std. Dev Distance	Score	
				Mean	Std. Dev
1	1	59.55	40.68	0.038	0.058
4	1	52.20	37.04	0.029	0.019
5	1	74.95	58.43	0.024	0.020
9	1	68.45	53.96	0.053	0.086
11	1	25.85	15.99	0.091	0.147
13	1	47.10	33.19	0.031	0.020
Overall group	1	54.68	39.88	0.04	0.06
2	2	18.51	4.93	0.054	0.013
7	2	20.98	8.62	0.054	0.027
8	2	12.31	9.13	0.148	0.133
10	2	17.05	6.53	0.063	0.025
12	2	22.13	6.99	0.047	0.014
17	2	24.11	15.05	0.090	0.135
Overall group	2	19.18	8.54	0.08	0.06
3	3	10.18	2.37	0.094	0.025
6	3	9.35	2.64	0.103	0.030
14	3	8.30	2.58	0.115	0.032
15	3	8.98	2.92	0.108	0.032
16	3	8.15	2.34	0.116	0.028
18	3	9.28	2.67	0.105	0.033
Overall group	3	9.04	2.59	0.11	0.03



Figure 16. Boxplots (min, first quartile, median, third quartile, max) for the distance from the cushion (cm) in the power control test. The numbered data points indicate outliers from the main cluster.



Figure 17. Boxplots (min, first quartile, median, third quartile, max) for the score in the power control test. The numbered data points indicate outliers from the main cluster.

# ANGLES TEST

The distance from the correct bounce point was recorded as 'alpha'. Figure 18 illustrates the results for distance alpha from the angles test (3.2) with Figure 19 providing the players score in the same test, calculated according to

SCORE = 
$$k_1/(1 + alpha) + k_2^*(1 - miss) + k_3^*PotWhite$$
 [2]

(alpha in cm,  $k_1=2$ ,  $k_2=1$ ,  $k_3=3$ ) Note: alpha is negative if above point, otherwise it is positive below point along cushion PotWhite: Far Miss Left: = -1, Near Miss Left: = -0.5, Near Miss Right: = 0.5, Far Miss Right: = 1

Table 2 provides a numerical summary of the means and standard deviations for each participant.

Table 2. Statistical data showing the performance of each participant in the angles test. The skill level (novice, intermediate and expert) is indicated by 1-3 respectively. The means and standard deviations are taken over 10 separate tests.

Player ID	Skill	Mean Distance (cm)	Std. Dev Distance	Score	
·				Mean	Std. Dev
1	1	56.00	9.17	2.32	1.57
4	1	64.00	3.89	1.01	1.64
5	1	59.45	3.50	1.74	1.48
9	1	61.80	1.40	2.82	1.59
11	1	54.50	5.46	0.85	1.17
13	1	58.50	6.20	0.24	0.22
Overall group	1	59.04	4.94	1.50	1.28
2	2	43.10	9.70	2.42	1.97
7	2	44.30	9.58	2.09	1.87
8	2	47.20	12.21	1.99	1.86
10	2	48.40	10.02	2.40	2.14
12	2	43.60	9.83	2.39	2.03
17	2	41.10	7.77	1.71	1.83
Overall group	2	44.62	9.85	2.17	1.95
3	3	45.80	3.12	3.43	1.96
6	3	48.00	3.65	2.52	2.01
14	3	44.30	4.69	2.61	1.87
15	3	45.80	4.08	3.02	1.89
16	3	44.90	3.87	3.61	1.83
18	3	46.90	4.15	2.37	2.30
Overall group	3	45.95	3.93	2.93	1.98



Figure 18. Boxplots (min, first quartile, median, third quartile, max) for the distance alpha (cm) in the angles test



Figure 19. Boxplots (min, first quartile, median, third quartile, max) for the score in the angles test

#### BACK SPIN TEST

Figure 20 illustrates the number of ball revolutions from the top spin test with Figure 21 providing the players score in the same test, calculated according to:

$$SCORE = (k_1 * Revolution + k_2 * PotRed) / (k_3 * (2-PotWhite))$$
[3]

 $k_1=2$ ,  $k_2=1$ ,  $k_3=0.5$ revolution = number of revolutions of cue ball PotRed: =1 for a pot, 0 if not PotWhite: =1 for a pot, 0 if not

Table 3. Statistical data showing the performance of each participant in the back-spin test. The skill level (novice, intermediate and expert) is indicated by 1-3 respectively. The means and standard deviations are taken over 10 separate tests.

