HOW EXPERTS LEARN: THE ROLE OF DELIBERATE PRACTICE

EDWARD COUGHLAN

A thesis submitted in partial fulfilment of the

requirements of Liverpool John Moores University

for the degree of Doctor of Philosophy

September 2015

Contents

Acknowledgements.....3

List of Tables and Figures.....4

Abstract.....7

Chapter 1: Review of deliberate practice theory and its applications to sport.....8

Chapter 2: How experts practice: a novel test of deliberate practice theory.....32

Chapter 3: An examination of the cognitive processes that underpin deliberate practice of a skill relevant to overall performance improvement 60

Chapter 4: Lessons from the experts: The effect of increasing cognitive processing and engagement in deliberate practice on intermediate-skilled performers.....90

Chapter 5: Epilogue.....117

Chapter 6: References 141

Chapter 7: Appendix 171

Acknowledgements

To my wife, Síofra and my two boys, Tayf and Seth, I dedicate this to you.

A sincere thank you to my Director of Studies, Dr Paul Ford, I could not have asked for better. As my family and coaching commitments changed and grew over the course of my PhD, you were a constant and for that I am truly grateful. To my supervisors, Prof Mark Williams and Dr Allistair McRobert, thank you for all your help and support along the way. I have learned more in this time than any other in my life and together you all have stimulated in me an interest in research to last me through my career, and beyond.

This PhD would not have been possible without the support throughout by the Gaelic Athletic Association (GAA). In particular, the support of Pat Daly, Director of Games for the GAA, and for that I am truly grateful.

Sincere thanks to all the senior inter-county football players from all over Ireland for their time and effort; with a special mention to the Mayo Senior Football team. Sincere thanks to DCU GAA Club and Clontarf GAA Club. In DCU, thank you Prof Niall Moyna, Dr Donal O'Gorman, Dr Noel McCaffrey, Dr Giles Warrington, Dr Paul O'Connor. In DCU Sport, a sincere thank you to Ken Robinson. In LJMU, thank you George Savage. Thank you to Dr Tynke Toering for your guidance and advice relating to the use of the SRL-SRS. In UL, thank you Dr PJ Smyth, Dr Ciaran MacDonncha, Dr Joe O'Halloran, Dr DJ Collins, Prof Phil Jakeman. In CIT, thank you Dr Cian O'Neill. To my family and friends who have offered support and light relief along the way – Thanks guys!

To my family: Síofra, Tayf and Seth – I L Y N M W R N R

Lists of Tables and Figures

1.1 Hours accumulated in solitary deliberate practice by 18 years of age for violinists who are middle-aged professionals, best in academy, good in academy, and music teachers (adapted from Ericsson et al., 1993)……. 12

2.1 Experimental set-up including graded Gaelic football goalposts through which participants could score 3pts when the ball went into the centre grid, 2pts for one grid left or right of centre, 1 pt for two grids left or right of centre, 0pts for goalpost or crossbar, -1pt for wide of goalposts or under the crossbar in the relative grid…….. 40

2.2 The 'out of the hands' kick from starting position (2a) to ball contact (2b) and the 'off the ground' kick from starting position (2c) to ball contact (2d)…… 41

2.3 Mean (SD) outcome scores for the weaker kick of the expert, intermediate and expert-control groups for the pre-test, post-test and retention test……. 49

2.4 Mean (SD) outcome scores for the stronger kick of the expert, intermediate and expert-control groups for the pre-test, post-test and retention test……. 49

2.5 Results of ANOVA on number of points scored for Group (expert, intermediate, control), Test (pre-test, post-test, retention test) and Kick (weak, strong)…….. 50

2.6 Mean (SD) scores recorded during the practice sessions using the deliberate practice tenets of enjoyment (PACES), mental effort (RSME), and physical effort (RPE) for the expert and intermediate groups during the acquisition phase……. 51

2.7 Mean (SD) frequency of verbal report statements for the expert and intermediate groups for monitoring, evaluation, and planning statements….. 53

3.1 Experimental set-up including Gaelic football goalposts. Participants could score 1 pt when the ball went over the crossbar and between the goalposts, and 0 pts for wide of the goalposts or under the crossbar…… 69

3.2 The activities chosen by the groups (expert, intermediate) for leisure…… 72

3.3 The questions asked in the post-acquisition semi-structured interview…… 73

3.4 Mean (SD) accuracy scores for the non-dominant kick of the expert, intermediate and expert-control groups for the pre-test, post-test and retention test…… 77

3.5 Results of ANOVA on number of points scored for Group (expert, intermediate), and Test (pre-test, post-test, retention test)…… 77

3.6 Mean (SD) accuracy scores for the non-dominant kick of the expert and intermediate groups for three individual practice sessions…… 78

3.7 Results of ANOVA on number of points scored for Group (expert, intermediate), and Practice (practice session 1, 2 and 3)…… 79

3.8 Mean (SD) scores recorded during the practice sessions and the leisure activity for enjoyment (4a – PACES) and mental effort (4b – RSME) for the expert and intermediate groups during the acquisition phase…… 80

3.9 Frequency of responses across the themes, categories and subcategories, with sample responses for the expert group to Question 2 of the post-study semi-structured interview. N.B. Numbers in brackets in bold represent the intermediate data…… 83

3.10 The frequency (percentage) of the 15 expert and 9 intermediate participants who reported reflecting on the kicking practice sessions at the five locations 84

4.1 Experimental set-up including Gaelic football goalposts and the 'out of the hands' kick. Participants could score 1 pt when the ball went over the crossbar and between the goalposts, and 0 pts for wide of the goalposts or under the crossbar…… 98

4.2 The self-regulation questions posed to the training group following the practice sessions…… 100

4.3 The leisure activities and the number of participants chosen by two groups (training, control) to rate for enjoyment and effort…… 102

4.4 Mean (SD) accuracy scores for the non-dominant kick of the training and control groups in the pre-, post-, and retention test…… 104

4.5 Results of ANOVA on number of points scored for Group (training, control), and Test (pre-test, post-test, retention test)…… 105

4.6 Mean (SD) accuracy scores for the non-dominant kick of the training and control groups for four individual practice sessions…… 106

4.7 Results of ANOVA on number of points scored for Group (training, control), and Practice Session (1, 2, 3, and 4)…… 107

4.8 Mean (SD) scores recorded during the four practice sessions using the deliberate practice tenets of enjoyment (PACES) and mental effort (RSME) for the training and control groups…….. 107

4.9 Themes and categories for the training group responses to the in-practice self-regulation questions…… 109

4.10 Themes and categories for the training group responses to the inter-session self-regulation questions…… 111

Abstract

The aim of this thesis was to examine how experts learn using the theory of deliberate practice. Expert and intermediate Gaelic football players practiced kicking, with their learning being assessed between a pre-test and retention test. A novel method to measure the tenets of deliberate practice during the activity, as opposed to retrospectively, was used throughout the thesis. Findings support previous research on the mechanisms and strategies engaged in by experts as they aim to improve performance and how they differ to lesser-skilled individuals. In line with the theory of deliberate practice, in Chapter 2 and 3 the experts rated practice higher for effort and lower for enjoyment, as well as practicing a more relevant skill in Chapter 2, when compared to intermediates. Moreover, they improved kicking accuracy between pre-test and retention test, whereas the intermediate group did not. In addition, the thesis identified differences between the cognitive mechanisms of experts and intermediates that underpin their respective performance. Expert groups engaged in greater cognitive processing during (Chapter 2 and 3) and between (Chapter 3) practice sessions when compared to intermediates. Chapter 4 examined the impact of applying these expert cognitive processes to the deliberate practice and performance of a youth intermediate group. A training group practiced kicking with an intervention designed to increase cognitive processing, whereas a control group practiced kicking without intervention. Findings support previous research by providing evidence of the outcome of such an intervention on deliberate practice. The training group demonstrated greater cognitive effort and less enjoyment during practice and greater improvements in accuracy after practice compared to the control group. Overall, findings in this thesis support the theory of deliberate practice and extend the research on the role of cognitive processing in effective skill acquisition.

Chapter 1: Review of deliberate practice theory and its applications to sport

[redacted]

[redacted]

[redacted]

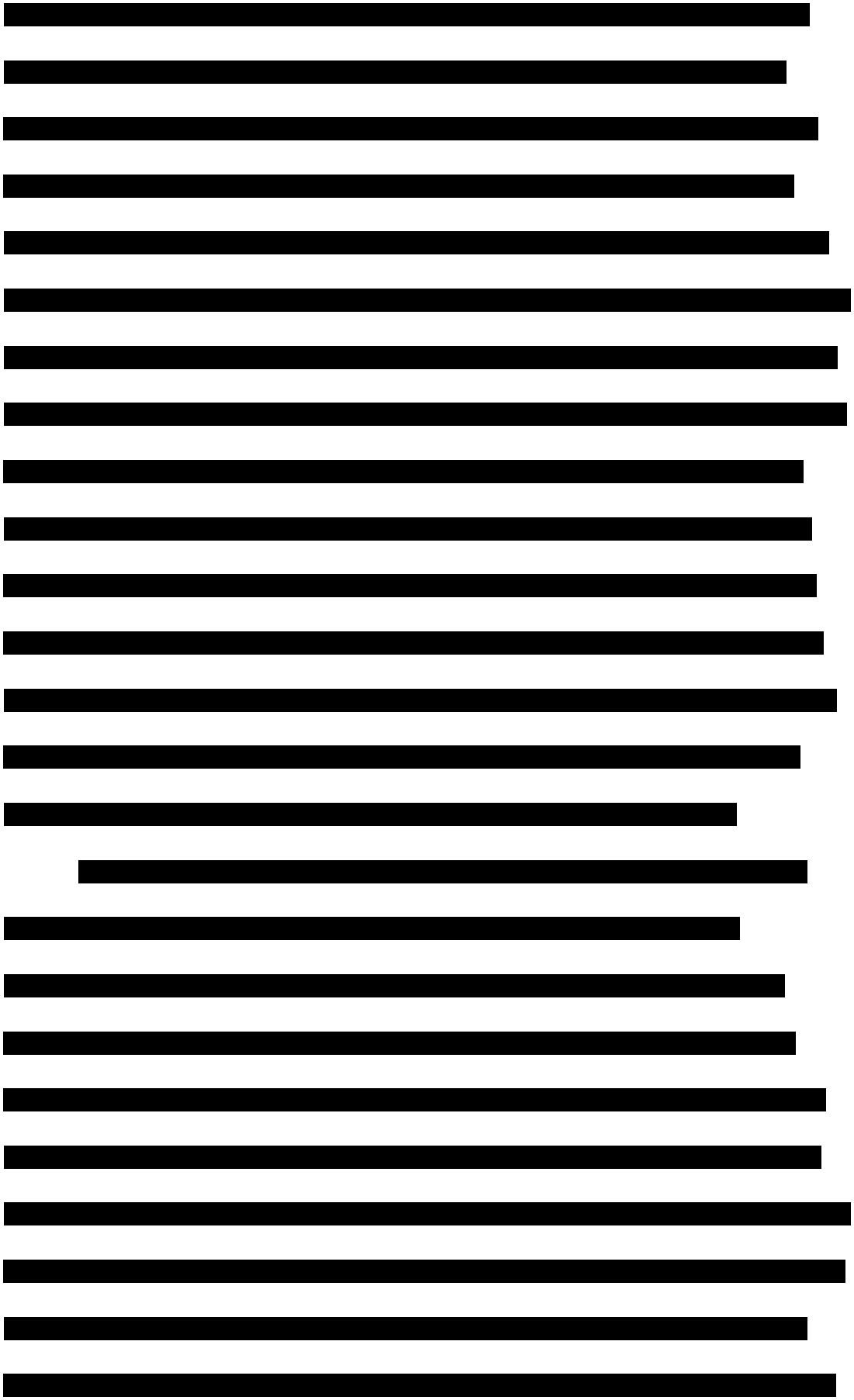
[redacted]

[redacted]

[redacted]

[redacted]

[redacted]



[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

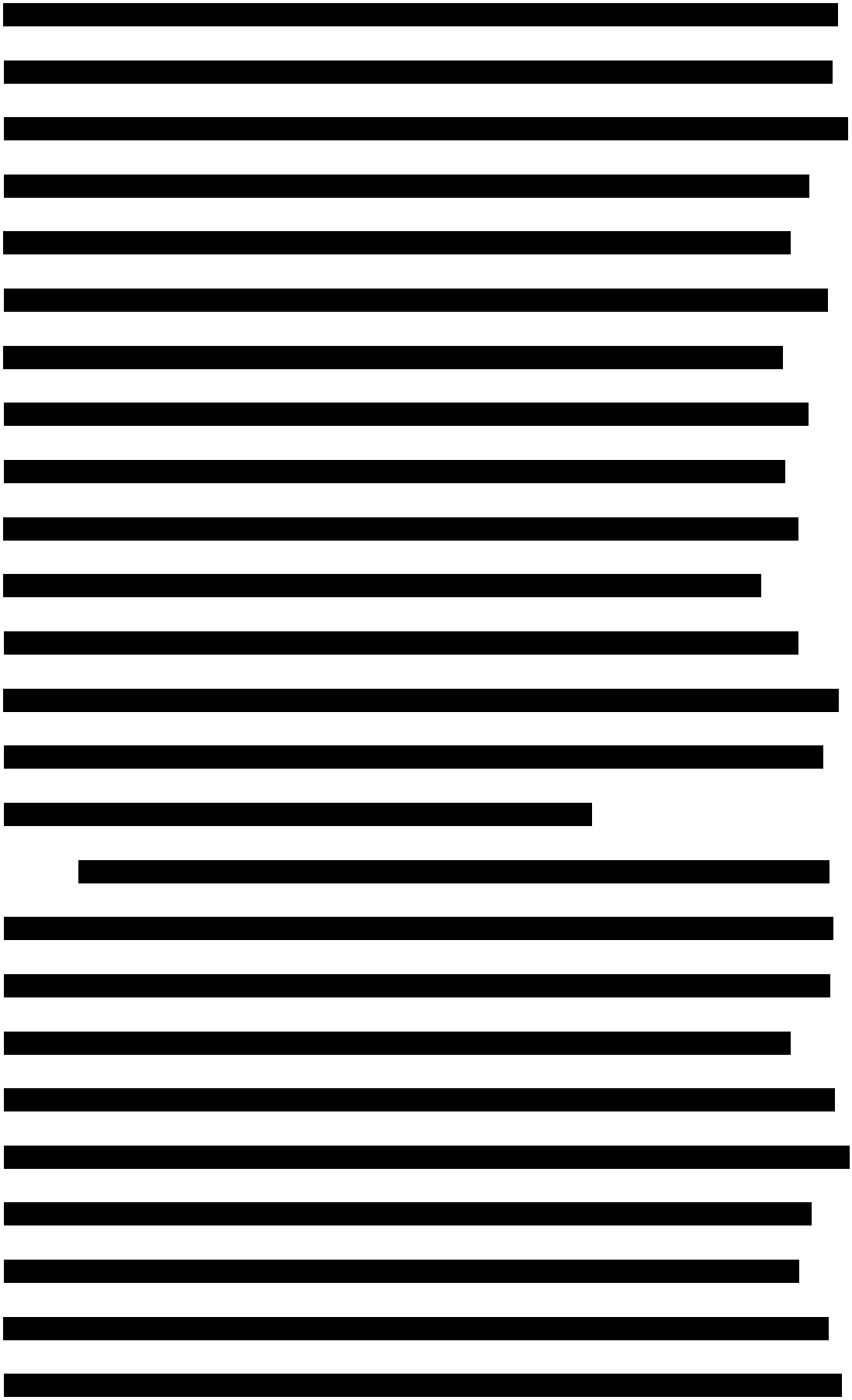
[redacted]

[redacted]

[redacted]

[redacted]

[redacted]



[redacted]

Thesis aims and hypotheses

The aim of the following thesis was to examine the tenets of deliberate practice theory and self-regulation *during* the practice of complex skills by expert and intermediate performers from the sport of Gaelic football. In Chapter 2, the aim of the study is to examine the practice behaviours of expert and intermediate performers as they self-select to practice two complex motor skills. A novel methodology was used to measure the tenets of deliberate practice during a series of practice sessions to determine how practice characteristics differentiated groups. Expert and intermediate performers were free to self-select practice of two kick tasks that were categorised as either stronger or weaker skills for each individual. In line with deliberate practice theory, the expert group were hypothesized to practice and improve the task they were weaker at more frequently compared to the task on which they were stronger. In contrast, the intermediate group were expected to practice and

improve the task they were stronger at more often compared to the task on which they were weaker. Because of this difference in skill practiced, it was expected that the expert group would experience the tenets of deliberate practice to a greater extent, including greater effort and reduced enjoyment, when compared to the intermediate group.

