USGA Green Section

Golfers' Decision Making on the Course

Annotated Bibliography

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December 2020

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Calmeiro, L. & Tenenbaum, G (2011). Concurrent verbal protocol analysis in sport: illustration of thought processes during a golf-putting task*. Journal of Clinical Sport Psychology*, 5(3), 223-236.

Three novice and three expert golfers were used to map the thought processes while completing a putting task. Experts' think-aloud content focused on information gathering, evaluation and planning of the shot. They also associated shot planning with previous putts. By contrast, novice golfers just focused more on technical aspects of hitting a putt.

Nicholls, A. R. & Polman, R. C. J. (2008). Think aloud: Acute stress and coping strategies during golf performances. *Anxiety, Stress, & Coping*, 21(3), 283-294.

Think-aloud data were collected from five male high-school golfers over six holes. Lie of the ball, hazards, weather, club selection and hole location were frequently identified as stressors. This paper suggests that golf course conditions influence players' performance even if that is by inducing stress rather than articulated decision making.

Oliver, A., McCarthy, P. J., & Burns, L. (2020). Using a "Think Aloud" protocol to understand meta-attention in club-level golfers. *International Journal of Sport and Exercise Psychology, 1 – 14.*

Seven golfers (Handicap Index® Mean (M) = 14.43) participated in a study to understand metacognition processes of golfers playing six holes using a think-aloud protocol. They were asked to verbalize their thoughts and explain their decisions. Thoughts were categorized as attentional metacognitions ("I quite fancy myself to get up and down. So I'm looking at this putt and what I'm thinking is, it's a putt that I should be able to hole"), attentional control ("Just always follow the routine that I have. Put the marker down for the ball. Line up the ball") and game situation ("It's thick rough, so I am conscious of the long grass might turn the head slightly"). The golfers verbalized attentional control processes most frequently, followed by game situation. Attentional metacognitions were least frequently used by the golfers. Simply put, golfers focused more on thought processes involving external factors than internal factors.

Perkins-Ceccato, N., Passmore, S. R. & Lee, T. D. (2003). Effects of focus of attention depend on golfers' skill. *Journal of Sports Sciences*, 21, 593–600.

A think-aloud study of high- and low-handicapped golfers examined how internal focus (on technique) verses external focus (on target) of attention affected pitching performance to a target. High-handicapped golfers performed better and had a lower

error average with an internal focus of attention. The opposite was true for lower-handicapped golfers who performed better with an external focus of attention.

Tenenbaum, G. & Calmeiro, L. (2011). Concurrent verbal protocol analysis in sport: Illustration of thought processes during a golf-putting task. *Journal of Clinical Sport Psychology*, 5, 223-236.

Think-aloud protocols were used to examine the decision making of golfers hitting 12-foot putts. Experienced players were aware of environmental factors and used them to inform strategy and performance. Beginner golfers' decisions focused more on technique and were made step by step.

Whitehead, A., Taylor, J. A. & Polman, R. C. J. (2016). Examination of the suitability of collecting in event cognitive processes using Think-Aloud protocol in golf. *Frontiers in Psychology*, 6, 1083.

Researchers used a think-aloud protocol to examine six male golfers' decision-making processes. The process revealed certain factors which affected shot decision like lie, slope of the green, or how wind affected aim. The researchers compared think-aloud data to data collected from retrospective interviews about golfers' decision making. Interviews conducted 10 minutes, 24 hours and 48 hours after play varied from in-the-moment think aloud protocols. This suggests the value of this research in understanding golfers' decision making.

Whitehead, A., Taylor, J. A. & Polman, R. C. J. (2016). Evidence for skill level differences in the thought processes of golfers during high and low pressure situations. *Frontiers in Psychology*, 6, 1974.