Player ID	Skill	Mean nrevs	Std. Dev nrevs	Score	
				Mean	Std. Dev
1	1	0.9	0.568	2.4	2.80
4	1	2.1	0.876	6.2	4.54
5	1	1	0.817	3.2	2.97
9	1	1.4	0.843	3.1	1.97
11	1	0.8	0.789	2	2.49
13	1	0.8	0.632	1	0.82
Overall group	1	1.17	0.75	2.98	2.60
2	2	1.5	0.707	4.4	2.84
7	2	2.5	0.527	8	3.94
8	2	1.7	0.483	3.7	1.25
10	2	1.6	0.699	5.2	2.82
12	2	2	0.471	6.6	3.10
17	2	1.5	0.707	5.5	3.10
Overall group	2	1.80	0.60	5.57	2.84
3	3	1.9	0.738	8.8	3.29
6	3	1.8	0.632	7.9	3.21
14	3	1.6	0.843	6.4	2.67
15	3	1.7	0.483	7.1	2.77
16	3	2	0.667	8.3	3.20
18	3	1.9	0.568	8.1	2.51
Overall group	3	1.82	0.66	7.77	2.94



Figure 20. Boxplots (min, first quartile, median, third quartile, max) for the number of ball revolutions in the back spin test. The numbered data points indicate outliers from the main cluster.



Figure 21. Boxplots (min, first quartile, median, third quartile, max) for the score in the top spin test. The numbered data points indicate outliers from the main cluster.

#### DISCUSSION

We have used the median to determine the player's central tendencies in our tests so far as it is least affected by any outliers that could occur. Each test showed strong correlation towards the different classification bands; where expert players in all skill tests out-performed the participants in the other categories. This suggests that our tests can effectively measure a player's performance. In general, on examining distances, we found that shot consistency (interquartile range) improved as we moved towards expert level. The scores that were generated from Eqs [1] - [3] reflected the improvement in median scores in moving from novice to expert, but the differences in interquartile range between levels tended to be reduced by this process.

Although the median provides a good overall summary on how a player performs, it is interesting to note that, in the power control test, the range of min and max scores between experts to intermediates and experts to novices differ by such a large amount. Albeit expected, we see that it can provide great insight towards identifying the technical strengths of each individual – for instance, one would say that an intermediate player would require coaching that focuses on playing a good shot (high scoring) more consistently (i.e., as performed by our expert players) in order to improve their game. Conversely, it is reasonable to say that novices need more coaching from the technical aspect of the game; for instance, stance, grip, and how they deliver the cue through the ball in order to achieve the desired effect.

The backspin test was perhaps the most difficult test undertaken due to the difficulty of ascertaining the number of revolutions of the ball. The lack of fine resolution in this measurement meant that the rotation data was deficient and might be improved by developing a better method for estimating ball revolutions. We also note that some uncertainty may be introduced in the performance score as a result of the sensitivity of the equipment (to the nearest cm). Further research on obtaining ball spin data and other spatial information using a more sophisticated video analysis method is continuing which will increase the reliability and validity of the top/back spin test, and improve the accuracy of measuring distances (for example in the angles test).

Depending on the objective for each snooker test, we weighted the measurements using the k coefficients to emphasise the ability we are assessing accordingly to the feedback of a snooker coach. For example, in the back spin test, the number of revolutions contributed more to a higher score as opposed to potting the red. In general, it is possible that our selection of the k coefficients might need to be revised in light of experience and further conversations with snooker coaches and professionals. Also, some of the measured outcomes (e.g., PotRed) might need to be looked at again to see if there is a better way of accounting for shot success. It was apparent that occasionally, some score outliers were generated as a result of our calculations.

# CONCLUSION

We have established a clear method for measuring the playing skill of snooker players over a range of ability levels from novice through to expert. The tests have established a logical and objective framework by which snooker skills can be assessed systematically. The three tests for which results are given here are merely a start; many more tests can be devised for many snooker skills required in a complete player. We hope to report the results for these in a future publication. As a future work, the process outlined in this article can be automated and extended using an image-based, computer vision system to speed up and make a more accurate assessment as described by Legg et al. [11]. This will allow us to implement our tests consistently in a number of venues. Such a system consists of using a single camera to capture the scene and a computer that processes and extracts the necessary measurements from the images. The advantage of using such a system will allow us to obtain additional information such as ball velocity and acceleration that can easily be incorporated to enhance our performance evaluation criterion. For example, ten shots on a specific test could potentially be recorded on camera and stored on the computer for analysis and scoring. The numerical scores in our tests can also be scaled to a set of convenient numbers (e.g., a 1-10 rating index) in accordance to a snooker coach's requirement. This will allow coaches and players to review their performance in a more comparative and summative manner. The visualization system presented by Hoferlin et al. [12] describes an automatic approach for measuring the number of revolutions of a half-white, half-black cue ball. We aim to make us of this technology to measure the number of revolutions in our back/top spin test in a more reliable and accurate manner. This is subject to further investigation by our team.

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