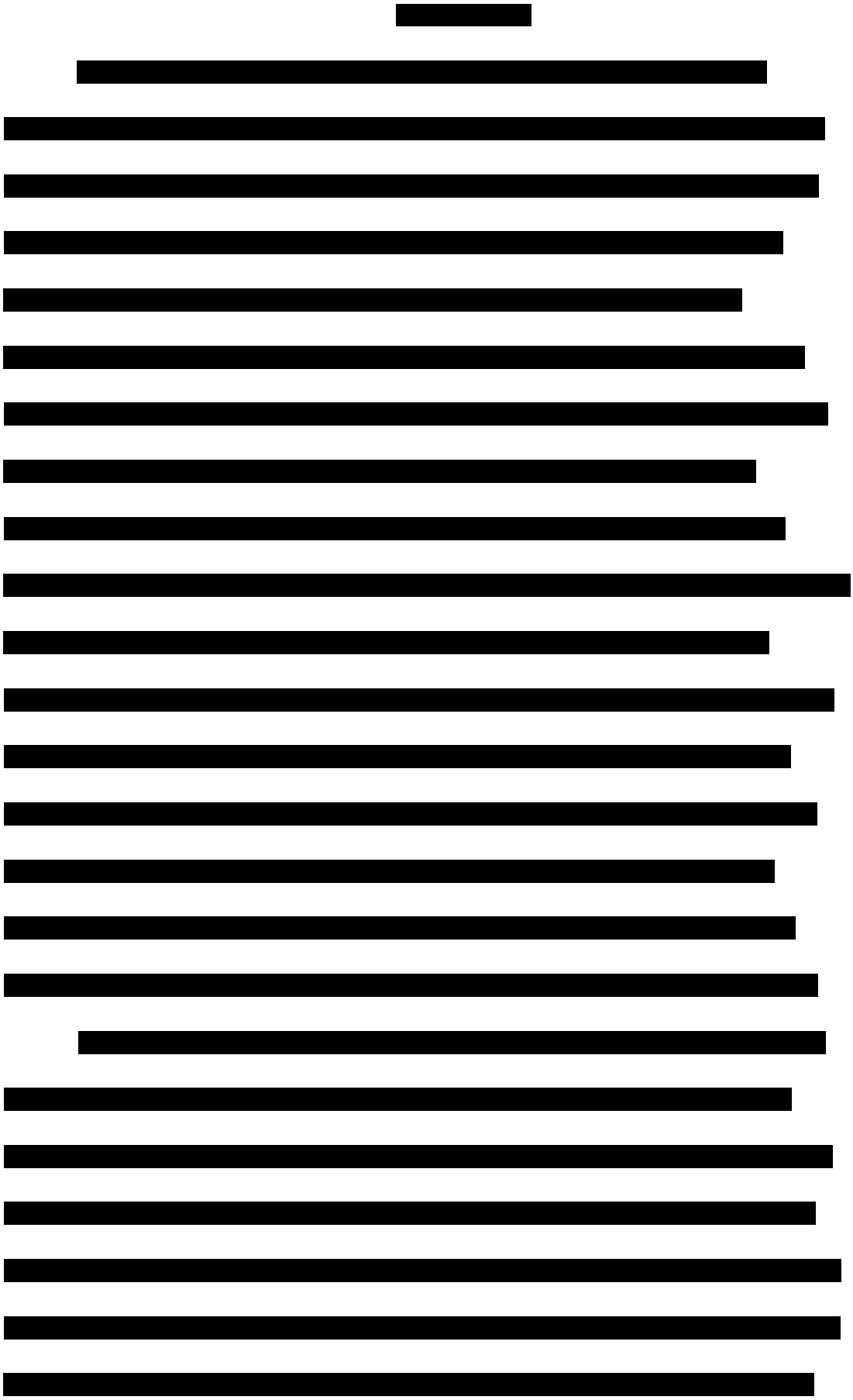
The aim of the study in Chapter 3 was to examine deliberate practice theory and self-regulation in expert and intermediate performers as they practice and reflect on a task they identified as requiring improvement. Participants identified and practiced kicking with their non-dominant foot across three practice sessions between a pre-, post-, and retention-test in an attempt to improve performance. Objective measures of cognitive effort and enjoyment from deliberate practice theory were recorded during practice, as well as self-regulation and reflective processes *between* practice sessions. It was expected that both groups would improve their performance on the kicking task, but that the expert group would make a greater and more permanent improvement in performance. The greater improvement for the expert group was expected to be associated with greater amounts of cognitive processing, including self-regulation and reflection between sessions, as well as lower ratings of enjoyment during practice and greater mental effort, when compared to the intermediate group.

The aim of the experiment in Chapter 4 was to create an intervention to examine the effect of deliberate practice and self-regulation on youth intermediate performers as they practice a task they identified as requiring improvement. Participants practiced kicking with their non-dominant foot across four practice sessions between a pre-, post-, and retention-test in an attempt to improve performance. Objective measures of reflection and evaluation were recorded at the

pre- and retention-test stage for both groups. During and between practice sessions one group engaged in a structured cycle of self-regulation, whereas the other group practiced without this additional intervention. Objective measures of cognitive effort and enjoyment from deliberate practice theory were recorded during practice for both groups. It was expected that both groups would improve their performance on the kicking task, but the self-regulation group were expected to make a greater and more permanent improvement in performance. The greater improvement for this group was expected to be associated with greater cognitive processes of self-regulation during and between sessions, as well as their rating practice sessions greater for mental effort and lower for enjoyment, when compared to the other group.

Chapter 2: How experts practice: a novel test of deliberate practice theory

[redacted]



[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

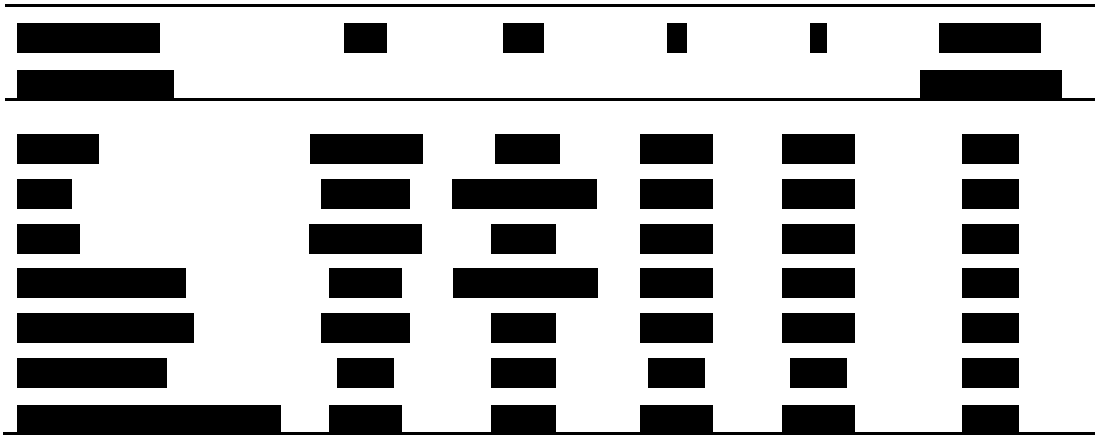
[redacted]

[redacted]

[redacted]

[redacted]

[redacted]



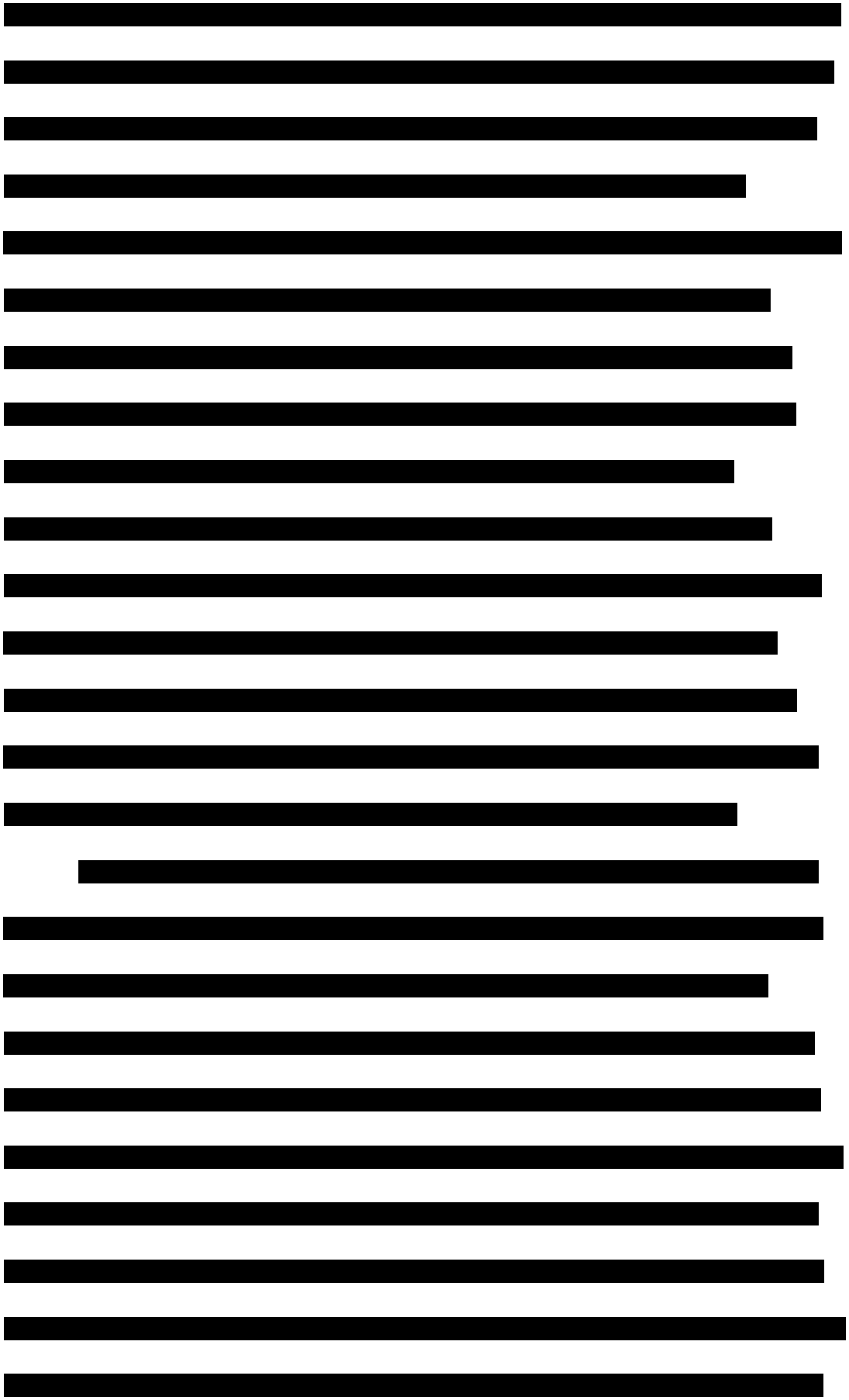
[redacted]

[redacted]

[redacted]

[redacted]

[redacted]



[redacted]

[redacted]

[redacted]

Chapter 3: An examination of the cognitive processes that underpin deliberate practice of a skill relevant to overall performance improvement

Abstract

Cognitive processes are thought to underpin deliberate practice before, during and after the activity. The aim of this study was to examine the cognitive processes of expert and intermediate performers during and between bouts of practice and its association to performance improvement. Expert and intermediate Gaelic football players practiced a kick they identified as relevant to improving overall performance during an acquisition phase and completed pre-, post-, and retention tests. During acquisition, participants rated practice for the deliberate practice tenets of effort and enjoyment. The expert group improved kicking accuracy between pre-, post- and retention tests. In contrast, the intermediate group improved kicking accuracy from pre-test to post-test, but not between pre-test and retention test. The expert group rated their practice as more effortful and less enjoyable compared to the intermediate group, whilst both groups rated the practice less enjoyable than leisure activity. The expert group demonstrated greater engagement in self-regulatory cognitive processes, such as reflection and evaluation, within and between practice sessions when compared to the intermediate group. Findings provide support for the theory of deliberate practice, as well as evidence of the cognitive processing that underpins how experts practice, learn and improve performance beyond its current level.