Think aloud processes of higher- and lower-skilled golfers were examined in stressful and nonstressful situations. In nonstressful conditions, higher-skilled golfers considered more strategy and shot planning compared to lower-skilled players who focused more on technique. In stressful conditions higher-skilled golfers gave relatively less attention to shot planning and more to technique. There was no change in lower-skilled players' process regardless of stress level.

PLAYER-CENTERED HYPOTHETICAL STUDIES OF GOLFERS' DECISION MAKING

Sachau, D., Simmering, L. & Adler, M. (2012). A birdie in the hand: Asymmetry in golf risk preferences. *International Journal of Golf Science*, 1, 81-89.

Eight-thousand recreational golfers completed a survey to examine their risk-taking decisions on the golf course. When faced with a likely outcome of birdie, par or bogey, they were asked to evaluate how much risk they would take on. Golfers were more willing to take on risk when facing a bogey than a birdie – this was moderated by handicap (lower-handicapped golfers were willing to take more risk to prevent a bogey than higher-handicapped players). Responses were also moderated when asked "What is the smart thing to do?" instead of "What would you do?'"

PLAYER-CENTERED RETROSPECTIVE STUDIES OF GOLFERS' DECISION-MAKING

Beilock, S. L. & Carr, T. H. (2001). On the fragility of skilled performance: What governs choking under pressure? *Journal of Experimental Psychology*, 130(4), 701-725.

Do experts or novices have greater recall of procedural or episodic memory for the putting task which they have completed? Under normal conditions, experts were better able to give generic procedural descriptions for what was involved in putting than novices (read the green, look at the distance, pick a target, etc.). But when recalling a specific putt (episode) they gave less descriptions than novices. This suggests a more automatic approach as expertise increases. When automaticity is disrupted – participants were asked to putt with a novel putter – experts became less automatic and more procedural which diminishes performance.

Cotterill, S. T., Sanders, R. & Collins, D. (2010). Developing effective pre-performance routines in Golf: Why don't we ask the golfer? *Journal of Applied Sport Psychology*, 22(1), 5164.

Six male, low-handicap players (Handicap Index M = 1.5) were interviewed retrospectively about their pre-shot routine. Videos were made of golfers playing and they watched when the videos were replayed. Golfers were asked to describe their process. Shot selection emerged as a theme that included task demands, difficulty and decision making. For example, distance, lie of the ball, wind speed and wind direction.

Giacobbi, P., Foore, B. & Weinberg, S. (2004). Broken clubs and expletives: The sources of stress and coping responses of skilled and moderately skilled golfers. *Journal of Applied Sport Psychology, 16(2), 166-182.*

To address the lack of research on non-elite players, eleven male, recreational golfers were interviewed to understand their coping strategies for golf. This included golf course strategies, e.g., swing easy, think analytically about distance, work on reading greens, take a safe club, use clubs you have confidence in, stay away from water, or play conservative off first tee. Players said they coped with golf stress by using mental

imagery, self-talk, relaxation techniques, pre-shot routines, distraction techniques, ignoring the stressful situation (pretending water was not there), verbalizing frustration and humor. The authors concluded that recreational golfers' stress may come from the discrepancy between their current performance and goals. To address stress, they engaged in more avoidance strategies than elite golfers.

Gnagy, E., Dixon, M., Clingerman, E. & Bartholomew, J. (2015). An exploration of strategic decision making in golf: Take a chance, it's worth the risk. ***International Journal of Golf Sciences*****, 4, 89 -109.**

A qualitative study of three male golfers' decision-making processes in tournament golf. Course management, club selection and aiming decisions were sources of stress for the players. Logical decision making is frequently outrun by situational gut feelings, or a sense of "manning up."

Lavallee, D., Bruce, D., & Gorely, T. (2003). The golfer-caddie partnership: An exploratory investigation into the role of the caddie. Science and Golf IV, 284-297.

Eight caddie-golfer partnerships were interviewed in this study. Topics investigated included decision making. The caddy was responsible for providing the parameters of the shot (distance, wind direction, etc.). The decision-making process had four stages: gather information, discuss possible strategies, agree/disagree with player's strategy, and endorse the strategy. In addition, caddies were relied on to remain logical when players became stressed and deviated from their usual decision-making process.

