

16 Augmenting golf practice through the manipulation of physical and informational constraints

Paul S. Glazier

Introduction

Over the years, the golf industry has flooded the market with a plethora of weird and wonderful practice tools and coaching aids. However, the vast majority of this equipment comes with nothing more than marketing hype promising a drastically improved game and few have been subjected to rigorous scientific analysis. Ubiquitous to many driving ranges and practice grounds around the world are the Explanar® Golf Training System and video feedback systems. In this chapter, I will evaluate the effectiveness of this teaching and training apparatus from a constraints-led, dynamical systems theoretical perspective.

The Explanar® Golf Training System

The Explanar® Golf Training System is a popular teaching and training aid endorsed by a number of reputable golf instructors, including, among others, Butch Harmon (ex-swing coach to World No. 1, Tiger Woods and current swing coach to World No. 2, Phil Michelson) and Peter Cowen. Indeed, Harmon regards the Explanar® Golf Training System as the “best training system I have seen in my 40 years as a teacher” (www.explanar.com). The apparatus, which consists of an adjustable circular hoop, a weighted roller, and a stance mat (see Figure 16.1), is designed to help golfers increase their distance and improve their accuracy and consistency by encouraging them to swing on their “optimal biomechanical swing plane” (www.explanar.com).

The swing plane concept was popularised by Ben Hogan in his famous text *The Modern Fundamentals of Golf* (Hogan, 1957) and is defined as an imaginary two-dimensional surface – extending from the centre of the golf ball through the sternum of the golfer – that the clubhead should travel on throughout the golf swing (see Figure 16.2). Users of the Explanar® Golf Training System are required to adjust the angle of inclination so that the outer edge of the circular hoop coincides with their “ideal” swing plane. Once they have taken up their correct stance inside the circular hoop, as guided by the stance mat, users are then required to swing the weighted roller whilst resting it on the outer edge of the circular hoop, enabling them to better “feel” their “correct” swing plane and to develop “muscle



Figure 16.1 The adjustable aluminium hoop, fin (Plane Fin™), roller (Power Roller™), and stance mat (Radial Stance Mat™) that comprises the Explanar® Golf Training System.

memory” (www.explanar.com).

In dynamical systems parlance, the circular hoop acts as a physical constraint, eliminating all other swing planes except the purportedly “optimal” swing plane. Theoretically, repetitive practice on the Explanar® Golf Training System promotes the development of deeper attractor regions in state space, leading to more robust movement solutions and greater stability of performance outcomes, particularly during perturbation (e.g. performing under pressure, inclement weather conditions, hilly terrain, etc.).

What the literature says about the Explanar® Golf Training System

Despite the plethora of testimonials endorsing the Explanar® Golf Training System, empirical support for this product is far less abundant. Indeed, only two scientific investigations examining the effectiveness of the Explanar® Golf Training System as a teaching and training aid have been published.

Building on previous work on the swing plane (Coleman & Rankin, 2005; Coleman & Anderson, 2007), Coleman & Ritchie (2008) compared swings performed using the roller on the Explanar® Golf Training System to normal swings using a golf club by a group ($n = 8$) of expert, single-figure handicap golfers.