Introduction

The acquisition and continued improvement of expert performance is required in most domains. Practice and engagement in other domain-specific activities contributes to performance improvement. The concept of *deliberate practice* was introduced by Ericsson, et al. (1993) as a specific type of practice activity that differs when compared to other types of practice. Deliberate practice is designed to improve key aspects of current performance, is effortful, and may not be inherently enjoyable or immediately rewarding (Ericsson et al., 1993). It has been shown to involve more cognitive processing compared to other activities (e.g., Coughlan, et al., 2014). However, only a few researchers have examined the cognitive processes employed by expert performers during practice and how these may differ to lesser-skilled performers (e.g., Cleary & Zimmerman, 2001), but never during deliberate practice. In this study, the cognitive processes employed by expert and intermediate performers engaging in deliberate practice of a complex perceptual-motor skill are examined.

Ericsson et al. (1993) examined the practice activities of four groups of violinists, three of which were based at the Berlin Music Academy. The groups in the Academy were the best violinists, good violinists, and music teachers. The violinists were selected into groups based on the level of competition they entered, the complexity of music they could perform and the expert opinion of music professors at the Academy. The fourth group were middle-aged professionals performing in world-class orchestras. Participants retrospectively recalled the amount of time spent in practice activities via interviews and diaries. The hours accumulated in solitary deliberate practice were positively related to the level of attainment of the musicians. By the age of 18 years, the middle-aged professionals

and the best violinists had accumulated 7,336 and 7,410 hours of solitary deliberate practice, respectively. In comparison, the good violinist group and the music teacher group had accumulated 5,301 and 3,420 hours, respectively. Subsequently, researchers examining performers in a range of domains have provided support for the positive relationship between deliberate practice and attainment (for reviews, see Baker & Young, 2014; Ericsson, 2004).

Ericsson et al. (1993) required participants to rate a taxonomy of everyday activities (e.g., household chores, shopping, leisure, sleep) and musical activities (e.g., solo performance, group performance, practice alone, practice with others). Participants rated each activity on a scale of 1 to 10 for how relevant it was to improving their overall musical performance, how much effort they expended during the activity, and what level of enjoyment they experienced during it, ensuring the outcome of the activity did not influence their rating. The rating scores for each activity were collapsed across groups and compared against the grand mean for all activities. The only everyday activity that scored higher for relevance than the grand mean was sleep. In relation to the musical activities, practice alone was rated highest for relevance to improving performance. Practice with others, taking music lessons, solo and group performance, music theory and listening to music all rated higher for relevance to improving performance when compared to the grand mean. The musical activities that were rated higher than the grand mean for relevance to improving performance were rated higher than the grand mean for effort and not different to the grand mean for enjoyment, apart from listening to music and, for enjoyment only, group performance. Ericsson et al. (1993) concluded that engagement in deliberate practice will be rated as effortful, low in inherent enjoyment and highly relevant to improving performance. Researchers have generally supported these predictions

when examining deliberate practice in a range of domains e.g., in sport, (Coughlan et al., 2014), although there is some debate about the level of enjoyment from engaging in the activity (for a review, see Ford, Coughlan, Hodges, & Williams, 2015).

Engagement in deliberate practice activity requires engagement in cognitive processing. Expert performers are thought to maintain cognitive control over their performances and practice by using working memory to monitor, plan, predict, reason, evaluate, and make other inferences towards improved future performance (Ericsson & Delaney, 1999; Ericsson & Kintsch, 1995, Sonnentag, 1998). Experts employ an analytical mind-set, utilizing feedback and feed-forward information or strategies to identify errors and make corrections to training and performance (Ericsson, 2006a). To do so, their working memory is expanded beyond conventional limits so that it can rapidly encode and retrieve domain-specific information. These dynamic memory representations that are online before, during, and after performance have been termed *long-term working memory* (LTWM, Ericsson & Kintsch, 1995).

The planning, reasoning, and evaluating towards the improvement of future performance outlined in deliberate practice theory aligns with the characteristics of *self-regulated learning* (e.g., Zimmerman, 1986). Self-regulated learning involves forethought, performance, and reflection, engaging performers in metacognitive, motivational, and behavioural processes and activities (Zimmerman, 1986; Zimmerman & Campillo, 2003). Forethought involves the motivational beliefs and learning processes that precede and potentially improve practice, learning, and performance. Performance addresses the quality and quantity of practice, learning, and performance. Reflection involves the cognitive processes that occur during and following periods of learning, practice, and performance (Zimmerman, 2006). Self-

regulation is a cognitive process linking domain-specific knowledge and metacognitive knowledge, enabling performers to consider plans made prior to practice, assess and adjust them during practice, and evaluate practice afterwards to begin the next cycle (Ertmer & Newby, 1996). Reflective, cognitive, and neural processes consolidate practiced skills to memory resulting in more permanent skill retention depending on the intensity of the process (Brashers-Krug, Shadmehr, & Bizzi, 1996).

Researchers (e.g., Jonker, Elferink-Gemser, & Visscher, 2010; Toering, Elferink-Gemser, Jordet, Jorna, Pepping, & Visscher, 2011; Toering, Elferink-Gemser, Jordet, & Visscher, 2009; Toering, Jordet, & Ripegutu, 2013) have examined the amount of self-regulation engaged in by skilled athletes. The self-regulatory aspects they assessed were monitoring, planning, and evaluation (see also, Ericsson & Delaney, 1999; Ericsson & Kintsch, 1995); and in addition, effort, self-efficacy, and reflection. They combined previously validated questionnaires assessing each aspect of self-regulation such as evaluation [Inventory of Metacognitive Self-Regulation (IMSR); Howard, McGee, Shia, & Hong, 2000] and self-efficacy (general self-efficacy scale; Schwarzer, 1993). These questionnaires contain Likert items on general traits related to self-regulation (e.g., "I correct my errors") requiring scaled responses (e.g., "always" to "never"). The combined questionnaire was distributed to 159 elite and 285 non-elite youth soccer players in the Netherlands (Toering et al., 2009). Elite players were distinguished from non-elite by having higher scores for their responses on reflection and effort, but not planning, monitoring, self-efficacy, and evaluation. In another study, Jonker et al. (2010) examined the responses of skilled youth athletes in the Netherlands across team and individual sports to the same combined questionnaire. International

standard performers demonstrated higher scores for reflection when compared to national standard performers, but there were no group differences for the other aspects of self-regulation (i.e., forethought and performance). Athletes from individual sports had higher scores for planning and effort compared to team sport athletes, but there were no between-group differences for the other aspects. Across both studies, higher skilled groups demonstrated greater self-regulation behaviours compared to lower-skilled groups. However, the questionnaires used in these studies measure general traits related to self-regulation that are open to biased responses and may not reflect actual behaviour as it occurs in the training environment. Moreover, the questionnaires do not assess the association between the self-regulation processes and the amount of performance improvement emanating from practice.

Some researchers have measured self-regulation processes as they occurred during the activity (Cleary & Zimmerman, 2001; see also Kitsantas & Zimmerman, 2002). For example, in Cleary and Zimmerman (2001), self-regulation processes were examined during the basketball free-throw practice of 15 expert, 13 intermediate, and 15 novice performers. Participants were required to practice 10 free-throw shots for approximately 10 minutes. When they either missed or scored two shots consecutively they answered a series of questions relating to their self-efficacy, self-satisfaction, goal-setting, strategy choice, and attributions. These measures are similar, if not identical, to those of monitoring, planning, and evaluation used elsewhere (Ericsson & Delaney, 1999; Ericsson & Kintsch, 1995; Jonker et al., 2010; and Toering et al., 2009). Experts had greater self-efficacy judgements than the other groups. Following two consecutive misses during practice, 53% of the experts attributed the misses to technique issues, in comparison to 15% of the intermediates and 13% of the novices. For the next trial following two

consecutive misses, 66% of the experts indicated that technique was their focus to ensure a successful trial, whereas only 20% of the intermediates and 7% of the novices did so. The expert group set more specific goals during practice than the other two groups. However, in this study, the researchers did not measure whether the practice and self-regulation led to performance improvement. Moreover, few, if any researchers have sought to measure the self-regulation processes that occur outside of practice bouts and how they are associated with performance improvement.

In the current study, the self-regulatory process of reflection of expert performers is examined during and between bouts of practice and its association to performance improvement when compared to intermediate performers. The expert and intermediate performers played the sport of Gaelic football. Gaelic football is the national sport of Ireland with over 2,300 clubs for a population of five million. It is a field invasion sport consisting of 15 players on each team who score points by kicking a ball between opposition goalposts. The sport shares characteristics with rugby, soccer, and Australian Rules football. Prior to the study, participants each independently identified kicking with their non-dominant foot towards goal as the skill they most needed to improve. They practiced this skill across three practice sessions between a pre-, post, and retention-test in an attempt to improve performance. During the practice, objective measures of the cognitive effort and enjoyment from deliberate practice theory were recorded. A reflection scale (Toering, Elferink-Gemser, Jonker, van Heuvelen, & Visscher, 2012) was administered to measure their cognitive processes between practice sessions. According to deliberate practice theory, the expert group should rate their practice lower for enjoyment and greater for mental effort compared to the intermediate

group. They should engage in self-regulatory processes and reflect on their practice to a greater extent compared to the intermediate group. Their self-regulation should be more effective, involving more specific goal-setting relating to process and outcome goals. The participants whose self-regulation data is of greater intensity and quality should experience greater improvements in performance. Finally, although both groups were expected to improve kicking performance during the practice sessions, the expert group were expected to make a greater and relatively permanent improvement in performance as a result of their cognitive processes of self-regulation.

Method

Participants

An initial selection process involved 56 Gaelic football players (41 expert and 15 intermediate players) notating in rank order the three football skills that they believed would have the greatest impact on improving their overall competition performance. Expert players were contracted to a senior County-level Gaelic football team that plays at the highest level of the sport in the country. Intermediate participants played lower-level club Gaelic football. There were 45 players (30 expert and 15 intermediate participants) who chose improving the kick from the hands (punt) with the non-dominant foot as the main skill they wished to improve and who, subsequently, became the participants in this study. The 11 expert players who did not choose improving the non-dominant kick as the main skill they wished to improve took no further part in the study. The 30 expert Gaelic football players were randomly divided into two groups of 15 players. One set of expert players formed the experimental group (n = 15; M age = 24.4 years, SD = 2.7, M playing years = 18.5 years, SD = 2.8). The other set formed a control group of expert players

(*n* = 15; *M* age = 24.6 years, *SD* = 3.5, *M* playing years = 18.9 years, *SD* = 3.5) who did not practice. A third group contained the intermediate players (*n* = 15; *M* age = 24.4 years, *SD* = 2.5, *M* playing years = 18.2 years, *SD* = 3.1). Participants provided informed consent prior to the study and the research was conducted according to the ethical guidelines of the lead institution.

Task and apparatus

The skill that was chosen by the players to improve was the kick from the hands with their non-dominant foot. In this study, the task required participants to execute kicks toward Gaelic football goalposts (height = 10m, width = 6.5m, crossbar height = 2.5m) with the intention of getting the ball over the crossbar to register a score. Figure 3.1 shows the experimental set-up and a participant executing a kick. On each kick participants were awarded one point if the ball entered between the goalposts and over the crossbar, but zero points if it did not.

Figure 3.1: Experimental set-up including Gaelic football goalposts. Participants could score 1 point when the ball went over the crossbar and between the goalposts, and 0 points for wide of the goalposts or under the crossbar.

In Gaelic football, kicks from the hands are used frequently to pass the ball to a team-mate, restart play when a foul has been committed, and depending on the

location on the pitch and closeness to the goal an attempt on goal is made by the player to score a point. A $4m^2$ kicking zone was marked out with cones at a distance of 30m directly in front of the goalpost target. Fifteen standard round-shaped Gaelic footballs (O'Neill's size-5 GAA All-Ireland footballs, Belfast, Northern Ireland) were placed on the ground immediately behind the kicking zone. A digital video camera (Canon Legria FS200, Canon, Tokyo, Japan) was used to record performance from 10m directly behind the kicking zone.

Procedure

The experiment consisted of a pre-test, an acquisition phase of three practice sessions, and a post-test, all of which occurred across a five day period, as well as a delayed retention test that occurred four weeks after the post-test (Shea, Lai, Black, & Park, 2000). The pre-test and first practice session occurred on the first day of the study period, whereas the second practice session occurred on the third day. The last practice session and post-test occurred on the fifth day, with the second and fourth days being non-practice days. The expert and intermediate groups engaged in all the tests and practice sessions, whereas the expert control group completed only the pre-, post- and retention tests.

Prior to the pre-test, verbal instructions were provided to each participant regarding the pre-test and experimental procedures outlining the timeline of the study, the content of each session and the measures to be collected. The pre-test occurred two hours before the first practice session. It consisted of 10 kicks toward the goal from the hands using the non-dominant foot. Participants engaged in two familiarisation trials prior to the pre-test. Following the pre-test, each participant was informed of his score, which was calculated as a function of ten points. The post-test and the retention test were the same as the pre-test. Prior to each of the three practice

sessions in the acquisition phase, the participants were reminded of their pre-test score and were informed that the goal of the task was to improve their pre-test score (Boyce, 1992). Each practice session began with two warm-up trials. A practice session consisted of 15 kicks from the hands using the non-dominant foot towards the goalposts. The score achieved on every trial was recorded using hand notation by the lead experimenter during the practice, which was checked for accuracy against the video footage.

Deliberate practice measures. Immediately following each of the three practice sessions, participants filled in two valid and reliable self-report measures to rate the effort and enjoyment tenets of deliberate practice for that particular session (Coughlan et al., 2014). The mental effort prediction was examined using the Rating Scale of Mental Effort (RSME, Zijlstra & Van Doorn, 1985). It is a continuous uni-dimensional scale with eight points that range from 0 (absolutely no effort; 0%), 75 (considerable effort; 50%), to 150 (extreme effort; 100%). The enjoyment prediction of the theory was examined using the Physical Activity Enjoyment Scale (PACES, Kendzierski & DeCarlo, 1991), which is used to examine enjoyment levels during physical activities. It consists of 18 Likert-scaled comments relating to the current activity with 11 of the comments reversed scored.

In addition, participants were required to complete both the RSME and PACES scale immediately following engagement in a leisure activity of their choice that occurred on a separate day after the study period. The activity chosen was required to be engaged in frequently by the participant with the focus of leisure, rather than performance improvement. The intention was to use the data collected from the two measures of leisure activity to compare against the same measures

collected during the practice sessions. Table 3.2 shows the leisure activities chosen by the participants.

Table 3.2: The activities chosen by the groups (expert, intermediate) for leisure.