Oliver, A., McCarthy, P. J., & Burns, L. (2020). A grounded-theory study of meta-attention in golfers. ***The Sport Psychologist,*** **(34), 11-22.**

Meta-cognition study via semi-structured interviews with eight elite male players. Players identified that course condition and factors like aim are part of pre-shot decision making and stimuli when playing. The participants identified stressors that affected their play for which they developed coping strategies to manage.

Pilgrim J., Robertson S. & Kremer P. (2016). A qualitative investigation into the role of the caddie in elite-level golf. ***International Journal of Sports Science & Coaching*****, 11(4),599609.**

Caddies were interviewed to examine golfers' decision-making processes. Caddies provided the information used to decide on shot strategy. This included relevant hazards that were in play, hole location, yardage to the front, back and side of the green and to the hole location. They assessed the wind direction and strength. The

information was used to determine the ideal landing zone, aim, shot shape (curve and trajectory). After the discussion of the relevant information the player selected a club.

DESCRIPTIVE PSYCHOLOGICAL CHARACTERISTICS OF GOLFERS

Bois, J., Sarrazin, P., Southon, J., & Boiché, J. (2009). Psychological characteristics and their relation to performance in professional golfers. *The Sport Psychologist*, 23, 252–270.

Forty-one male golfers were used to study the psychological characteristics of successful and unsuccessful professional golfers. The authors hypothesized that high-performing players at one event would report different mastery-approach and performance-approach goals. And more use of effective coping strategies to deal with stress. Success was defined as making the cut in the tournament at which the study was conducted. Players who made the cut scored higher on performance-approach goals, anxiety and emotional control measures. However, in a regression analysis only anxiety, relaxation strategies and emotional control were predictive of players' performance. To conclude, coping strategies are as important to performance as anxiety itself.

Hellström, J. (2009). Psychological hallmarks of skilled golfers. *Sports Medicine*, 39(10), 845855.

A summary of existing research that identifies the psychological skills of elite golfers. Hellström suggests that golfers describe the optimal state as "concentrated and focused on one shot at a time." However, good decision-making and strategy requires an assessment of the past and planning for the future. Strategic decisions are described as the player considering "the whole chain of events" that pivot around a decision. Hellström suggests that the information-gathering process involved *before* players decide their strategy (past play, lie, situation etc.) and their reflection *after* the shot is understudied.

Lochbaum, M., & Smith, C. (2015). Making the cut and winning a golf putting championship: The role of approach-avoidance achievement goals. *International Journal of Golf Science*, 4, 50–66.

Approach and avoidance goals are defined as whether a player's motivation comes from wanting to demonstrate mastery or skill (i.e., "My goal is to putt better on this hole than I did before") or avoid looking like they do not have mastery or skill for a task (i.e., "My goal is to avoid putting worse than everyone else in my group.") One hundred and seventy-five novice golfers enrolled in a university-run class participated in the study.

The study concluded that novice putters who endorsed mastery- and performance-approach goals (who were motivated to demonstrate mastery and performance) scored better than novice putters who were motivated to avoid showing that they were unable to master or perform at the putting task. The authors concluded that like professional golfers, novice golfers perform best when endorsing approach-style goals. Most of all, they perform best when endorsing mastery-approach goals.

BIG-DATA STUDIES THAT EXTRAPOLATE GOLFERS' DECISION MAKING

Elmore, R. & Urbaczewski, A. (2020). Loss aversion in professional golf. *Journal of Sports Economics.*

A natural experiment of data from two U.S. Opens (Pebble Beach Golf Links and Oakmont Country Club) was used to examine professional male golfers' risk aversion when a hole was changed from a par 5 to a par 4. Although the holes had not been fundamentally changed, players scored lower on the hole when played as a par 4 rather than a par 5. The authors controlled for other variables that could account for the difference in scores (weather, players' ranking, technology) and demonstrated that scores on other holes – that had not had their par adjusted – remained constant over time. They conclude that this natural experiment demonstrates the risk-adverse nature of professional golfers.