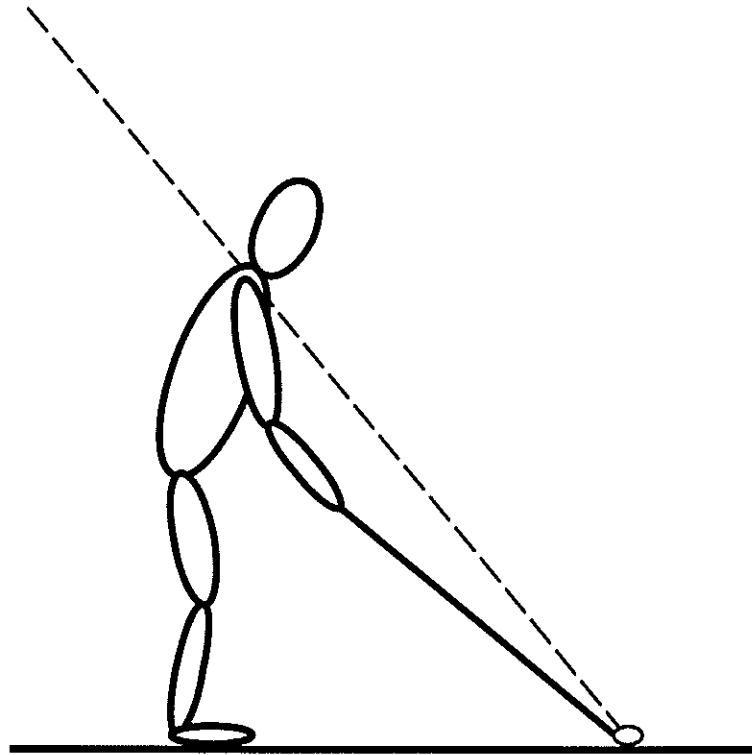


Figure 16.2 The swing plane concept was popularised by Hogan (1957) who suggested that it might best be visualised as a pane of glass inclined from the golf ball that rests on top of the shoulders. Over the years, the swing plane concept has been revised and now it is generally regarded to be an imaginary two-dimensional surface extending from the centre of the golf ball through the sternum of the golfer.

Image-based motion analysis was used to generate three-dimensional kinematic data (50 Hz) describing the motion of the club (6 iron) and roller from take-away to impact. Interpolating quintic splines were used to generate continuous time histories and better estimate the point of impact in both conditions. The digitised co-ordinates of the two markers affixed to the club and roller were entered into a multiple regression technique to calculate the swing plane in each condition (see Coleman & Anderson, 2007). The specific variables of interest were: angle of the swing plane to the horizontal, alignment of the swing plane to the target line, fit to plane (r^2) and fit to plane (RMS residuals). Average values for these variables during the backswing, downswing, and whole swing (i.e. the backswing and downswing combined) for the two conditions (normal vs Explanar® Golf Training System) were calculated and compared using inferential group mean difference statistics.

The results of this study revealed that no statistically significant differences existed between the swing performed on the Explanar® Golf Training System and normal swings with a golf club in the angle of the swing plane to the horizontal for any of the phases. However, there were statistically significant differences in the alignment of the swing plane to target line for all the phases, with the swing plane for the normal swing aligned more to the right of target than the swing plane for the Explanar® Golf Training System. The authors suggested that this

finding might indicate that the Explanar® Golf Training System produces a different geometry of swing to a normal swing performed with a golf club. Conversely, it could be argued that these results may simply be an artefact of an incorrectly configured experimental setup. Although the authors argued to the contrary, citing favourable results from error assessments that they had conducted as part of their investigation, it is possible that these results had several determinants. They could be related to the alignment of the Explanar® Golf Training System, or to how the golfers aligned themselves in relation to the intended target, or a combination of the two.

In terms of the fit to plane variables, there were no statistically significant differences for any of the phases for the r^2 , although the group data presented appeared to suggest that the single swing plane model fitted better to the normal swing with the golf club than to those performed on the Explanar® Golf Training System. Statistically significant differences were found in the RMS residuals, but only in the backswing phase, where they were lower in the normal swing condition than the Explanar® Golf Training System. However, as the authors note, it is only the motion of the club immediately prior to impact that determines the flight of the ball and analysis of consecutive club positions in the downswing revealed that golfers tended to be on a steeper plane approaching impact when swinging the golf club than when using the Explanar® Golf Training System. An issue not considered by the authors that could compromise the results of this study was the low sampling rate of their original data capture and the subsequent use of interpolation to effectively increase the number of (virtual) club positions. Clearly, further research utilising motion capture equipment of sufficiently high sampling rate (>200 Hz) is necessary to confirm these findings.