Leisure Activity	Expert	Intermediate
Gym	1	1
Soccer	4	2
Motor-car racing	1	0
Cycling	1	0
Golf	3	3
Rowing	1	0
10-pin bowling	1	0
Computer games	1	0
Shooting	1	0
Swimming	1	1
Hurling	0	3
Athletics	0	1
Tennis	0	1
Rugby	0	2
Fishing	0	1

Self-regulation measures. On the two non-practice days in the study period, participants completed the sport-specific Self-Regulation of Learning Self-Report Scale [(SRL-SRS), Toering, et al., 2012]. The questionnaire comprised of 18 questions that related to the *reflection* processes that take place on the day after a practice session, such as "since yesterday's training session I have thought back and evaluated whether I did the right things to become a better kicker". It also includes *evaluation* process questions such as "in each of these training sessions I try to identify my strengths and weaknesses and I think about how I can improve these". Each question contained a five point Likert scale ranging from "never" to "always".

The post-test was the same as the pre-test. It was conducted at the end of the last day of the five-day study period, two hours after the last practice session finished. The following day after the post-test, participants took part in a short semi-structured interview containing relatively closed questions to measure the frequency,

intensity, location, and nature of their cognitive processes during the study period. The questions from the interview are shown in Table 3.3. The first question was 'This week did you find yourself thinking about the kicking training when you were not at training?', which required a yes/no answer. Following a "yes" response to the first question, four subsequent questions were asked to accommodate deeper investigation (e.g., "If yes, what were you thinking of mainly?"). Following a negative response to the first question, one question was asked, which was "If no, was that intentional?".

Table 3.3: The questions asked in the post-acquisition semi-structured interview.

Q1.	This week, did you find yourself thinking about the kicking training sessions when you were not at training?
Q2.	If yes, what were you thinking of mainly?
Q3.	If yes, were these thoughts mainly intentional on your part or were they intrusions? If needed, could you expand further?
Q4.	If yes, when and where did this occur?
Q5.	If yes, for how long did these occur and how often in the day?
Q.6	If no, was that intentional?

Data Analysis

Accuracy. Mean accuracy scores were calculated as a function of group, test and practice session. The calculation was from 10 kicks per test (pre-, post-, retention test), whereas for the practice sessions it was for 15 kicks per practice session. Accuracy scores from the tests were analysed using 3 Group (expert, intermediate, control) x 3 Test (pre-, post-, retention test) ANOVA, with repeated measures on the last factor. The practice session accuracy scores were analysed using a 2 Group (expert, intermediate) x 3 Practice Session (first, second, third) ANOVA, with repeated measures on the last factor. For all ANOVAs, Tukey HSD tests and the Dunn-Bonferroni adjustment calculation were used as *post-hoc* tests

where appropriate. Cohen's *f* formula was used to calculate effect size for measures involving more than two means, whereas Cohen's *d* was calculated for effect sizes involving two means (Cohen, 1988). Values equal to or greater than 0.2, 0.5, and 0.8 represent a small, moderate, and large effect size, respectively.

Deliberate practice measures. The data from each of the two deliberate practice scales (enjoyment, mental effort) collected immediately after the practice sessions were calculated separately into a single mean score for each participant that represented the amount of that variable experienced during the practice phase. The leisure activity ratings were also calculated into a single mean score for each participant that represented the amount of that variable (enjoyment, mental effort) experienced during that activity. The scale scores from the practice sessions and from the leisure activity were mathematically transformed into percentages to make interpretation, comparison, and plotting of data clearer. Percentage scores for each rating type (enjoyment, mental effort) were analysed in separate 2 Group (expert, intermediate) x 2 Activity (practice, leisure) ANOVAs, with repeated measures on the last factor.

Reflection and evaluation. The data from the SRL-SRS reflection questionnaire that was collected on the non-practice days were calculated to give an overall mean score for each participant that represented the amount of reflection and evaluation they undertook across practice. The mean amount of reflection and evaluation was analysed between the expert and intermediate groups using an independent *t*-test.

The recorded interview data were transcribed verbatim using natural speech and syntactical markers (Hardy, Jones & Gould, 1996). The first question was "This week did you find yourself thinking about the kicking training when you were not at

training?". Responses were coded as a frequency with one mark for a positive "yes" answer and one mark for a negative "no" answer. A chi-square test for independence with Yates Continuity Correction was conducted on the frequency of positive responses between the expert and intermediate groups. The second and third questions were about the nature of cognitive processes. The second question was "If yes, what were you thinking of mainly?". Responses were analysed by the lead investigator using thematic coding. The interview responses were read and reread to identify themes, categories, and subcategories, with the number of statements within each of these recorded as a function of skill group. Themes, categories, and subcategories were discussed, verified, and agreed to be appropriate representations of the data by the project supervisors.

The third question was "If yes, were these thoughts mainly intentional on your part or were they intrusions?". Responses to the third question were coded separately for each thought-type as a frequency of participants, with one mark for 'intentional only', one mark for 'intrusion only', and one mark for 'both intentional and intrusion'.

The fourth question related to the location where the thoughts occurred. Responses to the fourth question ("If yes, where did this occur?") were used to create a location category (e.g., car, bedtime, home) and were coded as a frequency of participants in each group who responded that they reflected at that location. Responses were analysed by the lead investigator and the locations identified were agreed and verified to be appropriate by the project supervisors.

The fifth question was about the frequency and duration of thoughts ("If yes, for how long did these occur and how often in the day?"). Responses to the fifth question were divided into two categories for both frequency and duration. After

initial inspection of the responses, the frequency category was divided into two further categories: lower frequency (≤ 2 times per day) and higher frequency (> 2 times per day). The duration category was divided into two categories: shorter duration (≤ 3 min per day) and longer duration (> 3 min per day). Responses were coded as a frequency of participants in each group who reported frequency and duration within a category.

A random sample of 10% of the interview data was re-coded separately by an independent investigator and the lead investigator to assess the objectivity of the analysis. Inter- and intra-observer agreements were calculated using the equation: (agreements / (agreements + disagreements)) x 100 (Thomas & Nelson, 2001). The inter-observer agreement value was 89% and the intra-observer agreement value was 92%, which are greater than the 85% threshold required to show objectivity.

The alpha level required for significance for all tests was set at $p < .05$.

Results

Accuracy

Tests. Figure 3.4 shows mean number of points scored by the expert, intermediate, and expert-control groups across the pre-, post-, and retention tests. There were significant main effects for Group and Test in the predicted directions, and a significant Group x Test interaction. *Post-hoc* analysis showed that at pre-test the intermediate group (M = 1.5 points, SD = 1.0), 95% CI [1.0, 1.9] were less accurate compared to the expert (M = 4.9 points, SD = 0.7), 95% CI [4.4, 5.3] and expert-control groups (M = 4.7 points, SD = 1.0), 95% CI [4.3, 5.2], whereas there was no difference between the two expert groups. However, the expert group scored significantly more points on the post-test (M = 6.7 points, SD = 1.0), 95% CI [6.3, 7.1] and retention-test (M = 6.4 points, SD = 0.8), 95% CI [5.9, 6.9] compared to the

pre-test and compared to *both* of the other groups. In contrast, the expert-control group accuracy scores were not significantly different across the three tests.

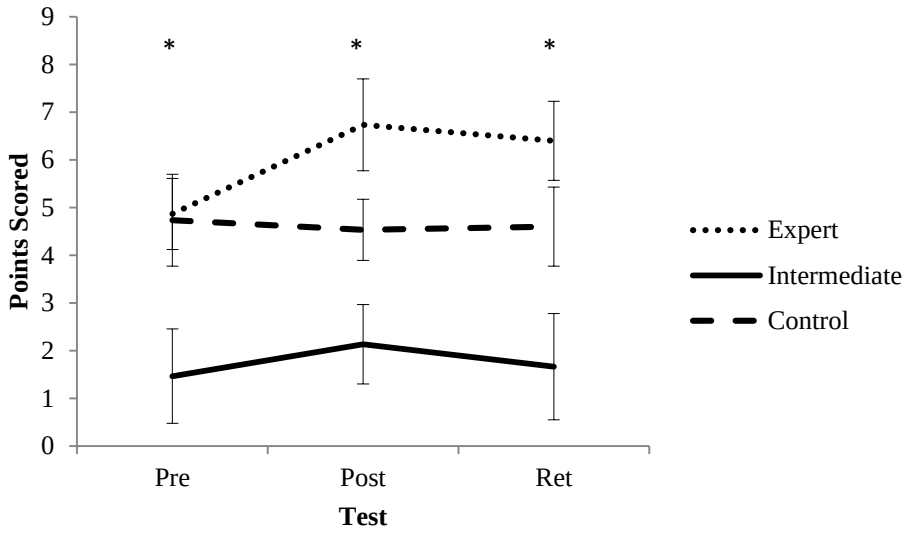


Figure 3.4: Mean (SD) accuracy scores for the non-dominant kicks of the expert, intermediate and expert-control groups for the pre-test, post-test and retention test.

Table 3.5 shows the statistical results for the ANOVA conducted on number of points scored during the tests.

Table 3.5: Results of ANOVA on number of points scored for Group (expert, intermediate, control), and Test (pre-test, post-test, retention test).

Variable & Comparison	*MS*	*dof*	*F*	*P*	Cohen's Effect Size
Group	210.99	2, 42	157.61	0.00*	0.89
Test	7.12	2, 84	13.87	0.00*	0.25
Group x Test	4.83	4, 84	9.41	0.00*	0.67

Note. ANOVA = analysis of variance

* $p < .05$

However, although the intermediate group scored significantly more points in the post-test (M = 2.1 points, SD = 0.8), 95% CI [1.7, 2.6] when compared to the pre-

test, they were unable to maintain this improvement on the retention test (*M* = 1.7 points, *SD* = 1.1), 95% CI [1.2, 2.2], where their accuracy scores returned to pre-test levels.

Practice. Figure 3.6 shows the accuracy in terms of number of points scored by the expert and intermediate groups across the three practice sessions.

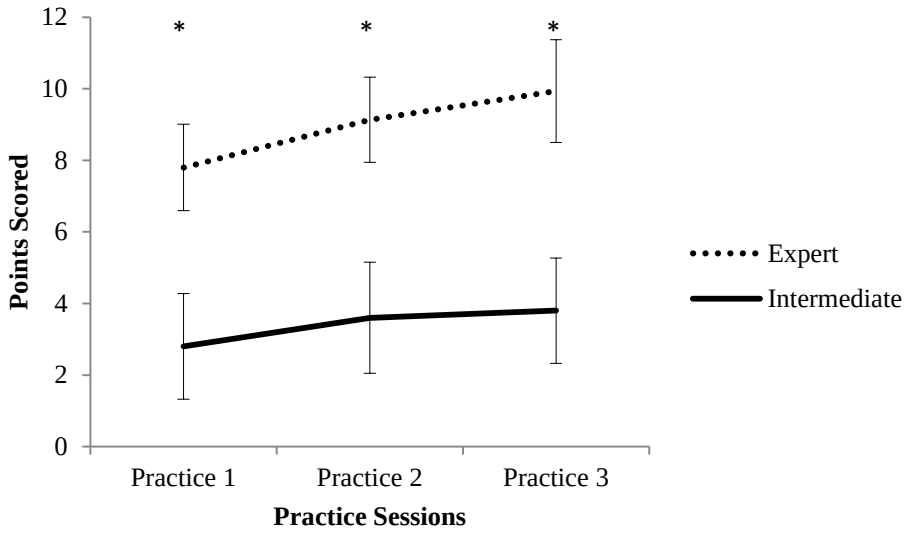


Figure 3.6: Mean (SD) accuracy scores for the non-dominant kicks of the expert and intermediate groups for three individual practice sessions.

Table 3.7 shows the statistical results for the ANOVA on number of points scored during the practice sessions. There was a significant main effect for Group in the predicted direction. The expert group were more accurate during practice compared to the intermediate group. The Group x Practice session interaction approached significance (*p* = .06). *Post-hoc* analysis showed the expert group improved accuracy significantly from the first (*M* = 7.8 points, *SD* = 1.2), 95% CI [7.1, 8.5] to the second (*M* = 9.1 points, *SD* = 1.2), 95% CI [8.4, 9.9] and from the second to the third (*M* = 9.9 points, *SD* = 1.4), 95% CI [9.2, 10.7] practice session. In comparison, the intermediate group significantly improved accuracy from the first

(*M* = 2.8 points, *SD* = 1.5), 95% CI [2.1, 3.5] to the second session (*M* = 3.6 points, *SD* = 1.6), 95% CI [2.9, 4.3], but not from the second to the third session (*M* = 3.8 points, *SD* = 1.5), 95% CI [3.0, 4.6].

Table 3.7: Results from ANOVA on number of points scored for Group (expert, intermediate), and Practice (practice session 1, 2 and 3).