Johansson, U., König, R., Brattberg, P., Dahlbom, A., & Riveiro, M. (2015). Mining TrackMan golf data. *International Conference on Computational Science and Computational Intelligence*, 381–386.

TrackMan™ shot data from 275 golfers was used to identify patterns that differentiated high- and low-skilled golfers. Each golfer hit five shots with a 7-iron and five shots with a driver. By handicap, golfers were divided into four groups: Low handicap (better than 4.5), Single handicap (4.6 to 9.9), Average (10 to 18) and high (over 18). The findings were predictable in that better players hit the ball farther and straighter, and were more consistent. The authors also concluded that the "majority of golfers do not hit the ball solid enough for the basic golf theory to apply." This suggests that for most players, decision-making strategy that relies on strike predictability may be flawed.

McFall, T. & Rotthoff, K. W. (2020). Risk-taking dynamics in tournaments: Evidence from professional golf. *Journal of Economic Behavior and Organization,* 178, 378-394.

Two hundred thousand ShotLink™ data points of professional golfers were used to assess risk-taking decisions on second shots to a par 5. Golfers are less likely to take risks as the distance to the hole location increases. Between 200- and 225-yards, golfers' risk-taking decreases by 7%. Uncertain lies (e.g., playing from rough instead of fairway) significantly reduces risk taking. Hazards, like water, also significantly decrease golfers' risk taking.

Ozbeklik, S. & Kiholm Smith, J. (2017). Risk taking in competition: Evidence from match play golf tournaments. *Journal of Corporate Finance,* 44, 506-523.

Analysis of ShotLink data of 573 professionals playing match play was used to parse out whether the winners were better players, or better decision-makers/risk-takers. Lower-ranked players and players behind in their matches were more likely to take on high-risk strategies than higher-ranked players.

Pope, Devin G., and Maurice E. Schweitzer (2011). Is Tiger Woods loss averse? Persistent bias in the face of experience, competition, and high stakes. *American Economic Review*, 101(1), 129-57.

Economic researchers used professional golf to test assumptions and behavior bias in decision making. Professional golf provides high stakes and experienced players. The researchers used 2.5 million putts and analyzed players' success rate based on whether the putt was for par, or a different score. Controlling for putt characteristics and conditions, golfers were 2 to 4% less likely to make birdie putts compared to similar par putts. In addition, golfers are more likely to leave birdie putts short of the hole compared to par putts. Similarly, eagle putts are less likely to be made than double bogey putts. In line with Prospect Theory, golfers are more risk adverse for gains than for losses.

Stöckl, M., Lamb, P. F., & Lames, M. (2012). A model for visualizing difficulty in golf and subsequent performance rankings on the PGA Tour. *International Journal of Golf Science*, 10–24.

In this paper the researchers developed a system for characterizing the difficulty of golf performance (ISOPAR), rather than predicting it (Strokes Gained). ISOPAR uses a systems-based approach that recognizes the constraints of each shot – environment, organism and task. An ISOPAR map is used to understand where the difficult areas of a hole are based on past performances. They use an analogy of a weather front with compacted bars meaning high pressure, in this case meaning high difficulty. The relative difficulty of shots on holes was calculated using ShotLink data. This system has originally been used to map greens, but the researchers extended it to the whole course in this paper. It was concluded that an ISOPAR map would help players visualize the difficulty

of a hole and the shot difficulty can be considered when comparing to others. The ISOPAR system can provide two metrics for golf shots – Shot Quality (considering difficulty) and Shots Saved is a comparative measure to the rest of the field that also accounts for difficulty.