The only other published study to examine the Explanar® Golf Training System was by Bertram *et al.* (2008), who investigated the effects of kinesthetic practice on golf swing performance. In this study, 20 golfers were randomly assigned to either a self-guided or a kinesthetic group. The self-guided group was instructed to hit golf shots for 20 minutes without any kind of feedback except data on swing characteristics (club-head speed, club-face angle and tempo) produced by a launch monitor. The kinesthetic practice group were given 20 minutes practice on the Explanar® Golf Training System with verbal instruction. After a five minute warm-up period, a pre-test that involved golfers performing 12 shots on a launch monitor was conducted to determine baseline swing characteristics. Immediately following the 20 minute training sessions, each participant was asked to hit 12 shots on the launch monitor with a 5 iron (post-test 1). Following a 10 minute rest period, participants were requested to hit a further 12 shots on the launch monitor (post-test 2). A final testing session (post-test 3) was conducted one week later when all participants were asked to hit a further 12 shots on the launch monitor so that the long-term training benefits of being exposed to kinesthetic feedback via the Explanar® Golf Training System could be examined.

Statistical analyses of the launch monitor data indicated that there was a significant increase in the club-head speed in the kinesthetic practice group from the pre-test to the final post-test (no data provided). In contrast, there were no

immediate changes in club-head speed for the self-guided group and, in fact, there was a slight decrease by the final post-test (no data provided). In terms of tempo, the kinesthetic group slowed significantly from the pre-test to the final post-test and the tempo variability (indicated by the standard deviation) also reduced. The self-guided practice group, on the other hand, had no statistically significant change of tempo from the pre-test to the final post-test and, indeed, it became increasingly more variable. There were no statistically significant differences in club-face angle at impact, although the general trend was that club-face angle variability increased slightly in the self-guided practice group across tests, whereas the club-face angle variability for the kinesthetic group decreased. The results of this study have since been used as empirical verification for the Explanar® Golf Training System and have featured prominently on the Explanar® website (see www.explanar.com).

A significant shortcoming of this study was that it was product-driven rather than process-driven. By focusing on outcome variables, the underlying movement dynamics were largely ignored.¹ Of course, one may argue, with some merit, that the method by which the outcome is achieved may be of little consequence providing the task goal is accomplished (see Wiren, 1990). However, the purpose of the Explanar® Golf Training System is to help facilitate changes in technique and encourage the adoption of the “optimal biomechanical swing plane”, but as movement patterns were not analysed, the effectiveness of this apparatus in achieving this purpose could not be evaluated.

Is the Explanar® Golf Training System an effective coaching and practice tool?

The studies reviewed above are not only inconclusive in their assessment of the Explanar® Golf Training System but they also appear to be somewhat flawed in their methodologies. Consequently, they cannot be used to provide a definitive verdict either way about the suitability and effectiveness of the Explanar® Golf Training System as a coaching and practice tool.

From a constraints-led dynamical systems theoretical standpoint, the Explanar® Golf Training System might be useful during the initial stages of learning when the novice golfer is attempting to assemble a “ballpark” movement solution, as it acts as a physical constraint, thereby restricting or preventing superfluous movements of the golf club during the swing and encouraging the development of stable attractor regions. Furthermore, it may also help to reduce attentional demands in the early stages of learning. However, at more advanced stages of learning, the Explanar® Golf Training System should be used less frequently so that the golfer can explore and probe the boundaries of the “perceptuo-motor workspace” without restraint (see Newell *et al.*, 1989; Newell *et al.*, 1991; Newell & McDonald, 1992; Button *et al.*, 2008). It is important that more skilled golfers are allowed to “search and discover” their own unique movement solutions that better compliment their intrinsic dynamics² rather than having them forced upon them by overly restrictive physical constraints. Ultimately a naturally evolving technique is likely to have

greater robustness when performing under pressure than an artificially enforced swing (see Masters, 1992).