Variable & Comparison	*MS*	*dof*	*F*	*p*	Cohen's Effect Size
Group	694.44	1, 28	165.66	0.00*	0.41
Practice	19.21	2, 56	23.34	0.00*	0.91
Group x Practice	2.41	2, 56	2.93	0.06	0.32

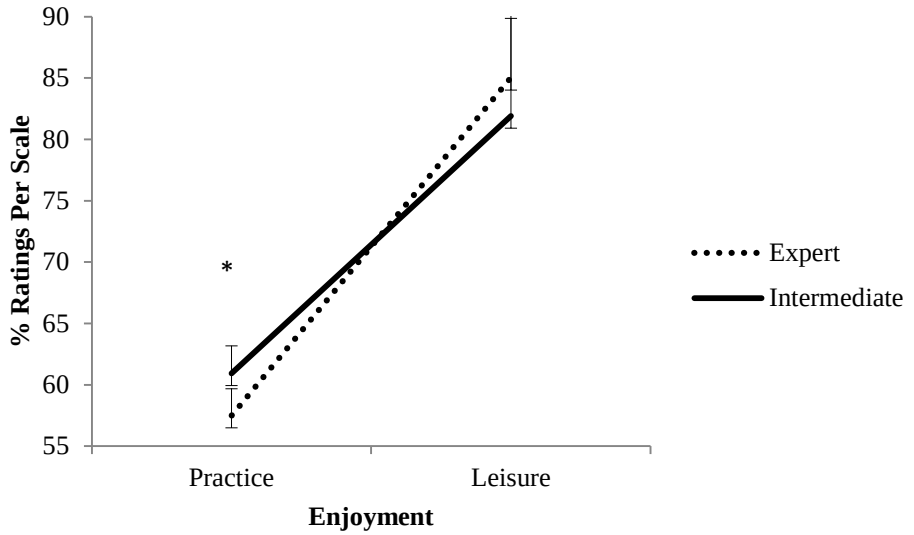
Note. ANOVA = analysis of variance

* $p < .05$

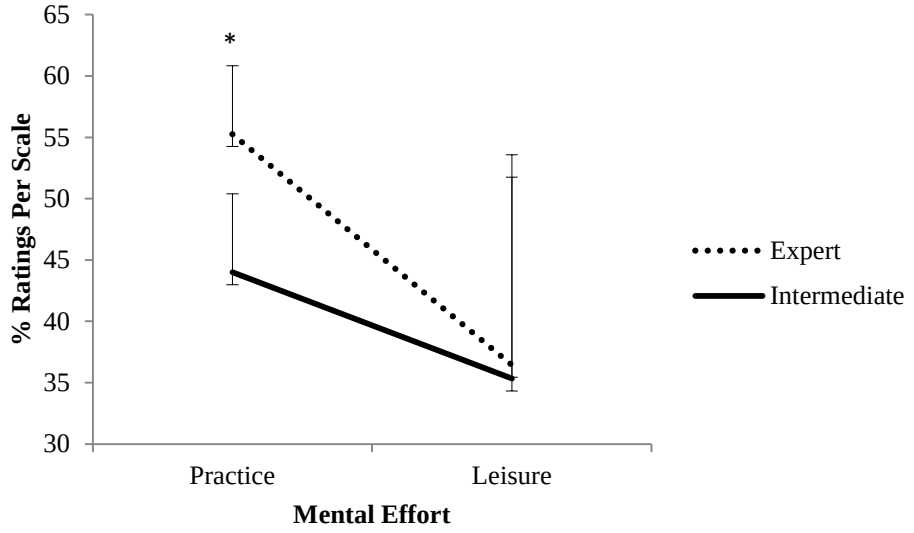
Deliberate practice measures

Figure 3.8 shows the percentage ratings for mental effort and enjoyment by the expert and intermediate groups across the practice sessions and the leisure activity. For enjoyment, there was a significant main effect for Activity, $F_{1, 28}$ = 243.61, p = .00, d = 4.17. *Post-hoc* analysis showed enjoyment was greater in leisure compared to the practice activity. There was a significant Group x Activity interaction, $F_{1, 28}$ = 4.46, p = .04, f = .01. *Post-hoc* analysis reported that the expert group (*M* = 57.5%, *SD* = 2.2) rated the practice sessions as significantly less enjoyable compared to the intermediate group (*M* = 60.9%, *SD* = 2.2), whereas there was no difference between-groups for their enjoyment of leisure activity (*M* = 83.5%, *SD* = 8.8). With respect to mental effort, there was no main effect for Group though the result did approach statistical significance (p = .07) in the predicted direction. There was a significant main effect for Activity, $F_{1, 28}$ = 18.01, p = .00, d =

1.11. *Post-hoc* tests showed that mental effort was greater during practice compared to leisure activity.



4a



4b

Figure 3.8: Mean (SD) scores recorded during the practice sessions and the leisure activity for enjoyment (4a – PACES) and mental effort (4b – RSME) for the expert and intermediate groups during the acquisition phase.

Though the ANOVA showed no Group x Activity interaction, $F_{1, 28} = 2.47$, $p = .13$, $f = .01$; an independent *t*-test did show the expert group ($M = 55.3\%$, $SD = 5.6$;

considerable effort, Zijlstra & Van Doorn, 1985) rated the practice sessions significantly greater for mental effort compared to the intermediate group (M = 44.0%, SD = 6.4; rather much effort, Zijlstra & Van Doorn, 1985), $t(28) = 5.14$, p = .00, d = 1.9, 95% CI [6.8, 15.8]. The variance in the mental effort scores for leisure activity was relatively high (Expert SD = 15.3%, Intermediate SD = 18.3%), perhaps providing some explanation for these results. Some leisure activities, such as motor car racing (73.3%) required mental effort that was far higher than those recorded during practice, whereas others, such as fishing (0.0%) required far less mental effort.

Reflection and evaluation

The expert group (M = 66.2 points, SD = 9.3) scored higher on the SRL-SRS for reflection and evaluation between practice sessions compared to the intermediate group (M = 36.8 points, SD = 13.7), $t(28) = 6.87$, p = .00, d = 2.6, 95% CI [20.7, 38.3]. The post-study interview revealed that there were also clear differences between groups in their cognitive processes between practice sessions.

Q1: Did you think about the kicking training sessions when you were not at training? Every member of the expert group thought about the practice sessions when they were not at training compared to only nine members of the intermediate group χ^2 (1, n = 30) = 5.21, $p < .05$, phi = -.50. The other six intermediate participants that did not think about the practice reported that it was *not* an intentional act. Ten of fifteen expert participants commented about their high volume of reflection on the practice intervention (e.g., “I’d be constantly running through things” or “I think it’s always brewing away in the background”). In comparison, only two of the nine intermediate participants made comments about the volume (e.g., “It was on my mind”).

Q2: What were you thinking of mainly? Table 5 details the themes, categories, sub-categories, and sample responses. Three themes were identified to classify the retrospective thoughts of the participants: monitoring, evaluation, and planning. Monitoring statements described observed elements of the practice sessions and consisted of two categories: outcome and process. The outcome category referred to descriptive comments related to the practice session, such as accuracy, score, and ball flight. The process category referred to descriptive comments related to the technical act of kicking, the ability to maintain concentration, general comments about the practice session, and the elements of the session that would transfer to a game situation. Evaluation statements involved assessments of the outcome of a kick, the quality of the kicks technically, and practice sessions in general, which were again divided into outcome and process categories. Planning statements involved goals regarding future kicks and practice sessions as well as how previous instances could be learned from to have a positive impact on future instances. Again, this theme consisted of the two categories of outcome and process. The expert group had more reported instances and more in-depth responses for monitoring, evaluation, and planning categories with greater amounts of outcome and process thoughts for each and their subcategories (i.e., technique, practice, concentration, and score) when compared to the intermediate group (see Table 3.9).

Q3: Were these thoughts intentional or were they intrusions? A third of the expert group reported that thoughts were intentional only (e.g., “I make a conscious effort to think about it”), a third reported having intrusion thoughts only (e.g., “just coming into my head, just naturally”), and the other third had thoughts

Table 3.9: Frequency of responses across the themes, categories and subcategories, with sample responses for the expert group to Question 2 of the post-study semi-structured interview. N.B. Numbers in brackets in bold represent the intermediate data.

Theme (frequencies)	**Categories (f)**	**Subcategories (f)**	**Expert group sample answers**
Monitoring (22) **(5)**	Outcome (2) **(2)**	Practice (2) **(0)**	"I would find myself thinking exactly about the session and what happened during the session."
		Technique (0) **(2)**	
	Process (20) **(3)**	Technique (11) **(0)**	"Just the way I was striking it, I always feel that if I am striking it well then the result will take care of itself."
		Practice (5) **(3)**	"When it (the sessions) is planned, you're always thinking about it."
		Concentration (2) **(0)**	"Because I was aware of my concentration going in and out from one kick to the next."
		Transfer (2) **(0)**	"That's probably one of the biggest things I need to work at in a game, my execution in the final third. So if I can work at that, it will help me."
Evaluation (35) **(6)**	Outcome (25) **(5)**	Technique (11) **(0)**	"How it felt when I was kicking, so that even if I got it over, I'd question whether it was a good connection or not."
		Score (12) **(5)**	"Thinking of the score I got and whether that was as much as I could have got."
		Practice (2) **(0)**	"Thinking about whether I was happy with the practice."
	Process (10) **(1)**	Technique (4) **(0)**	"On Monday's session I was definitely forcing it more – pulling on it more, whereas on Wednesday night it was more controlled and I was getting a better connection."
		Practice (4) **(0)**	"I think what I realised after the first session was that I didn't have a clear plan for the session."
		Concentration (2) **(1)**	"So I was thinking of that (concentration), if I did lose concentration, why did I lose concentration?"
Planning (64) **(15)**	Outcome (24) **(7)**	Technique (11) **(1)**	"I need more work on my technique so that my accuracy will improve as I go along."
		Score (10) **(6)**	"Then you'd be conscious of the score and trying to ensure that you improve it each session."
		Practice (3) **(0)**	"You'd think about it (practice) again … I need to work on that, or change that, or do a bit more of that' or whatever it might be."
	Process (40) **(8)**	Technique (22) **(6)**	"It would be a case of correcting things in your head so that you didn't do them again the next night."
		Practice (14) **(1)**	"So, you think about the things you want to address in the session and how you want to address them."
		Concentration (1) **(1)**	"I'd have a goal for each training session so that I wouldn't get too distracted."
		Transfer (3) **(0)**	"Just different things like, how can I bring that into a game situation from that."

that were both intentional and intrusions. Four out of nine intermediate participants reported having intentional thoughts only, four out of nine reported intrusion thoughts only, and one out of nine reported thoughts that were both intentional and intrusions.

Q4: Where did this occur? Five locations were consistently reported as places where reflection occurred. These locations were at home, at bedtime, in transit, immediately before or after training, and at work. A greater proportion of the 15 expert participants reported reflecting upon the practice at home, at bedtime (e.g., "I would make it my business to do it [reflect] before I go to bed"), in transit, and at work when compared to the intermediate participants (see Table 3.10). In contrast, a greater proportion of the 9 intermediate participants reported reflecting upon the practice before or after training compared to the expert group.

Table 3.10: The frequency (percentage) of the 15 expert and 9 intermediate participants who reported reflecting on the practice sessions at the five locations.

Group	At Home	Bedtime	In Transit	Immediately before/after training	At Work
Expert	11 (73%)	7 (47%)	8 (53%)	5 (33%)	12 (80%)
Intermediate	5 (56%)	1 (11%)	2 (22%)	7 (78%)	3 (33%)

Q5: How often in the day and how long did these occur? Responses revealed that 14 of the 15 (93.3%) expert participants reflected on their practice ssession more than twice a day during the study period (e.g., "I am awake 16-hours in a day, it [reflection] would definitely be a few times every hour"). In comparison, 4 of the 9 (44.4%) intermediate participants reflected more than twice daily during the study (e.g., "You couldn't help but think about it right before the session and immediately after the session too"). Responses revealed that 10 of the 15 (66.6%)

expert participants reflected for greater than 3-minutes each time they thought about the practice session. In fact, 6 of the 15 (40.0%) expert participants mentioned reflection durations greater than 8-minutes (e.g., "The bedtime thoughts would last about 10-15 minutes"). In comparison, none (0.0%) of the intermediate group reported reflecting on the kicking practice sessions for longer than 3-minutes (e.g., "Just a couple of minutes before and after the session").

Discussion

The self-regulatory processes of expert and intermediate players during and between bouts of deliberate practice in which the goal was to improve kicking performance was examined. The expert group rated practice as involving greater mental effort and being less enjoyable when compared to the intermediate group, supporting these predictions of deliberate practice theory. Moreover, practice was generally rated as lower for enjoyment compared to leisure activity. The expert group engaged in greater amounts of more detailed self-regulation processes during and between bouts of practice when compared to the intermediate group. These between-group differences in cognitive processing that occurred during and between practice sessions were associated with group differences in kicking accuracy improvement. Although both practice groups improved kicking accuracy from pre- to post-test, the expert group maintained improvement from the post-test to retention, whereas the accuracy of the intermediate group in the retention test returned to pre-test levels. There was no change in the kicking performance of the expert-control group who did not engage in the practice activity.

Deliberate practice is predicted to be not inherently enjoyable (Ericsson, et al., 1993), although debate exists regarding the amount of enjoyment experienced when engaging in the activity (for a review, see Ford et al., 2015). The expert group

rated their practice as lower for enjoyment compared to the intermediate group, and both groups rated the practice as less enjoyable than an activity they chose to do for leisure. These findings support the prediction of Ericsson et al. (1993) that engagement in deliberate practice will be rated relatively low for inherent enjoyment compared to other activities, such as leisure. In the current study, some leisure activities were similar in nature to Gaelic football, such as soccer, but they were rated higher for enjoyment compared to the practice activity. In addition, deliberate practice is predicted to be effortful and greater effort is expected to be associated with lower enjoyment (Ericsson et al., 1993). As predicted, the expert group rated practice as greater for mental effort compared to the intermediate group and both groups rated the practice as more effortful than leisure activity. The expert group may have rated practice as less enjoyable because they rated it as more effortful compared to the intermediate group. As predicted, the expert group ratings for effort (55%) were not different to previous research of a similar standard of performer in which they practiced another skill that was highly relevant to improving their performance (58%, Coughlan et al., 2014). In contrast, the intermediate group rated the practice higher for effort (44%) compared to previous research (31%, Coughlan et al., 2014), perhaps because this practice was more relevant to improving their performance compared to that in the previous study. These findings support the predictions of deliberate practice theory (Ericsson et al., 1993) and some previous research (e.g., Coughlan et al., 2014) that engaging in the activity will be less inherently enjoyable and more effortful compared to other activities.

It was predicted that the expert group would engage in more cognitive processing, self-regulation, and reflection on the practice activity between bouts compared to the intermediate group (Ericsson, 2006; Ericsson & Delaney, 1999;

Ericsson & Kintsch, 1995; Jonker et al., 2010; Sonnentag, 1998; Toering, et al., 2009). As predicted, the SRL-SRS showed that the expert group engaged in greater amounts of self-regulation and reflected more on their practice between sessions than the intermediate group. This data supports the findings of other researchers using the SRL-SRS (Toering et al., 2009; Jonker et al., 2010) who have shown that skilled groups demonstrate greater general traits of self-regulation compared to lower-skilled groups. In addition to this previous work, the current data extend the research by showing a positive relationship between self-regulation or reflection and performance improvements. All of the expert participants reported in the interview that they engaged in processes of self-regulation between practice sessions in comparison to only nine of the 15 intermediate participants. Moreover, the expert group engaged in this cognitive processing between sessions more frequently, at more locations and for longer durations compared to the intermediate group. They engaged in more monitoring, evaluating, and planning compared to the intermediate group. These data support the idea that experts maintain cognitive control over their performances and practice, using long-term working memory to monitor, plan, predict, reason, evaluate, and make other inferences towards improved future performance (Ericsson & Delaney, 1999; Ericsson & Kintsch, 1995, Sonnentag, 1998). The expert group engaged in cognitive processes about kicking technique more so compared to the outcome of the kicks or compared to other processes such as concentration. They also engaged in cognitive processing about technique more so compared to the intermediate group. These data support the findings of Cleary and Zimmermann (2002) by showing the content of this processing for experts is related to technical process-oriented aspects of performance, rather than outcome-oriented aspects.