Stöckl, M., & Lamb, P. F. (2018). The variable and chaotic nature of professional golf performance. *Journal of Sports Sciences*, 36(9), 978–984.

Decision making on the course and performance is influenced by the constraints of each shot. These constraints can influence the stability of player performance. Using ShotLink data, the authors investigated the stability of players' shot patterns with different clubs and shot lengths. Results showed that across all shot categories the mean length of a stable phase was 3.3 to 3.7 shots. Stable phases or variability in shots did not predict tournament performance. However, lower variability in driving data did correlate with tournament performance. In conclusion, the shot patterns of PGA Tour players were more chaotic than anticipated.

BIOMECHANICAL STUDIES OF GOLFERS' BODY MOVEMENT AND PERFORMANCE

Blenkinsop, G. M., Gallimore, N. J., Hiley, M. J., Liang, Y. (2018). The effect of uphill and downhill slopes on weight transfer, alignment and shot outcome in golf. *Journal of Applied Biomechanics*, 0–12.

Twelve elite male golfers were used to evaluate the effect of slope on golfers' swing and ball flight. The players hit 10 shots from an uphill slope, 10 shots from a downhill slope and 10 shots from a flat lie. Authors found that the weight shifted approximately 9% towards the lower foot regardless of slope. More interestingly, when hitting from slopes the launch angle, spin rate and shot dispersion changed. A downhill lie spun the ball right, and an uphill lie spun the ball left. This data should be considered in golfers' decision making.

Dias, G., Couceiro, M. S., Barreiros, J., Clemente, F. M., Mendes, R., & Martins, F. M. L. (2014). Distance and slope constraints: Adaptation and variability in golf putting. *Motor Contro*l, 18, 221–243.

Ten male elite golfers were used in this study to examine how golfers adapt to external constraints. As the putt length increased, or slopes of the putt increased, variability of measured factors (stroke length, ball speed and radial error) also increased. This

variability was described as the adjustment players made to adapt to the different putting conditions and could reflect learning that occurs with constraints-based training.

Evans, K., Horan, S. A., Neal, R.J., Barrett, R.S. & Mills, P.M. (2012). Repeatability of three-dimensional thorax and pelvis kinematics in the golf swing measured using a field-based motion capture system. *Sports Biomechanics*, 11(2), 262-272.

3D (three dimensional) technology can help players and coaches understand their swing and performance. In this paper, the researchers measure variability in a natural outdoor setting rather than in an indoor lab setting. Eighteen male and two female high-performance golfers were used as participants. Golfers' swing was measured 10 times (five using driver and five with a 5 iron) one day apart. Results found no difference in the 3D measurements regardless of whether they were measured inside or outside, nor any variation from day to day. This suggests the thorax and pelvis kinematics sequence of high-performing golfers is reliable under these test conditions.

Hiley, M. J., Barjwa, Z., Blenkinsop, G.M., Liang, Y. (2019). The effect of uphill and downhill slopes on centre of pressure movement, alignment and shot outcome in mid-handicap golfers. *Journal of Applied Biomechanics*, 1–15.

This replicated the paper by Blenkinsop et al., (2019) but with male recreational golfers (Handicap Index M = 12.1). The researchers found that unlike elite golfers who aligned their body parallel to the slope, recreational golfers were more likely to lean into the slope. However, their strategy for playing from uphill or downhill slopes did not result in significantly different ball flight outcomes compared to shots from a flat lie. The authors recommend that coaches can learn from this study and emphasize that players should allow weight to move onto the lower foot when playing on slopes.

Peters, R., Smith, N., & Lauder, M. (2015). Quantifying the gradients exposed to a professional golfer during a round of golf. *33rd International Conference on Biomechanics in Sports*, Poitiers, France. 1153–1156.