These theoretical insights are consonant with a recent critique of the swing plane concept by Jenkins (2007), who suggested that there was not one single, or optimal, swing plane on which all golfers should swing the golf club. In fact, a quick survey of the golf-coaching literature seems to suggest that there is some degree of confusion about the definition of the swing plane with some renowned golf coaches arguing, for example, that it is simply an extension of the shaft at address (see Haney, 1986). Moreover, other coaching texts have advocated a “plane shift” during the golf swing, with the backswing following a more upright plane and the downswing following a shallower plane (see Leadbetter, 1990). Additionally, it is unclear whether the club-head, the shaft or the golfer’s arms and hands should follow the plane. Considering the amount of conjecture surrounding what constitutes the swing plane, one could argue, as Cheetham (2007) did, that the swing plane concept is of little practical use so, therefore, by implication, neither is the Explanar® Golf Training System.

Video feedback technology

Possibly the most important contribution of technology to sports coaching over the past 30 years has been the advent and integration of video capture and playback facilities. High-definition digital video camcorders of ever-increasing sampling rates and sophistication are now readily available, as are purpose-built software applications such as cSwing®, V1 Pro Swing Analysis® and GASP Golf Swing Analysis®, which enable golf coaches to conduct frame-by-frame and semi-quantitative analysis of the golf swing almost in real-time *in situ* on the practice ground. However, is there any need for such fine-grained analyses of the golf swing? Is there any scientific evidence proving that video analysis leads to improvements in technique and performance?

In this section, I review the literature specifically related to the use of video feedback technology in the teaching and coaching of the golf swing. Owing to the plethora of theoretical and empirical studies that have considered video feedback in sport generally and the extensive reviews that have already been published on this topic (e.g. Liebermann *et al.*, 2002; Liebermann & Franks, 2008), I will only refer to this part of the literature where necessary.

What the literature says about video feedback in golf teaching and coaching

Comparatively few studies have examined the role and influence of video feedback in golf. Guadagnoli *et al.* (2001) set out to establish what type of feedback – verbal, video or a combination of the two – was most influential in teaching the golf swing. Forty-five apparently novice golfers participated in an initial pre-test that involved striking 15 golf balls with a 7 iron at a target 200 m away. “Accuracy distance” (AD) for each shot was calculated by subtracting the “error distance”

(ED) from “target distance” (TD) (see Figure 16.3 for definitions). Immediately after pre-test, a 20 minute instructional video about the grip, stance and swing mechanics was shown to each participant before they were randomly assigned to one of three experimental groups – verbal, video and verbal + video. The day following pre-testing, each participant hit 10 golf balls into a practice net with a 7 iron, which was followed by either verbal feedback from a qualified PGA teaching professional (verbal group), video feedback from high-speed video recordings (video group), or a combination of the two (verbal + video). This sequence was repeated four times so that 40 balls were hit in a single practice session and four practice sessions were conducted, separated by one day between each session where no practice was permitted. Once their four practice and feedback sessions had been completed, participants completed a post-test, which was identical to the pre-test.

No statistically significant differences in AD between the verbal, video and verbal + video groups for the pre-test were reported. However, the video and verbal + video groups performed significantly better than the verbal group during post-test, although there was no statistically significant difference between the video and verbal + video groups. There was also a statistically significant increase in AD between pre-test and post-test. However, the graphical representation of these results suggests that much of this difference was primarily attributable to large improvements for the video and verbal + video groups, with the verbal group only showing a very modest improvement. The results of this study suggest that video and verbal + video produces greater learning effects in novice golfers than verbal feedback, although the authors could not provide a convincing explanation as to why there was no significant difference between the video and verbal + video groups.

In a follow-up study, Guadagnoli *et al.* (2002) examined the efficacy of video instruction (i.e. practicing with the aid of a teacher or coach and video feedback) relative to that of verbal instruction (i.e. practicing with the aid of a teacher or coach) and self-guided instruction (i.e. practicing without the aid of a teacher or coach). Thirty experienced golfers (handicap range 7 to 16 strokes) volunteered to participate in this study and were randomly assigned to one of three experimental groups – video, verbal and self-guided. The research design used was the same as their previous study outlined above except that an additional post-test was introduced two weeks after the initial post-test. In addition, no instructional video was shown to the participants after the pre-test, presumably because they were already fairly accomplished golfers, and each of the four practice sessions lasted for 90 minutes in duration. In addition to calculating AD, variability of TD and ED were also calculated to determine consistency of performance.