The greater cognitive processing between and during practice sessions for the expert group was expected to be associated with greater and more permanent improvement of the skill when compared to the intermediate and control groups. In support of this latter prediction, the expert group improved their kicking accuracy from the pre- to the retention test, whereas the other groups did not improve accuracy between these two tests. These data support the prediction that greater cognitive processing between and during practice sessions is associated with more permanent performance improvement. Findings support previous work showing that cognitive processing consolidates practiced skills to memory, resulting in more permanent skill retention (Brashers-Krug et al., 1996). In contrast to the expert group, the control group of experts who did not engage in the practice sessions showed no improvement in kicking performance between the tests. Moreover, the intermediate group who engaged in less cognitive processing between and during practice sessions compared to the expert group improved kicking accuracy between the pre- and post-test, but not between these tests and the retention test.

Findings also support the power law of practice (Fitts & Posner, 1967; Newell & Rosenbloom, 1981) which expects improvement through practice to be ubiquitous. The findings of this study differ from other research that suggests practice should have an external focus of attention (Wulf, 2013; Wulf & Su, 2007) and be implicit in nature (Masters & Poolton, 2012) to ensure relatively permanent change in performance. However, as Ericsson et al. (1993) suggest that as a person moves through the learning continuum, from cognitive to autonomous, in order to prevent a period of arrested development, it is imperative to maintain an explicit awareness to know when to alter and manipulate a training stimulus to induce a performance enhancement. It is also suspected that the attentional demands on a task

differ along the expertise continuum (Bernier, Codron, Thienot, & Fournier, 2011) and that experts possess the ability to switch from unconscious to conscious cognitive processing in order to make adjustments to the skill as required (Carson & Collins, 2011). Findings suggest that the expert and intermediate participants may be at differing stages along the skill acquisition continuum that requires them to be more conscious of their actions before becoming unconscious again as they become automated.

In summary, an expert group of Gaelic football players rated their practice greater for mental effort and lower for enjoyment compared to an intermediate group, supporting the predictions of deliberate practice theory. The expert group engaged in more cognitive processing, self-regulation, and reflection during and between practice sessions compared to the intermediate group. These between-group differences in cognitive processes were associated with differences in the outcomes of practice with the expert group improving their kicking accuracy from pre- to retention test, whereas the intermediate group only improved their kicking from pre- to post-test, but did not maintain this to the retention test.

Chapter 4: Lessons from the experts: The effect of increasing cognitive processing and engagement in deliberate practice on intermediate-skilled performers

Abstract

Deliberate practice is effortful, not inherently enjoyable, not immediately rewarding, challenging, must be adequately resourced, and is underpinned by advanced cognitive processing. The aim of this experiment was to examine the effect of increasing cognitive processing and deliberate practice in intermediate performers. Two matched groups of youth intermediate Gaelic football players practiced a kick they identified as most relevant to improving overall performance during an acquisition phase and completed pre-, post-, and retention tests. During acquisition, participants rated the practice for the deliberate practice tenets of effort and enjoyment. In addition, the training group engaged in an intervention to increase the cognitive processes of self-regulation before, during and after the practice sessions, while a control group did not. Both groups improved kicking accuracy between pre-, post- and retention tests, however, the training group improved accuracy significantly more than the control group. The training group rated practice greater for mental effort compared to the control group, whilst both groups rated practice lower for enjoyment compared to leisure activity. The training group increased engagement in the self-regulatory processes of reflection and evaluation as a result of the cognitive processing intervention compared to the control group. Findings provide support for the theory of deliberate practice and the effectiveness of applying the principles of deliberate practice and increasing cognitive processing to expedite the learning of intermediate-level youth performers.

Introduction

Deliberate practice is an activity involved in the development and improvement of expert performance. The characteristics of deliberate practice are that it is effortful, resourced, informative, not inherently enjoyable, not immediately rewarding, and challenging in that it is highly relevant to improving an aspect of current performance (Ericsson, et al., 1993). The monotonic benefits assumption in the theory holds that the number of hours accumulated in domain-specific deliberate practice correlates with the level of expertise attained. Data on violinists from the West Berlin Music Academy supports this assumption because the standard achieved by the best students, lower-skilled students and least-skilled music-teacher students was positively correlated to the number of hours of domain-specific deliberate practice they had accumulated (Ericsson et al., 1993). In addition, the accumulated hours of deliberate practice by age 18 years for the best students, was not different when compared with a group of world-class middle-aged violinists at the same age. Engagement in deliberate practice is thought to involve concentration and cognitive processing, such as planning and evaluating actions and their outcomes (Ericsson & Towne, 2010). To date, few researchers have examined the cognitive processes associated with deliberate practice or sought to intervene with lesser-skilled performers to improve these processes. The aim of this experiment was to examine the effect of increasing cognitive processing of intermediate performers during the deliberate practice of a skill.

Researchers examining self-regulation have provided empirical support for the role of cognitive processes in expert performance (Anshel & Porter, 1996; Kitsantas & Zimmerman, 2002; Zimmerman, 2008). Self-regulation entails the cognitive processes of forethought, performance and reflection. Forethought involves

goal-setting and planning prior to the task, whereas performance involves attention and monitoring of the task and processes. Reflection encompasses the metacognitive processes of evaluation and casual attribution during and after the task (Zimmerman, 2002). Self-regulation enables performers to compare and contrast their actions and outcomes to predetermined goals or standards during and between bouts of practice (Zimmerman, 1998; 2000). Self-regulated performers are defined as motivationally, behaviourally and metacognitively engaged in their personal process of learning (Zimmerman, 1986). Expert performers have been shown to engage in self-regulation in a quantitatively different manner to novice performers. Kitsantas and Zimmerman (2002; see also Cleary & Zimmerman, 2001) examined the self-regulation processes of expert, intermediate and novice volleyball players practicing serving. They found that expert players planned their practice routines with more advanced strategies (forethought) and evaluated their performance during and after practice (reflection) to a greater degree when compared to the lesser-skilled groups. Other researchers have predicted and shown that the cognitive processes of expert performers are characterised by their ability to encode, index, update and access task-relevant information in long-term working memory (LTWM – Charness, 1981; Ericsson, 2003b; 2003c; Ericsson & Crutcher, 1990; Ericsson & Kintsch, 1995; Ericsson & Towne, 2010; Ward, Ericsson, & Williams, 2013). LTWM enables them to build mental representation of future, current or past domain-specific situations that allow them to plan, anticipate, monitor, maintain control over, evaluate, and improve upon performance and its consequences (Ericsson & Towne, 2010; Ward et al., 2013; Ward, Suss, Eccles, Williams, & Harris, 2011). It is assumed that the advanced cognitive processes used by expert performers have been acquired through practice and experience in a domain (Ericsson & Towne, 2010; Ward et al., 2011;

2013), raising the possibility that the acquisition of these processes can occur and be expedited for lesser-skilled performers.

Some researchers have examined how increasing cognitive processing influences the acquisition of skill in lesser-skilled performers. Cleary, et al. (2006; see also, Singer, Lidor, & Cauraugh, 1993; Zimmerman & Kitsantas, 1996; 1997) examined the effect of increasing self-regulation in novice basketball players practicing free-throw shots. Participants were divided into five groups, three of which were intervention groups and two of which were control groups. The three intervention groups were differentiated by the amount of self-regulation they were required to engage in during practice. The three-phase group completed a cycle of forethought, performance and self-reflection, whereas the two-phase group engaged in forethought and performance, and the one-phase group engaged in forethought only. One control group practiced without engagement in self-regulation and the other group did not practice. Participants in the intervention groups were coached on the self-regulation processes they should adhere to during practice. For example, the three-phase group were instructed to set process goals (planning), record their cognitions on previous throws (evaluating) and record their plans for future throws (planning). The study consisted of a 10-trial pre-test, a 12-minute practice session, and a 10-trial post-test. Findings showed a positive relationship between the amount of self-regulation during practice and free-throw success in the post-test. The three-phase (65%) and two-phase group (67%) did not differ in free-throw accuracy in the post-test, but both groups were significantly more accurate compared to the one-phase (43%) and practice-only group (40%). There was a negative correlation between self-regulation and the number of trials executed, with more self-regulation being associated with fewer trials. This study concluded that an intervention

designed to increase cognitive processing improved the acquisition of skill in novice performers beyond that from practice alone.

Although researchers (e.g., Cleary et al., 2006; Singer et al., 1993; Zimmerman & Kitsantas, 1996; 1997) have examined the effects of increasing self-regulation during practice on the performance of novice performers; evaluation and adjustments to performance are limited because novice performers are in the early stage of learning where a significant amount of thought and attention is required to control actions (Fitts & Posner, 1967). For novices, current performance levels require large improvements to reach intermediate or expert levels and performance improvement should be relatively straightforward (Ericsson, 2003a; Newell & Rosenbloom, 1981). However, more explicit thought processes, such as those involved in self-regulation, particularly regarding errors in performance, may prevent the acquisition of automaticity by these performers in some motor processes that characterise more skilled performance (for a review, see Masters & Poolton, 2012). In contrast, the actions of intermediate level performers are more skilled, demonstrate greater levels of automaticity, and are underpinned by more advanced cognitive processing (Fitts & Posner, 1967). As such, their performance is closer in its characteristics to expert performers when compared to novices. For these intermediate level performers, greater improvements may be hindered by their competence in the domain leading to a plateau in performance improvement termed 'arrested development' where they are satisfied with their current performance level (Ericsson, 2003a). In order to improve performance, these individuals must engage in extended bouts of domain-specific deliberate practice (for review, see Baker & Young, 2014).

In Chapter 2, intermediate Gaelic football players who were able to self-select their practice of two kicking skills *did not* engage in deliberate practice, choosing instead to practice the skill they were stronger at and experiencing more enjoyment and less mental effort, when compared to an expert group. Therefore, it appears that intermediate performers must be instructed and guided to engage in deliberate practice activity. Moreover, in Chapter 2 and 3, intermediate performers rated practice lower for mental effort and engaged in less advanced cognitive processing when compared to the expert groups. Findings suggest that intermediate performers may require instruction and guidance in order to acquire the cognitive processes that characterise expert performance. No researchers have examined the effect on skill acquisition of intermediate performers engaging in deliberate practice and the advanced cognitive processes of experts.

The aim of this experiment is to measure the effect of increasing self-regulatory cognitive processes and the deliberate practice of a kick in Gaelic football on intermediate performers. Gaelic football is a national sport in Ireland. It is similar to the sport of rugby and other invasion sports with two teams of 15 players on a pitch with goals at either end. Participants were guided to self-select the skill or task from the game that they wanted to improve and that would most improve their overall performance. They practiced this skill or task across four sessions, thereby satisfying a key part of deliberate practice theory that the practiced skill should be highly relevant to improving overall performance (Ericsson et al., 1993). As such, because participants were engaging in deliberate practice, it was expected that they would experience its other characteristics. According to deliberate practice theory, participants should rate their practice lower for enjoyment and greater for mental effort when compared to an activity they do for leisure. Moreover, the effect of

practicing a skill relevant to overall performance improvement should be an improvement in accuracy of the skill from pre- to post- and retention-tests. In addition, participants were divided into two groups that practiced under conditions that were differentiated by the amount of cognitive processing. The first group engaged in a structured process of self-regulation that ensured they planned, monitored and evaluated performance during and between practice sessions, whereas the second group did not engage in any structured cognitive processing. The group who received the intervention are expected to demonstrate more cognitive processing and mental effort during practice, as well as greater self-regulation processes and gains in acquisition after practice, when compared to the group who did not receive the intervention.

Method

Participants

A total of 34 male youth intermediate Gaelic football players were participants. They were split into a training group (n = 17; M age = 16.1 years, SD = 0.78, M playing years = 9.8 years, SD = 0.97) and a control group (n = 17; M age = 16.1 years, SD = 0.85, M playing years = 9.9 years, SD = 1.03). After completing the Self-Regulation of Learning Self-Report Scale (SRL-SRS, Toering et al., 2012); participants were quasi-randomly assigned to groups. Scores were ranked and were used to assign participants to groups in a step-procedure. As such, SRL-SRS scores did not differ between the training group (M = 21.0 SRL-SRS points, SD = 2.2) and the control group (M = 20.8 SRL-SRS points, SD = 2.4), $t(32) = 0.30$, $p = 0.77$, d = 0.10, 95% CI [-1.4, 1.8]. Participants provided informed consent and the research was conducted according to the ethical guidelines of the lead institution.

Procedure

Participants were initially asked to rank the three skills or areas that were most important to them in improving their overall performance in Gaelic football. All participants chose kicking the ball with their non-dominant foot as most important. Participants rated the relevance of practicing the non-dominant kick to improving their overall performance using a 10-point Likert scale ranging from one or "not relevant at all" to ten or "highly relevant" (M = 9.7 points out of 10, SD = 0.5).

Figure 4.1 shows the experimental set-up. Participants were required to execute kicks from their hands using the non-dominant foot toward Gaelic football goalposts (height = 10m, width = 6.5m, crossbar height = 2.5m) with the intention of getting the ball over the crossbar to register a score. Kicks from the hands are used frequently in Gaelic football to pass to another team-mate and restart play when a foul has been committed, and depending on the location on the pitch an attempt on the goalposts is made by the player to score a point.

Figure 4.1: Experimental set-up including Gaelic football goalposts and the 'out of the hands' kick. Participants could score 1 pt when the ball went over the crossbar and between the goalposts, and 0 pts for wide of the goalposts or under the crossbar.

Participants were awarded one point if the ball entered between the goalposts and over the crossbar. A $4m^2$ practice zone marked out with cones was created directly in front of the goalposts at a distance of 25m. Fifteen standard round-shaped Gaelic footballs (O'Neill's size-5 GAA All-Ireland footballs, Belfast, Northern Ireland) were placed on the ground immediately behind the practice zone. A digital video camera (Canon Legria FS200, Canon, Tokyo, Japan) was used to record performance from 10m directly behind the practice zone.

The experiment consisted of a pre-test, four practice sessions, a post-test, and a retention test, all of which occurred across a three-week period. Both groups completed all tests and practice sessions. The pre-test occurred one week prior to the practice sessions. The four practice sessions occurred on four consecutive days and the post-test occurred on the fifth consecutive day (Shea, et al., 2000). The retention test occurred one week after the post-test. The experiment took place in the training grounds of the Gaelic football club the participants represented. Prior to the pre-test, verbal instructions were provided to each participant regarding the pre-test and experimental procedures. The pre-test consisted of 10 kicks toward the goal from the hands using the non-dominant foot. Participants engaged in two familiarisation trials prior to the pre-test. Following the pre-test, each participant was informed of his score, which was calculated as a function of ten points. The post-test and the retention test were the same as the pre-test.