Twenty-two professional male golfers participated in a study to measure the effect of slopes on golf shots. During a round of golf an inclinometer was used to measure the slope of the shots that followed a drive. The authors state that a slope > 4.4% is noticeable to a golfer. In all, 50% of shots were hit from a slope +/- 2.25 degrees. (2.25 degrees is a gradient larger than 4.4%.) The authors concluded that as golf shots are seldom hit from a flat lie then research is needed to understand how slopes effect the swing and performance.

Sim, M., & Kim, J. (2010). Human movement science differences between experts and novices in kinematics and accuracy of golf putting. *Human Movement Science*, 29(6), 932–946.

Independent variables in this study were skill of golfer (5 x novice and 5 x expert), length of putt, and weight of putter. Dependent variables measured were movement time, amplitude, velocity, and directionality. Results showed no difference in time-to-impact and time-to-peak velocities between novice and expert golfers. However, there was an expert-novice difference in the movement times in different phases of putting, and stroke amplitude. Expert golfers controlled the clubhead velocity and ball speed efficiently, but novice golfers slowed the clubhead down at impact to control speed. With directionality, experts became increasingly less accurate as putt length increased. This was not true for novice golfers – whose accuracy was more random. The authors concluded that motor learning requires both control of micro movements and overall movement patterns.

STUDIES OF GOLFERS' EQUIPMENT AND GOLF COURSES

Alam, F., Steiner, T., Chowdhury, H., Moria, H., Khan, I., Aldawi, F., & Subic, A. (2011). A study of golf ball aerodynamic drag. *Procedia Engineering*, 13, 226–231.

The authors hypothesized that understanding the golf ball's aerodynamic behavior can enhance player performance. In this paper, eight commercial high-performance balls with different dimple patterns were tested in a wind tunnel. It was concluded that dimple pattern could vary the drag coefficient on the golf ball by up to 40%.

Baek, S., & Kim, M. (2013). Flight trajectory of a golf ball for a realistic game. *International Journal of Innovation, Management and Technology*, 4(3), 346–350.

Golf simulation games do not factor in the effect of dimples on the ball's drag and lift. Neither do they realistically factor in the effect of temperature, humidity, altitude or wind based on the height of the shots hit. The authors offer different formulas that can be used in simulated golf games to account for these factors. They suggest that incorporating these data will provide players with more realistic feedback about their real-world golf performance.

Chowdhury, H., Loganathan, B., Wang, Y., Mustary, I., & Alam, F. (2016). A study of dimple characteristics on golf ball drag. Procedia Engineering, 147, 87–91.

Eleven balls were manufactured using 3D printers with different depth dimples. The depth of dimples on each ball ranged from 0.5 – 1.5 mm. A smooth ball (with no dimples) was also tested in a wind tunnel to measure the drag coefficient. The study found that deeper dimples and a rougher surface decreased the Reynolds Number

(dimensionless ratio of inertial forces to viscous forces within a fluid such as air) and increased the drag coefficient. The paper concludes that golf ball dimple depth should be a consideration for players' strategic approach to improving their games.

Ivanov A.I., & Javorova J.G. (2017). Three-dimensional golf ball flight. *Journal Tehnomus-New Technologies and Products in Machine Manufacturing Technologies*, 54-61.

This paper focuses on the Magnus effect (ball pushes air one way, so the air applies an equal force on the ball the other way) of the golf ball flight. Faster initial linear velocity of the ball is correlated with the height of the ball. Increased angular velocity (particularly top spin) decreases the length and height of the shot.

Leach, R. J., Forrester, S. E., Mears, A. C., & Roberts, J. R. (2017). How valid and accurate are measurements of golf impact parameters obtained using commercially available radar and stereoscopic optical launch monitors. *Measurement*, 112, 125–136.

Two Hundred and forty shots by eight golfers with a driver, 7-iron and wedge were used to compare data between two commercially available launch monitors (TrackMan and Foresight) and GOM Inspect Optical Motion Tracking System. The different launch monitors were consistent and reliable for ball parameters, but less so for clubhead parameters. The differences between TrackMan and Foresight compared to GOM for clubhead parameters were more pronounced for the driver data than the 7-iron data. Despite the discrepancies the authors concluded that, "Coaches, golfers and club-fitters should find the data to be of sufficient quality for most of their needs."