No statistically significant differences in AD between the video, verbal and self-guided groups for the pre-test and the first post-test were reported. However, there was a statistically significant difference between the three groups on the second post-test, with the video group performing better than the verbal group, which, in turn, performed better than the self-guided group. Similar results were reported for variability of TD and ED. The authors concluded that these results indicate

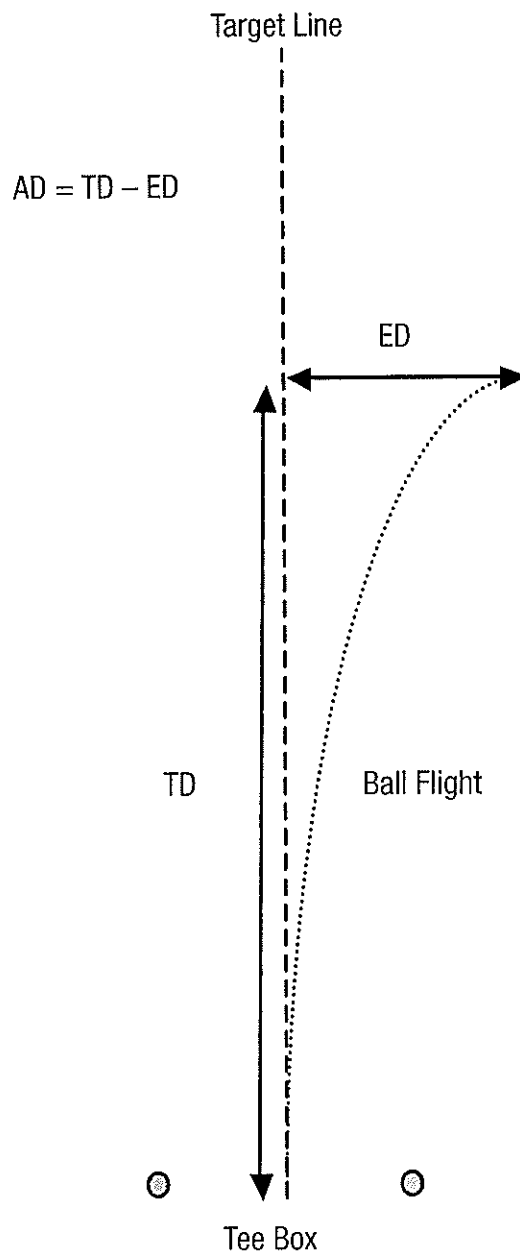


Figure 16.3 Pre- and post-testing involved the calculation of “accuracy distance” (AD) by subtracting “error distance” (ED) from “target distance” (TD). ED was defined as the perpendicular distance from the initial ball-to-target line from where the ball landed and TD was defined as the distance where this perpendicular line bisected the initial ball-to-target line (adapted from Guadagnoli *et al.*, 2001).

that video instruction is an effective method of augmenting learning, although improvements in performance may take some time to develop.

In a more recent study, Bertram *et al.* (2007) combined and extended the previous two studies of Guadagnoli and colleagues. Of the 48 male and female golfers that were recruited for this study, half were considered novices (handicap ≥ 25) and the other half experts (handicap ≤ 10). An initial pre-test was conducted where each participant was required to hit 12 shots with a standard 6 iron into a practice net. Each stroke was captured on video and a launch monitor was used to calculate club-head speed at impact (CHS), club-face angle at impact (CFA) and