Prior to each practice session, participants were verbally informed by the experimenter of their pre-test score and that the goal of the task was to improve their pre-test score (Boyce, 1992). Each practice session began with two warm-up trials. A practice session consisted of 15 kicks from the hands using the non-dominant foot towards the goalposts. The score achieved on every trial was recorded using hand

notation by the lead experimenter during data collection, which was checked for accuracy against the video footage. Participants were informed to not discuss the details of their practice sessions with other participants or people in general.

Intervention. During the practice sessions, the training group engaged in an intervention designed to increase their cognitive processing and self-regulation of the practice session, whereas the control group did not engage in this intervention. The training group were required to verbally answer three questions after each odd-numbered trial during their 15-kick practice session (McPherson & Thomas, 1989). The aim of these questions was to ensure they engaged in the cognitive processes of self-regulation (Cleary, et al., 2006; Ericsson, 2006a; Kolb, 1984; Lee, et al., 1994; Schön, 1983). These questions were: (i) briefly describe that kick (performance); (ii) briefly describe what was good or bad about that kick (evaluation and reflection); and (iii) briefly describe what you could have done and what you will do in the next kick (planning and forethought). Monitoring statements during the kick were not recorded because the time period of approximately 3 seconds during the kick was too short to collect concurrent thoughts (Ericsson & Simon, 1993). In addition, at the end of each practice session, the training group answered in written form three self-regulation questions. The three questions are shown in Table 4.2.

Table 4.2: The self-regulation questions posed to the training group following the practice sessions.

No.	Question
1.	What happened in today's kicking training session? (performance)
2.	What worked well and/or did not work well for you in today's kicking training session? (evaluation and reflection)
3.	What will you do the next time to ensure that you will improve your performance? (planning and forethought)

Moreover, prior to practice sessions two, three, and four, the training group answered in written form the question 'What will you do in this upcoming session to ensure you will improve your performance?' (planning). In contrast, the control group completed a sham questionnaire at this stage about their daily nutrition in place of the self-regulation questionnaire. The aim of the nutrition questionnaire was to ensure the control group thought the experiment was examining nutrition, rather than the effect of cognitive processing.

Following each test and practice session, a manipulation check (Boudreau, Gefen, & Straub, 2001) for self-regulation was administered (Perdue & Summers, 1986). The manipulation check question was "I kept track of my performance during this training session so that I can see which skills I must improve". The check comprised of two other sham questions related to physical effort (e.g., "During this session I felt tired, which affected my kicking performance") in an attempt to hide the true nature of the experiment. Each question contained a five point Likert scale ranging from "never" to "always".

Deliberate practice measures. During the practice sessions, both groups completed two valid and reliable self-report measures to rate the tenets of deliberate practice for that particular practice session (Coughlan et al., 2014). The mental effort prediction was examined using the Rating Scale of Mental Effort (RSME, Zijlstra & Van Doorn, 1985). It is a continuous uni-dimensional scale with eight points that range from 0 (absolutely no effort; 0%), 75 (considerable effort; 50%), to 150 (extreme effort; 100%). The enjoyment prediction of the theory was examined using the Physical Activity Enjoyment Scale (PACES, Kendzierski & DeCarlo, 1991), which is used to examine enjoyment levels during physical activities. It consists of 18 Likert-scaled comments relating to the current activity with 11 of the comments

reverse-scored. Enjoyment scores greater than 65% to 70% are interpreted as higher enjoyment, whereas lower scores indicate lower enjoyment (Coughlan et al., 2014).

Participants in both groups were required to complete each scale following engagement in a leisure activity of their choice that occurred on a separate day after the experiment period. Table 4.3 shows the leisure activities chosen by the participants of both groups. The activity was required to be one they frequently engaged in with the focus of leisure, and not for performance improvement. The intention was to use the leisure activity ratings to compare against the same measures collected during the practice sessions.

Table 4.3: The leisure activities and the number of participants chosen by two groups (training, control) to rate for enjoyment and effort.

Leisure Activity	**Training**	**Control**
Gym	0	1
11-a-side soccer	3	0
Sailing	1	0
Cycling	1	0
Golf	1	3
Computer games	1	0
Hurling	2	4
Athletics	3	2
Tennis	0	1
Rugby	5	6

Self-regulation measures. Participants in both groups completed the sport-specific SRL-SRS (Toering, et al., 2012) on two occasions. They completed it at the pre-test and for a second time at the retention test to measure the impact of the intervention on self-regulation processes. The questionnaire comprises of 18 questions that related to the reflection (e.g., since yesterday's practice session, I have thought back and evaluated whether I did the right things to become a better kicker) and evaluation processes of self-regulation that take place following a practice

session (e.g., in each of these practice sessions I try to identify my strengths and weaknesses and I think about how I can improve these).

Data Analysis

Accuracy data. Mean accuracy scores in terms of the number of successful kicks that passed between the goal posts out of the 10 kicks in each test (pre-, post-, retention test) or out of the 15 kicks in each practice session were calculated as a function of group. Accuracy scores from the tests were analysed using a 2 Group (training, control) x 3 Test (pre-, post-, retention test) ANOVA with repeated measures on the last factor. Accuracy scores from the four practice sessions were analysed using a 2 Group (training, control) x 4 Practice Session (first, second, third, fourth) ANOVA, with repeated measures on the last factor. Tukey HSD tests and the Dunn-Bonferroni adjustment calculation were used as *post-hoc* tests where appropriate. Cohen's *f* formula was used to calculate effect size for measures involving more than two means, whereas Cohen's *d* was calculated for effect sizes involving two means (Cohen, 1988). Values equal to or greater than 0.2, 0.5, and 0.8 represent a small, moderate, and large effect size, respectively.

Deliberate practice data. Data from the two deliberate practice scales (enjoyment, mental effort) were calculated separately into a single mean score for each participant representing the amount of that variable experienced across the practice sessions. The scale scores from the practice sessions and from the leisure activity were mathematically transformed into percentages to make interpretation, comparison, and plotting of data clearer. Percentage scores for the deliberate practice scales of enjoyment and mental effort were analysed in separate 2 Group (training, control) x 2 Activity (practice, leisure) ANOVAs, with repeated measures on the last factor.

Self-regulation data. The data from the SRL-SRS reflection questionnaires collected at the pre-test and retention test were calculated into an overall mean score for each participant that represented their self-regulation value. The mean amount of self-regulation was analysed using a 2 Group (training, control) x 2 Test (pre-, retention) ANOVA, with repeated measures on the last factor. The data from the in-practice self-regulation questions were transcribed verbatim using natural speech and syntactical markers (Hardy, et al., 1996). Following thematic coding and categorisation of the in-practice questions and the inter-session self-regulation questions, percentage scores for each category in each theme were calculated. The alpha level required for significance for all tests was set at $p < .05$.

Results

Accuracy

Tests. Figure 4.4 shows the mean number of points scored by the two groups across the pre-, post-, and retention tests. Table 4.5 shows the results of the 2 Group x 3 Test ANOVA conducted on number of points scored.

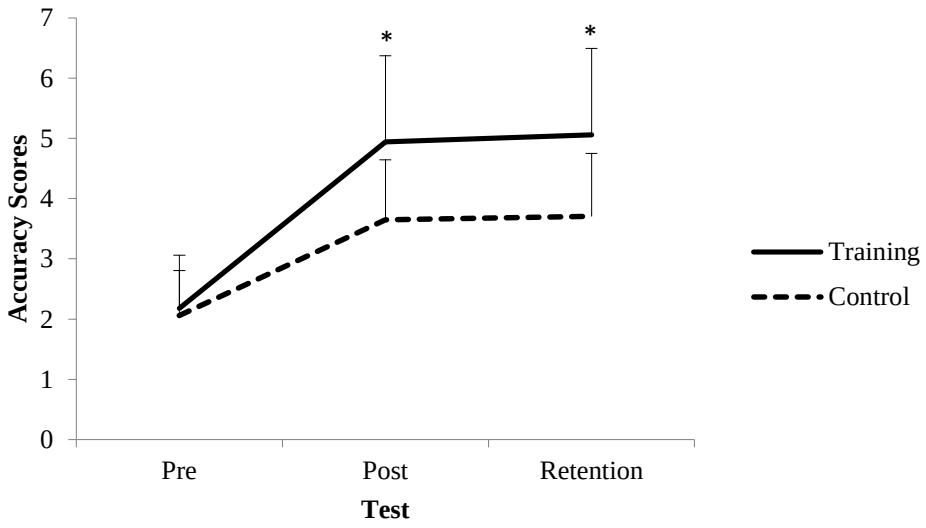


Figure 4.4: Mean (SD) accuracy scores for the non-dominant kick of the training and control groups in the pre- post-, and retention test.

There were significant main effects for Group and Test in the predicted directions, as well as a significant Group x Test interaction. *Post-hoc* analysis showed that accuracy in the pre-test did not differ between the training (*M* = 2.2 points, *SD* = .88, 95% CI [1.8, 2.6]) and the control group (*M* = 2.1, *SD* = .75, 95% CI [1.7, 2.5]). However, the training group in the post-test (*M* = 4.9 points, *SD* = 1.4, 95% CI [4.3, 5.6]) and retention test (*M* = 5.1 points, *SD* = 1.4, 95% CI [4.4, 5.7]) had greater accuracy compared to the control group in the post-test (*M* = 3.6 points, *SD* = 1.0, 95% CI [3.0, 4.3]) and retention test (*M* = 3.7 points, *SD* = 1.0, 95% CI [3.1, 4.3]). Both groups improved accuracy from pre- to post-test, and accuracy did not differ between the post-test and retention test.

Table 4.5: Results of ANOVA on number of points scored for Group (training, control), and Test (pre-test, post-test, retention test).

Variable & Comparison	*MS*	*dof*	*F*	*p*	Cohen's Effect Size
Group	21.66	1, 32	7.36	0.01*	0.48
Test	55.95	2, 64	135.06	0.00*	0.81
Group x Test	4.13	2, 64	9.96	0.00*	0.56

Note. ANOVA = analysis of variance

* $p < .05$

Practice sessions. Figure 4.6 shows the mean number of points scored by the two groups across the four practice sessions. Table 4.7 shows the results of the 2 Group x 4 Practice Session ANOVA on number of points scored. There were significant main effects for Group and Practice Session in the predicted directions. Accuracy improved from one session to the next across the four practice sessions,

but the training group were more accurate across practice compared to the control group. There was a significant Group x Practice Session interaction.

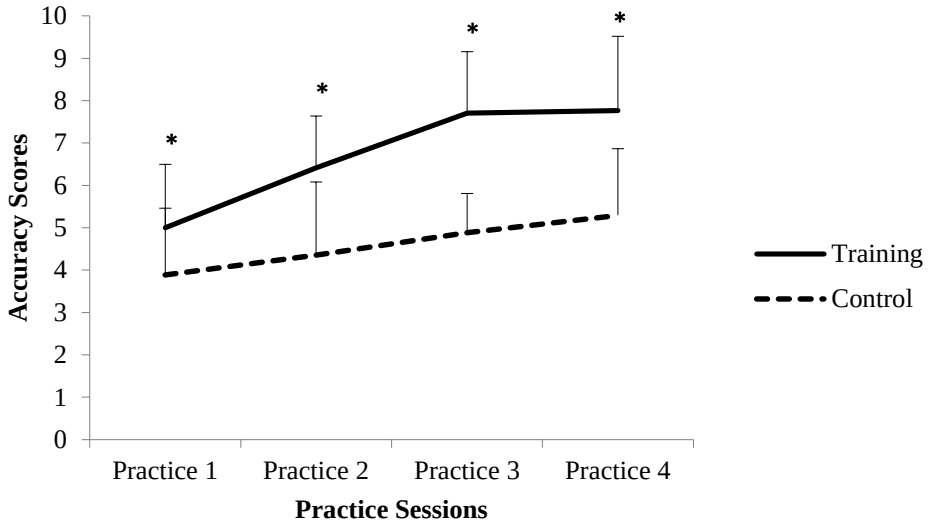


Figure 4.6: Mean (SD) accuracy scores for the non-dominant kicks of the training and control groups in the four practice sessions.

The *post-hoc* analysis showed that the training group were more accurate across all practice sessions compared to the control group. The training group made significant improvements from the first practice session (*M* = 5.0 points, *SD* = 1.5, 95% CI [4.2, 5.8]) to the second practice session (*M* = 6.4 points, *SD* = 1.2, 95% CI [5.7, 7.2]) and, again, from the second practice session to the third practice session (*M* = 7.7 points, *SD* = 1.4, 95% CI [7.1, 8.3]). There was no significant difference in accuracy between the third and fourth practice session. In comparison, the rate of change in accuracy for the control group was slower. The control group showed a significant improvement in accuracy from the first practice session (*M* = 3.9 points, *SD* = 1.6, 95% CI [3.1, 4.6]) to the third practice session (*M* = 4.9 points, *SD* = 0.9, 95% CI [4.3, 5.5]) and, again, from the second practice session (*M* = 4.4 points, *SD* = 1.7, 95% CI [3.6, 5.1]) to the fourth practice session (*M* = 5.3 points, *SD* = 1.8, 95% CI [4.5, 6.1]).

Table 4.7: Results of ANOVA on number of points scored for Group (training, control), and Practice Session (1, 2, 3 and 4).

Variable & Comparison	*MS*	*dof*	*F*	*p*	Cohen's Effect Size
Group	152.47	1, 32	25.28	0.00*	0.89
Practice Session	30.83	3, 96	32.64	0.00*	0.79
Group x Practice Session	4.61	3, 96	4.88	0.01*	0.53

Note. ANOVA = analysis of variance

* $p < .05$

Deliberate practice. Figure 4.8 shows the percentage ratings of the deliberate practice tenets of enjoyment and mental effort for the training and control groups across the four practice sessions.

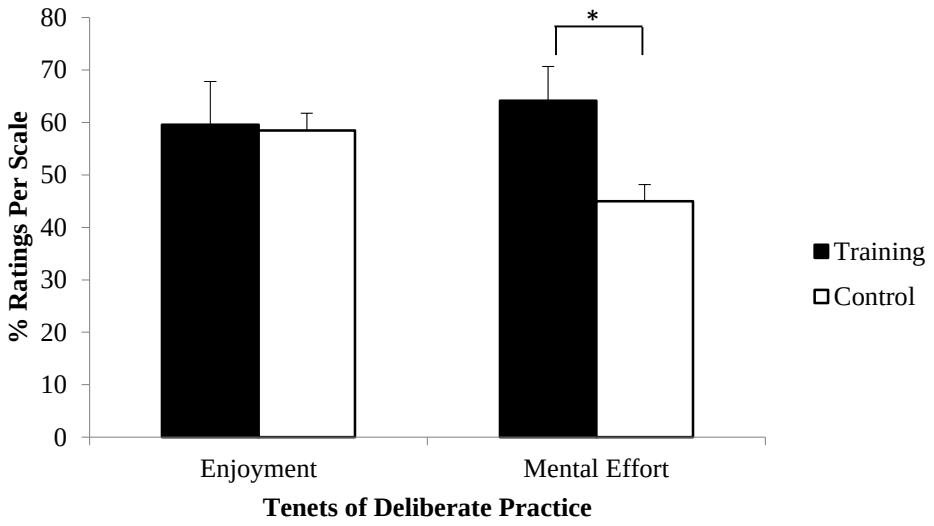


Figure 4.8: Mean (SD) scores recorded during the four practice sessions using the deliberate practice tenets of enjoyment (PACES) and mental effort (RSME) for the training and control groups.