Mehta, R. D. (2008). Sports ball aerodynamics. *Sport Aerodynamics*, 229-331.

This book chapter focuses on the Magnus effect of sports balls. Mehta argues that the curve of a ball is not always caused by "human influence." Specifically, the seam of a cricket ball can change the dynamics of the ball and create curve. A golf ball is not immune to this effect which is perhaps why the rules of golf state that foreign material must not be applied to the ball for the purpose of changing its playing characteristics. Or the rule that allows the player to change the ball when it is visibly cut.

R&A. (2017). *Club decision-making model*. Distance Insights Resources.

This paper examined the club selection male professional golfers choose from the tee based on hole length, width of fairway, and a player's average driving distance. ShotLink data was used to develop decision trees accounting for the variables being studied. Short hitters who are also inaccurate may lack confidence in any club have a complex decision. Short hitters (less than 278 yards) who are also accurate are less likely to

consider fairway width as a deciding factor. Medium hitters (between 278 and 306 yards) who are also inaccurate use a range of clubs and are likely to use an iron when the fairway is narrow. The same conclusion is made for long hitters (greater than 306 yards). The need for shot accuracy makes the decision-making process complex for male professional golfers.

R&A. (2018). *European tour weather conditions and relationship with driving distances*. Distance Insights Resources.

Is there a link between weather conditions and driving distance? Players on the European Tour averaged 4.1 yards less on their drives when rain was present than when rain was not present. A 5 MPH increase in wind speed correlated to a decrease of 2.1 yards in driving distance. A 5 degree increase in temperate indicated a 1.7-yard increase in driving distance. The report emphasized that the effect size of weather on driving distance was small with large variability. Furthermore, the weather was not always a statistically significant influence on driving distance.

R&A. (2018). *Playing lengths of golf courses used for amateur golf competitions in the United States*. Distance Insights Resources.

Data on golf course length was analyzed for USGA championships between 1979 and 2018. Across all sectors (Open, Senior, Mid, Junior) the course length increased by a statistically significant average of 10 yards per decade. Additionally, the course length for female events were 978 yards shorter than for male events. Tournament organizers concluded that only 21% of all golf courses are considered for elite competition due to length requirements.

R&A. (2019). *Effect of launch monitor technology on performance in golf*. Distance Insights Resources.

This paper suggests there is insufficient evidence to validate the accuracy of all commercially available launch monitors (TrackMan is identified as an exception), or that the introduction of launch monitors has improved player performance. Launch monitors have allowed coaches to train players with data, improve the efficacy of practice sessions, and enhance club fitting. Although driving distance increased while launch monitors were introduced, the paper suggests that other improvements in swing knowledge, solid-core balls, training and practice could also be factors that led to distance gains.

R&A. (2019). *Lengths of golf courses on the professional tours*. Distance Insights Resources.

Course length on the European and PGA Tours were analyzed over the last twenty years. There has been an increase of course length on both tours. And the PGA Tour, on average, plays longer courses than the European Tour. Sunningdale Golf Club in Berkshire, England, is a course that is played regularly on the Ladies European Tour. Between 1978 and 2008 the course length increased by 218 yards for tournament play.

Strunk, W. D., Karcher, D. E., Young, J. R., Patton, A. J. & Richardson, M. D. (2015). Golf shot performance characteristics influenced by ball lie. ***Crop, Forage & Turfgrass Management.***

The researchers investigated the effect on lie with a series of shots by two golfers hitting a 7-iron. Shorter grass constituted a good lie. As lie improved backspin increased, smash factor (ratio of ball speed to club head speed) increased, ball speed increased, and distance increased. This suggests that clubhead speed was not necessarily changed by lie and wasn't causing the lower distance. Looking at outcome, shot accuracy improved with a better lie.

