PRACTICE CONDITIONS: HOW DO THEY INFLUENCE MOTOR LEARNING IN GOLF?

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This study reviewed the literature for the effect that various practice conditions have on motor learning in golf. All eligible studies had to use outcome measures of direct (ball displacement, shot accuracy) or indirect (clubhead velocity, clubface angle) golf performance. Results of the six eligible studies suggests that a distributed practice approach involving multiple sessions per week of block, errorless practice may be best for improving putting accuracy of novice golfers. Random (variable) practice may however lead to greater putting performance improvements in skilled golfers. Coaches and golfers should therefore consider the way they structure their practice sessions in order to better facilitate improvements in golf performance.

KEY WORDS: motor control; review; skill acquisition.

INTRODUCTION: A considerable amount of biomechanical research has been conducted on the golf swing as a golfers' technique has a large effect on golf performance where the aim is to hit the golf ball into a small hole in as few shots as possible (Hume, Keogh, & Reid, 2005). Golf performance (driving, chipping and putting) can be assessed via direct (ball displacement, shot accuracy) or indirect (e.g., clubhead velocity, clubface angle at contact) outcome measures. The magnitude and direction of the linear clubhead velocity at impact is determined by the angular velocity of the clubhead during the swing and the length of the club. Interestingly, relatively few motor learning studies have been conducted to determine what constitutes optimal golf teaching strategies and how these may differ for golfers of varying standards. This relative lack of motor learning research in golf is quite surprising when you consider the popularity of this sport worldwide, the large prize money and sponsorship deals that professional golfers attract and the considerable amount of biomechanical research on this sport.

Motor learning studies typically involve a practice block which may last from one day to several weeks in which a small number of tasks are practiced in each session. At the conclusion of the practice block, retention and transfer tests are then conducted across one or several sessions which can occur on the same day as practice and up to several weeks post-practice. As the retention test is identical to the tasks performed in the practice sessions, it assesses the persistence of learning. In contrast, transfer tasks examine the adaptability of learning by testing the individuals during performance of different variations of the practice task. Therefore, Magill (2011) proposed that changes in transfer task performance several days after practice better quantifies the true learning that occurs when compared to retention tests, especially when they are conducted on the last day of practice.

Due to the high importance of swing technique, golfers devote considerable practice time to improving their driver, irons and putting swings. Traditionally, many golfers have used constant (block) practice where they use the same club and practice hitting golf balls to the same target for many consecutive shots before moving on to a different target or club (Farrally et al., 2003). In contrast, random (variable) practice involves performing different golf shots each swing so that no two consecutive shots involve the same club, target and distance. Magill (2011) stated that the majority of the general motor learning literature supports the use of variable rather than block practice. This is purported to be due to the concept of contextual interference, which can be viewed as the disruption in memory and

performance that occurs when performing multiple variations of a skill, in this case different consecutive golf shots within a variable practice session.
Another question in the general motor learning literature is whether initial practice should be done using simple or harder versions of a task, with these approaches often referred to as errorless and errorfull learning, respectively (Magill, 2011). Errorless practice involves initially performing simple tasks whereby only small errors will be made (e.g. short distance putts) and working up to the longest distances where the magnitude of the error will tend to be greater. In contrast, errorfull practice starts at the longest distance and finishes at the shortest distance. Errorless practice derives its name from the likelihood that the absolute errors in putting accuracy should be minimised due to starting with the shortest distance; with errorfull practice involving the greatest errors in the initial stage. Magill (2011) stated that there is some equivalence in the results of this literature, with preliminary evidence suggesting that while health populations may benefit more from errorfull training, those with cognitive disorders may improve more with errorless learning.
Motor learning research has also sought to determine how the distribution of practice influences changes in performance. Variations in the distribution of practice are commonly referred to as massed and distributed practice which differ based on the number of practice trials within a given time period. Specifically, distributed practice allows greater rest periods between trials within a practice session and/or involved more frequent shorter, practice sessions than massed practice (Magill, 2011). Anecdotally, it would appear that many amateur, recreational golfers use a massed practice schedule as they may struggle to get to a golf course more than once a week, and therefore feel they need to perform as many swings as possible within their weekly practice session. Current motor learning evidence suggests that distributed rather than mass practice facilitates better motor learning, with this believed to reflect the reduced fatigue, increased cognitive effort put into every trial and better long-term memory consolidation of distributed practice (Magill, 2011).
Therefore, the purpose of this review was to determine the strength of the evidence and gaps in the literature for how variations in the structure of practice may assist golfers improve their performance; and to gain any insight into whether this may differ for novice versus elite golfers.