tempo (T). Following the pre-test, each participant was randomly assigned to one of three experimental groups – verbal, verbal + video and self-guided. Participants in the verbal group were given 20 minutes of tuition from a qualified PGA teaching professional. During this period, each golfer was permitted to hit a maximum of 30 shots with the 6 iron used in the pre-test. Tuition provided by the teaching professional focused specifically on improving the quality and squaredness of the club-face at impact. Data obtained from the launch monitor was also available and used to supplement the coaching points being conveyed by the teaching professional. Participants in the verbal + video group followed the same procedure as the verbal group except that after their 5th, 10th, 15th, 20th and 25th shots, a video replay was shown of their preceding five shots. A set format was used for playing back video replays, which included replaying each shot: (1) three times at normal speed; (2) three times in slow motion with interactive commentary from the teaching professional; and (3) three times again at normal speed. Finally, participants in the self-guided group were permitted to hit 30 shots during their 20 minute practice session. No form of instruction was provided, although participants were allowed to view launch monitor data after each stroke. Approximately 20 minutes after their practice session, each participant was required to participate in a post-test, which was identical to the pre-test.

The results of this study showed that novice golfers in the verbal group significantly improved their club-head speed from pre-test to post-test, whereas neither the verbal + visual or the self-guided group showed any significant changes. In contrast, only expert golfers in the self-guided group showed any significant improvements in club-head speed from pre-test to post-test. No significant changes in club-head speed variability were observed across skill level or feedback conditions. In terms of club-face angle, verbal feedback significantly improved the squaredness and consistency of the club-face angle at impact for novice golfers. However, verbal + visual feedback had the opposite effect for novice golfers, causing a significant reduction in the squaredness and consistency of the club-face angle at impact. No significant changes were reported across feedback conditions for club-face angle and club-face angle variability for expert golfers. Finally, no significant differences in tempo were observed in any of the feedback groups for novice golfers, whereas expert golfers in verbal + video feedback group showed a significant slowing of tempo between pre-test and post-test. In terms of shot-to-shot tempo variability, there was a significant increase in consistency between pre-test and post-test for novice golfers in the verbal group. However, verbal + video feedback significantly reduced the consistency of tempo in novice golfers, although the opposite was true for expert golfers.

Despite the inherent limitations and lack of clarity of this study, it appears that novice golfers benefit more from verbal feedback than expert golfers. Conversely, expert golfers appear to benefit more from verbal + video feedback than novice golfers, which seemed to help slow, and make more consistent, their tempos. Self-guided instruction, according to this study, does not appear to lead to any substantial improvements in performance, which seems to be at odds with the literature on discovery learning (see Vereijken & Whiting, 1990).

A word of caution on the use of video feedback

Although not as unequivocal as some golf coaches may envisage, the preceding review of the work of Guadagnoli and colleagues provides some evidence that video feedback may be useful in the coaching process and could lead to improvements in performance. However, from a constraints-led dynamical systems theoretical perspective, caution should be applied when using video feedback technology. The main issue appears to be the implicit or explicit use of criterion models or templates of the “perfect” golf swing as a basis for detecting faults and directing remedial action (see also Sherman *et al.*, 2001). Many instructional texts advocate a standard grip, stance, backswing, downswing and follow-through that are generally considered to characterise the “ideal” golf swing. Indeed, support for this “one-size-fits-all” approach has even been forthcoming in the scientific literature. For example, Mann & Griffin (1998) produced a computer-generated model of the best features of the golf swings of over 100 US PGA, LPGA and Senior PGA tour players, which has since been promoted as *the* template or criterion golf swing that *all* golfers should aspire to achieve. However, owing to the unique confluence of constraints acting to shape and guide the co-ordination patterns of individual golfers, it could be argued, from a dynamical systems theoretical standpoint, that the “perfect” golf swing does not exist (Glazier & Davids, 2005). Accordingly, rather than using video feedback technology to compare the golf swings of specific individuals to those of leading tournament professionals in a bid to replicate their perceived picture-perfect form, it should primarily be used to improve the application, and increase awareness, of general mechanical principles as they relate to the golf swing (Button, 2008).