PRESCRIPTIVE ANALYSIS OF GOLFERS' DECISION MAKING

Barzeski, E., & Wedzik, D. (2014). ***Lowest score wins. Techniques, stats and strategies to Shoot lower scores on the golf course NOW. Analyzr Golf L.L.C***

The authors, two golf instructors, debunk myths that golfers should spend more time on their short game. They argue that driving and driving distance are more important. The book offers strategies for course management and practice strategies.

Broadie, M. (2008). Assessing golfer performance using Golfmetrics. Science and Golf V. ***Proceedings of the World Scientific Congress of Golf*****, (34), 253–262.**

A paper introducing Golfmetrics – a system for assessing golfer performance. Of note is that Broadie suggests that the rough has more of an effect on professionals' approach shots than amateurs. This may be because amateurs are not accurate from the fairway or rough or because professionals are very accurate from the fairway so shots from the rough appear relatively errant. In comparing the difference between games of amateur and professional players, Broadie states, "If a low-handicap golfer had Tiger Woods do all of the putting, the gain would be about 2.2 shots per round, but having Tiger Woods hit all [approach] shots over 100 yards would lower the score by about 9.3 shots per round. If a professional player hit only long tee shots for the amateur golfer (about 13 or 14 shots per round) the difference would be about 4.3 shots per round."

Broadie, M. (2014). ***Every shot counts.*** **Gotham Books, New York, NY.**

Chapter 8: Tee-to-green strategy provides data suggesting how golfers can be better decision-makers about the next shot. It suggests that recreational golfers' strategy is both too aggressive and not aggressive enough. The book uses data to recommend decision making and strategy – it doesn't delve into how golfers make decisions.

Fawcett, S. (2019a). Fat side wins: An amazingly simple strategy that will lower your scores. *Practical Golf*.

Scott Fawcett does not examine golfers' decision-making process retrospectively, instead he prescribes decision-making strategies to golfers to reduce their scores. In this article he suggests that all golfers will benefit from deciding to aim at the fat side of the green to mitigate shot errors.

Fawcett, S. (2019b). This simple strategy will lower your scores (I'm serious). *Practical Golf.*

Scott Fawcett does not examine golfers' decision-making process retrospectively, instead he prescribes decision-making strategies to golfers to reduce their scores. In this article he suggests that all golfers will benefit from deciding to aim at the middle back of the green to mitigate shot errors.

GENERIC DECISION-MAKING THEORY

Gold, J. I., & Shadlen, M. N. (2007). The neural basis of decision making. *Annual Review of Neuroscience*, 30(5), 35–74.

A broad review of what is generally known about neuroscience in the decision-making process of sensory-motor tasks. The goal of a decision is to achieve the intended outcome goals. Conceptually, the elements of a decision include the decision variable (deliberation of prior knowledge, evidence, value) that occurs sequentially until a person is ready to commit to one option over another. When decisions are based primarily on value, behaviors can appear more random than when equal consideration is given to the other decision-making variables. The authors argue against the decision-making process being both intuitive and deliberate. Instead, they argue that almost all decisions have a deliberate element – even the ones we consider instinctive.

Kahneman, D., & Egan, P. (2011). *Thinking, fast and slow* (Vol. 1). New York: Farrar, Straus and Giroux.

Kahneman is a Nobel Prize winner in economics for his work in decision making. "Thinking Fast and Slow" lays out two systems that humans use to make decisions. System 1 is instinctive. System 2 is a more analytical approach to decision making. Anchoring theory is also introduced to explain that our decisions are influenced by the

way choices are presented to us. For example, if an initial offer is $1,000s, we are more likely to make a higher counteroffer than if the initial offer is in the $100s. The book extends to Prospect Theory (as reviewed in Pope et al., 2011) that suggests professional golfers are not exceptions to being risk adverse. This book lays the groundwork for many research papers exploring human-centered decision making in golf.