METHODS: Electronic databases (Web of Knowledge, Scopus, Medline, SportsDiscus, ProQuest Direct, Cinahl, Scirus Current Contents, ABI/INFORM Global and ProQuest Direct) from January 1975 to July 2011, and the internet (e.g. Journal of Biomechanics on line, Google Scholar) were searched using keywords golf, motor control, motor learning, variable practice and performance. Keywords were used separately and in combination. Reference lists of retrieved articles were manually checked for additional studies. Initial exclusion criteria were that the article was not: 1) available in English and in full text; 2) in a peer reviewed journal or conference proceedings with full papers rather than abstracts only; 3) previously referred to by other sources; or 4) adding knowledge to the aim of the review.

RESULTS AND DISCUSSION: Six motor learning studies compared the learning effects of altering the golf practice conditions via massed versus distributed practice (Dail & Christina, 2004), block versus variable practice (Goodwin & Meeuwsen, 1996; Guadagnoli, Holcomb, & Weber, 1999; Porter & Magill, 2010) as well as errorless versus errorfull practice (Lam, Maxwell, & Masters, 2010; Maxwell, Masters, Kerr, & Weedon, 2001). Interestingly, all of these studies examined golf putting, with no studies on short or long iron play or the driver.
Dail and Christina (2004) examined the effect of distributed practice (performing 60 putts of 3.7-m on each of four days) compared to performing all 240 putts on the same day (massed practice) using a group of 90 novice golfers. At a 28 day retention test (which only involved 15 golfers from each group), the distributed practice group had significantly less error when performing 3.7 m puts than the massed practice group. Since this result of Dail and Christina (2004) was consistent with the overall motor learning literature (Magill, 2011), it would appear that golfers should spread their practice out over the course of the week and not just perform one large weekly practice session. As acute fatigue and a loss of motivation may contribute to the reduced effectiveness of the massed practice effect (Magill, 2011), golfers who can

only practice once weekly should use some variety in their practice drills and ensure that the most physically and/or cognitively demanding drills do not cause excessive fatigue early within the practice session (Evans, Refshauge, Adams, & Barrett, 2008).

Three studies (Goodwin & Meeuwsen, 1996; Guadagnoli, et al., 1999; Porter & Magill, 2010) directly compared the learning benefits of block and random practice on golf putting performance. Additionally, Goodwin and Meeuwsen (1996) and Porter and Magill (2010) included combination practice groups that started their acquisition phase with block practice and finished with variations of variable practice. The three studies involving block and variable practice differed in the number of acquisition days (1-4), but all involved novice golfers performing putting tasks over three distances, with a retention and/or transfer test a day after acquisition. In general, Goodwin and Meeuwsen (1996) and Porter and Magill (2010) reported no significant difference in putting error between the block and variable groups in the retention and transfer tests across all three assessed distances. There were however some exceptions to this generalisation. Specifically, Goodwin and Meeuwsen (1996) found that during the transfer test, the variable and block-variable groups performed significantly better than the block group at the longer 6.23 m distance. Similarly, Porter and Magill (2010) found that the combination group performed significantly better than the block and variable groups in retention testing and significantly better than the variable group in transfer testing. Guadagnoli et al. (1999) reported a significant interaction between skill and type of practice, whereby novice golfers significantly improved their putting accuracy more through block practice, whereas experienced golfers improved significantly more through variable practice. These golf related findings were somewhat mixed and in contrast to the general motor learning literature which suggests that variable practice is more effective than block practice. Specifically, the findings of the golf studies suggest that the expected benefit of variable practice may only apply for longer, more difficult putts (Goodwin & Meeuwsen, 1996) and for experienced rather than novice gofers (Guadagnoli, et al., 1999).