Conclusion

In this chapter, I have reviewed two of the most used (and sometimes abused) teaching and training aids in golf. Both the Explanar® Golf Training System and video feedback technology might be useful in helping golfers improve their games but it is important that they are used sparingly and in the correct manner to maximise motor learning and performance benefits. Over-reliance on the Explanar® Golf Training System or video feedback technology, or any other coaching and practice tool for that matter, may adversely affect motor learning and performance because they may prevent golfers from fully exploring their “perceptuo-motor workspace”. Theoretical insights presented in this chapter suggest that “manufacturing” or “cloning” golf swings by using artificial mechanical devices or attempting to mimic the technique of a champion performer, respectively, may not be the most efficient or effective ways to learn how to play golf. Indeed, the development of a golf swing that is not consonant with the unique intrinsic dynamics of the individual golfer could be prone to breaking down in certain performance contexts (e.g. when performing under pressure in competition, during inclement weather conditions etc.) owing to lack of robustness.

Notes

- 1 This problem is not new. Indeed, a previous investigation by Yost *et al.* (1976) of the “Golfer’s Groove” – a similar, but now defunct, training aid – had comparable issues focusing solely on outcome scores that may not have been valid (see Skrinar & Hoffman, 1978).
- 2 The term intrinsic dynamics is used here to refer to the spontaneous co-ordination tendencies or preferred modes of co-ordination that exist in the movement system at the start of the learning process (Corbetta & Vereijken, 1999).

References

- Bertram, C. P., Grosser, L. & Guadagnoli, M. A. (2008). Getting the “Feel” for It: The Effects of Kinesthetic Practice on Golf Swing Performance. In D. Crews & R. Lutz (eds), *Science and Golf V*, Mesa, AZ: Energy in Motion, pp. 279–285.
- Bertram, C. P., Marteniuk, R. G. & Guadagnoli, M. A. (2007). On the Use and Misuse of Video Analysis. In S. P. Jenkins (ed.), *Annual Review of Golf Coaching*, Brentwood, UK: Multi-Science Publishing pp. 37–46.
- Button, C. (2008). Enhancing Skill Acquisition in Golf – Some Key Principles. *ISBS Coaches’ Infoservice*. Available online at: <http://www.coachesinfo.com> (accessed 21 June 2009).
- Button, C., Chow, J.-Y. & Rein, R. (2008). Exploring the Perceptuo-motor Workspace: New Approaches to Skill Acquisition and Training. In Y. Hong & R. Bartlett (eds) *Handbook of Biomechanics and Human Movement Science*, London: Routledge, pp. 538–553.
- Cheetham, P. (2007). Golf Coaching and Swing Plane Theories: A Commentary. In S. P. Jenkins (ed.), *Annual Review of Golf Coaching*, Brentwood, UK: Multi-Science Publishing, pp. 23–24.
- Coleman, S. G. S. & Ritchie, S. (2008). Mathematical Comparison of Swing Planes with and without the Explanar® Trainer. In D. Crews & R. Lutz (eds), *Science and Golf V*, Mesa, AZ: Energy in Motion, pp. 263–269.
- Coleman, S. G. S. & Anderson, D. (2007). An Examination of the Planar Nature of Golf Club Motion in the Swings of Experienced Players. *Journal of Sports Sciences*, 25, 739–748.
- Coleman, S. G. S. & Rankin, A. J. (2005). A Three-dimensional Examination of the Planar Nature of the Golf Swing. *Journal of Sports Sciences*, 23, 227–234.
- Corbetta, D. & Vereijken, B. (1999). Understanding Development and Learning of Motor Co-ordination in Sport: The Contribution of Dynamic Systems Theory. *International Journal of Sport Psychology*, 30, 507–530.
- Glazier, P. S. & Davids, K. (2005). Is There such a Thing as a “Perfect” Golf Swing? *ISBS Coaches’ Infoservice*. Available online at: <http://www.coachesinfo.com> (accessed 21 June 2009).
- Guadagnoli, M. A., McDaniels, A., Bullard, J., Tandy, R. D. & Holcomb, W. R. (2001). The Influence of Video and Verbal Information on Learning the Golf Swing. In P. R. Thomas (ed.), *Optimising Performance in Golf*, Brisbane: Australian Academic Press, pp. 94–103.
- Guadagnoli, M., Holcomb, W. & Davis, M. (2002). The Efficacy of Video Feedback for Learning the Golf Swing. *Journal of Sports Sciences*, 20, 615–622.
- Hall, M., Colclough, S., MacBeth, J. & Currie, S. (2008). The Effectiveness of Two

- Commercial Golf Swing Training Aids in Teaching Beginning Golf. In D. Crews & R. Lutz (eds), *Science and Golf V*, Mesa, AZ: Energy in Motion, pp. 286–292.
- Haney, H. (1986). The Robot Swing. *Golf Monthly*, 3, 45–50.
- Hogan, B. (1957). *The Modern Fundamentals of Golf*. London: Kaye & Ward.
- Jenkins, S. P. (2007). Golf Coaching and Swing Plane Theories. In S. P. Jenkins (ed.), *Annual Review of Golf Coaching*, Brentwood, UK: Multi-Science Publishing, pp. 1–19.
- Leadbetter, D. (1990). *The Golf Swing*. London: Collins Willow.
- Liebermann, D. G. & Franks, I. M. (2008). Video Feedback and Information Technologies. In M. Hughes & I. M. Franks (eds), *Essentials of Performance Analysis: An Introduction*, London: Routledge, pp. 40–50.
- Liebermann, D. G., Katz, L., Hughes, M. D., Bartlett, R. M., McClements, J. & Franks, I. M. (2002). Advances in the Application of Information Technology to Sport Performance. *Journal of Sports Sciences*, 20, 755–769.
- Mann, R. & Griffin, F. (1998). *Swing Like a Pro: The Breakthrough Scientific Method of Perfecting Your Swing*. New York: Broadway Books.
- Masters, R. S. W. (1992). Knowledge, Knerves and Know-how: The Role of Explicit Versus Implicit Knowledge in the Breakdown of a Complex Motor Skill under Pressure. *British Journal of Psychology*, 83, 343–358.
- Newell, K. M. & McDonald, P. V. (1992). Practice: A Search for Task Solutions. In R. W. Christina & H. M. Eckert (eds), *Enhancing Performance in Sport: New Concepts and Developments*, Champaign, Illinois: Human Kinetics, pp. 51–59.
- Newell, K. M., Kugler, P. N., van Emmerik, R. E. A. & McDonald, P. V. (1989). Search Strategies and the Acquisition of Co-ordination. In S. A. Wallace (ed.), *Perspective on the Coordination of Movement*, Amsterdam: North-Holland, pp. 85–122.
- Newell, K. M., McDonald, P. V. & Kugler, P. N. (1991). The Perceptual-motor Workspace and the Acquisition of Skill. In J. Requin & G. E. Stelmach (eds), *Tutorials in Motor Neuroscience*, Dordrecht: Kluwer, pp. 95–108.
- Sherman, C. A., Sparrow, W. A., Jolley, D. & Eldering, J. (2001). Coaches' Perceptions of Golf Swing Kinematics. *International Journal of Sport Psychology*, 31, 257–270.
- Skrinar, G. & Hoffman, S. (1978). Mechanical Guidance of the Golf Swing: The Golfer's Groove as an Instructional Adjunct. *Research Quarterly*, 49, 335–341.
- Vereijken, B. & Whiting, H. T. A. (1990). In Defence of Discovery Learning. *Canadian Journal of Sports Sciences*, 15, 99–106.
- Wiren, G. (1990). Laws, Principles and Preferences: A Teaching Model. In A. J. Cochran (ed.), *Science and Golf I: Proceedings of the First World Scientific Congress of Golf*, London: E & F. N. Spon, pp. 3–13.
- Wiren, G. (2007). Golf Coaching and Swing Plane Theories: A Commentary. In S. P. Jenkins (ed.), *Annual Review of Golf Coaching*, Brentwood, UK: Multi-Science Publishing, pp. 21–22.
- Yost, M., Strauss, R. & David, R. (1976). The Effectiveness of the Golfer's Groove in Improving Golfers Scores. *Research Quarterly*, 47, 569–573.