Another two studies (Lam, et al., 2010; Maxwell, et al., 2001) examined the effect of errorless and errorfull block practice on golf putting learning. As Maxwell et al. (2001) also included a variable group, their results also provide some additional insight into the relative effect of variable versus block practice comparisons. Both studies involved novice golfers performing putts over eight distances and on the same day performing a retention and/or transfer test. The errorless groups in both studies had significantly greater putting accuracy in the retention and transfer tests than the other groups. Maxwell et al. (2001) also reported that when the retention tests were performed with a secondary task of tone counting**,** there were further significant reductions in putting performance for the errorfull and variable groups, but no significant changes for the errorless group. Such results supporting the benefit of errorless over errorfull learning again appear in contrast to the literature which stated that healthy individuals learn better from errorfull practice (Magill, 2011). Interestingly, the findings of Maxwell et al. (2001) also suggest that errorless block learning may be better than variable practice for novice golfers.

CONCLUSION: The results of this review suggest that golfers may improve their putting ability more by distributing their golf practice over several sessions rather than one day per week. However, the results for the relative effect of block versus variable and errorless versus errorfull learning were more mixed and somewhat in contrast to the overall motor learning literature. Based on this relatively limited body of research, there is some evidence to suggest that novice golfers should perform block putting practice starting with short distance putts and increasing this distance through the practice session; whereas more experienced golfers may benefit more from variable practice. Further studies involving golfers of varying standards who perform longer practice blocks and multiple days of retention and transfer testing are required to better confirm the initial findings. In addition, some studies should examine the short and long irons as well as the driver to better generalise the findings of the six reveiwed studies to overall golf practice.

REFERENCES:

Dail, T. K., & Christina, R. W. (2004). Distribution of practice and metacognition in learning and long-term retention of a discrete motor task. *Research Quarterly for Exercise and Sport,* 75(2), 148-155.

Evans, K., Refshauge, K. M., Adams, R., & Barrett, R. (2008). Swing kinematics in skilled male golfers following putting practice. *Journal of Orthopaedic and Sports Physical Therapy,* 38(7), 425-433.

Farrally, M. R., Cochran, A. J., Crews, D. J., Hurdzan, M. J., Price, R. J., Snow, J. T., & Thomas, P. R. (2003). Golf science research at the beginning of the twenty-first century. *Journal of Sport Sciences,* 21, 753-765.

Goodwin, J. E., & Meeuwsen, H. J. (1996). Investigation of the contextual interference effect in the manipulation of the motor parameter of over-all force. *Perceptual and Motor Skills,* 83(3 Pt 1), 735-743.

Guadagnoli, M. A., Holcomb, W. R., & Weber, T. (1999). The relationship between contextual interference effects and performer expertise on the learning of a putting task. *Journal of Human Movement Studies,* 37, 19-36.

Hume, P., Keogh, J., & Reid, D. (2005). The role of biomechanics in maximising distance and accuracy of golf shots. *Sports Medicine,* 35(5), 429-449.

Lam, W. K., Maxwell, J. P., & Masters, R. S. (2010). Probing the allocation of attention in implicit (motor) learning. *Journal of Sports Sciences,* 28(14), 1543-1554.

Magill, R. A. (2011). *Motor Learning and Control: Concepts and Applications* (9th ed.). New York: McGraw-Hill.

Maxwell, J. P., Masters, R. S., Kerr, E., & Weedon, E. (2001). The implicit benefit of learning without errors. *The Quarterly Journal of Experimental Psychology,* 54(4), 1049-1068.

Porter, J. M., & Magill, R. A. (2010). Systematically increasing contextual interference is beneficial for learning sport skills. *Journal of Sports Sciences,* 28(12), 1277-1285.