The 2 Group x 2 Activity ANOVA for mental effort showed a significant main effect for Group, $F(1, 32) = 10.16$, $p = .00$, $d = 0.24$. *Post-hoc* analysis showed mental effort across practice sessions was greater for the training group compared to the control group. There was no main effect for Activity. There was a significant Group x Activity interaction, $F(1, 32) = 39.64$, $p = .00$, $d = 0.62$. *Post-hoc* analysis showed the training group reported greater mental effort during the practice sessions ($M = 64.1\%$, $SD = 6.5$, 95% CI [61.6, 66.7]; great effort, Zijlstra & van Doorn, 1985) compared to the leisure activity ($M = 48.2\%$, $SD = 10.9$, 95% CI [43.1, 53.3]; considerable effort, Zijlstra & van Doorn, 1985). In contrast, the control group rated the practice sessions lower for mental effort ($M = 45.0\%$, $SD = 3.2$, 95% CI [42.4, 47.5]; rather much effort, Zijlstra & van Doorn, 1985) compared to the leisure activity, ($M = 55.7\%$, $SD = 9.7$, 95% CI [50.6, 60.8]; considerable effort, Zijlstra & van Doorn, 1985).

The 2 Group x 2 Activity ANOVA for enjoyment during the practice sessions showed no significant main effect for Group, $F(1, 32) = 2.682$, $p = .11$, $d = 2.8$. There was a significant main effect for Activity, $F(1, 32) = 133.42$, $p = .00$, $d = 2.78$. The ratings of enjoyment in the leisure activity were significantly greater compared to the practice sessions. There was a significant Group x Activity interaction, $F(1, 32) = 4.78$, $p = .04$, $d = 0.43$. *Post-hoc* analysis showed the ratings of enjoyment for the practice sessions were not different between the training ($M = 59.6\%$, $SD = 8.2$, 95% CI [56.5, 62.7]) and the control group ($M = 58.5\%$, $SD = 3.2$, 95% CI [55.4, 61.6]). In comparison, for the leisure activity, the ratings of enjoyment were lower for the training group ($M = 79.5\%$, SD = 11.5, 95% *CI* [74.1, 84.9]) compared to the control group (M = 87.7%, SD = 10.2, 95% CI [82.3, 93.1]), $F(1, 32) = 133.4$, $p = .00$.

Self-regulation. The 2 Group x 2 Test ANOVA for the SRL-SRS scores showed significant main effects for Group and Test in the predicted directions, as well as a significant Group x Test interaction. *Post-hoc* analysis showed no difference in the pre-test scores from the SRL-SRS between the training (M = 21.0 points, SD = 2.2, 95% CI [19.9, 22.1]), and the control group (M = 20.8, SD = 2.4, 95% CI [19.6, 21.9]). The retention test self-regulation score of the training group (M = 67.7 points, SD = 11.5, 95% CI [62.4, 73.0]) was significantly greater compared to the control group, (M = 33.1 points, SD = 9.9, 95% CI [27.7, 38.4]).

Table 4.9 shows the responses of the training group to questions during the kicking sessions. In response to the performance question, verbalisations on either kick outcome or kick outcome with technique accounted for 96% of all responses. In response to the evaluation and reflection question, 81% of all responses were related to either technique or kick outcome with technique. In response to the planning and forethought question, verbalisations focused on technique for 90% of all responses as technique alone, technique with target, technique with concentration, or a combination of technique, target and concentration.

Table 4.9: Themes and categories for the training group responses to in-practice self-regulation questions.

Question 1: Briefly describe that kick? (Performance)	
Question 1: Briefly describe that kick? (Absolute evaluation)	
Outcome (86.7%)	"It went wide and to the left".
Technique (3.8%)	"Good connection and follow through. Effortless".
Outcome & Technique (9.5%)	"Snapped at it. Wide and short".

Question 2: Briefly describe what was good or bad about that kick? (Evaluation and reflection)	
Outcome (20.0%)	"Still too high, that's 5 or 6 on the bounce".
Technique (62.2%)	"I got under it too much".
Outcome & Technique (17.8%)	"Direction was off. Connection and power was good".

Question 3: Briefly describe what you could have done and what you will do in the next kick (Planning and forethought)	
Technique (26.9%)	"I need to swing my foot around it more and make sure I kick through it instead of hooking it".
Target (1.2%)	"Maybe I should pick a smaller target beforehand. Pick a spot behind the goals and kick to it".
Concentration (6.3%)	"Take it easy and concentrate more. Calm it down".
Technique & Target (22.9%)	"I need to focus on the strike and aim to the right more".
Technique & Concentration (26.5%)	"Focus on doing that type of kick again, good power".
Target & Concentration (2.1%)	"More to the posts with the right body shape. Give it power with accuracy. Focus on the one kick at a time".
Technique & Target & Concentration (14.1%)	"Follow through higher and to the goals. Take my time and follow through".

Table 4.10 shows the responses of the training group to the inter-session self-regulation questions. For the performance question, 91% of all responses related to either process alone or process with outcome. Process is defined as focusing on procedure rather than the outcome of the action (Zimmerman & Kitsantas, 1996). In response to the evaluation and reflection question, 72% of all responses related to technique with kick outcome, with a further 25% of the responses being a combination of technique, kick outcome and process. In response to the planning and forethought question, 90% of all responses mentioned routine, either as routine alone, routine with concentration, routine with target, or a combination of routine,

concentration and target. Routine is defined as performance-related actions and procedures that are repeated for every trial. In response to the pre-session planning and forethought question, all of the responses referred to routine, either as routine alone, routine and concentration, routine and target or a combination of routine, concentration and target.

Table 4.10: Themes and categories for the training group responses to the inter-session self-regulation questions.

Question 1: What happened in today's kicking training session (Performance)	
Process (80.9%)	"I kicked 15 shots with my weaker foot".
Outcome (8.8%)	"I kicked 5 or 6 over the bar but with the others I didn't connect with them right at all and they sliced off to the left".
Process & Outcome (10.3%)	"Another day of kicks and questions. I got 10 points today".
Question 2: What worked well and/or did not work well for you in today's kicking training session (Evaluation and reflection)	
Technique (7.4%)	"I struck a few nicely when I swung at them. I hurt my foot a couple of times from bad kicks".
Outcome (4.4%)	"Most of my kicks were reasonably good. A few of my kicks were quite bad".
Process (0.0%)	
Technique & Outcome (60.3%)	"I kicked reasonably well. I didn't kick through the ball enough. A few dropped short".
Technique & Process (2.9%)	"Figured a couple of things out today like I need to line my shoulder up to the goals and swing across the ball to get a good shot away. I snapped at a few of them if I did not get myself ready first of all".
Outcome & Process (0.0%)	
Technique & Outcome & Process (25%)	"Not much. I did score 5 I think. If I aimed for the back of the goals I did better. I rushed some kicks. A lot of my kicks fell short because I kicked under the ball too much".

Question 3: What will you do the next time to ensure that you will improve your performance (Planning and forethought)

Question 3: What will you do the next time to ensure that you will improve your performance? (Planning)

Routine (27.9%)	"Try to hit it harder and have more consistency".
Concentration (8.8%)	"Continue to focus on my kicks before I take them".
Target (0.0%)	
Routine & Concentration (35.3%)	"If I didn't stop to focus before a kick, it would not be a good kick".
Routine & Target (17.7%)	"Make sure I don't lean back when I kick and kick right to the back of the goals".
Concentration. & Target (1.5%)	"I need to focus on the goalposts more and ready myself for the kick every time. Clear the head".
Routine & Concentration & Target (8.8%)	"Concentrate on each kick and follow through to the goals every time".

Question 4: What will you do in this upcoming session to ensure you will improve your performance (Planning and forethought)

Routine (3.9%)	"Kick it with more power and get a better connection with the ball".
Concentration (0.0%)	
Target (0.0%)	
Routine & Concentration (56.9%)	"I will take time before my kicks to concentrate on them".
Routine & Target (9.8%)	"Concentrate on the target and get a smooth strike".
Concentration & Target (0.0%)	
Routine & Concentration & Target (29.4%)	"Take my time and make sure that I don't lean back".

Discussion

The aim of this experiment was to examine the effect of increasing cognitive processing in intermediate level performers during the deliberate practice of a task.

Two groups of Gaelic football players engaged in the deliberate practice of a kick from their hands using their non-dominant foot. The training group received an intervention during practice designed to increase self-regulatory cognitive processes, whereas the control group engaged in practice without this intervention. Both groups improved kicking accuracy from pre- to post-test and maintained their improvement in a retention test, but the improvement in accuracy was significantly greater for the training group compared to the control group. Mental effort was greater across practice sessions for the training group compared to the control group, but both groups rated the practice sessions lower for enjoyment and higher for mental effort when compared to leisure activity. At the retention test, the training group reported greater self-regulatory cognitive processes of reflection and evaluation compared to the control group and at pre-test.

Deliberate practice is thought to require cognitive processing, such as planning and evaluation, to support performance and improvement of a task (Chase & Ericsson, 1980; 1982; Ericsson, Chase, & Faloon, 1980; Ericsson & Towne, 2010). It was expected that increasing these self-regulatory cognitive processes during the deliberate practice of a task would result in greater improvements in kicking accuracy by the training group compared to the control group. As predicted, the improvement in accuracy between the pre-test and retention test was greater for the training group compared to the control group, although both groups demonstrated improvements in accuracy across test sessions. In addition, it was predicted that the intervention would lead to greater mental effort during practice and the use of more self-regulatory processes after practice for the training group compared to the control group. As predicted, increasing the self-regulatory cognitive processes of the training group during and between practice sessions significantly

increased mental effort during and cognitive self-regulatory processes after practice when compared to the control group. Findings support Cleary et al. (2006) showing the effectiveness of increasing self-regulation during practice as a method for enhancing skill acquisition and extends this finding to intermediate performers engaging in deliberate practice of a task. Findings provide empirical support for predictions about the cognitive processes that underpin expert performance, self-regulation and deliberate practice (Cleary et al., 2006; Ericsson & Kintsch, 1995; Ericsson & Towne, 2010; Zimmerman, 1989).

The cognitive processes of expert performers as they engage in performance or deliberate practice of a task are thought to involve planning, monitoring and evaluation (Cleary et al., 2006; Ericsson & Towne, 2010; Zimmerman, 1989). When the training group were required to engage in these processes, the task-specific nature of these cognitions was revealed. When evaluating their kick in the inter-trial period, the training group predominantly focused upon outcome in terms of the result of the kick or technique by describing technical and movement details of the kick. When planning the next kick in the inter-trial period, they focused mainly upon technique. At the end of each practice session, their answers to the inter-session self-regulation evaluation questions were process-related referring to the content and procedure of the practice session, as well as the technique of the kick and outcome-related referring to the score they achieved for the session. When planning for the upcoming session, their responses always related to routine in some capacity; either with concentration, target or a combination of all three responses. While these cognitions were task-specific in nature, they demonstrate that the training group engaged in planning and evaluation, with cognitive effort and SRL-SRS measures suggesting that they did so to a greater degree when compared to the control group.

Deliberate practice is predicted to be not inherently enjoyable and effortful (Ericsson et al., 1993). It was predicted that because both groups engaged in the deliberate practice of a skill they would rate the practice lower for enjoyment and higher for mental effort when compared to an activity they did for leisure. As expected, both groups rated the deliberate practice sessions lower for enjoyment when compared to leisure activity, in accordance with deliberate practice theory (Ericsson et al., 1993) and previous studies (Chapter 2 and 3). In addition, the training group rated the practice higher for mental effort when compared to the leisure activity, again supporting deliberate practice theory. Their rating of mental effort during practice was greater compared to the expert groups in previous studies (Chapter 2 and 3), probably because of the intervention focusing on cognitive processing. In comparison, mental effort for the control group was not different between practice and leisure, and their rating for mental effort in practice was lower compared to expert groups in previous studies (Chapter 2 and 3). Findings support the idea of measuring the tenets of deliberate practice during the activity, as opposed to retrospectively, when examining deliberate practice theory.

In summary, two groups of youth intermediate Gaelic football players engaged in deliberate practice of a kicking skill they selected as the most relevant to improving overall performance. Both groups improved kicking accuracy across the acquisition phase and retained their improvements to show that learning had occurred, but the group who engaged in a structured intervention to increase cognitive self-regulation processes before, during and after practice demonstrated a greater improvement in retention. This same group rated the practice greater for mental effort compared to the control group and both groups rated the practice lower for enjoyment compared to leisure activity. Findings support deliberate practice

theory and the idea that cognitive processing underpins the performance and improvement of domain-specific skills.

Chapter 5: Epilogue

This chapter will synthesise the work of the thesis and discuss the theoretical and applied implications. Potential limitations of the research will be included, as well as directions for future research.

Aims of the thesis

The main aim of the thesis was to examine how experts learn and the role of deliberate practice in that process. Deliberate practice theory holds that the activity will be highly relevant to improving an aspect of current performance, effortful, not immediately rewarding or inherently enjoyable and involve advanced cognitive processes (Ericsson et al., 1993). The retrospective recall methodology used in this research is limited by having participants rate activities engaged in a long time ago, leading to possible memory recall issues. An alternative method is to measure the characteristics, tenets and outcomes of deliberate practice during practice sessions. In the current thesis, the tenets of deliberate practice were examined during actual practice (Chapter 2, 3 and 4), as opposed to retrospectively, along with the cognitive processes that underpin deliberate practice (Chapter 3 and 4), and the effect of increasing cognitive processing on the deliberate practice of lesser-skilled performers (Chapter 4).

Participants were required to practice kicking a Gaelic football between goalposts. In each study/experiment, the task was administered in a pre-practice-post-retention test design. In Chapter 2, the aim of the study was to examine the approaches of expert and intermediate Gaelic football players as they self-selected to practice two kicking skills. The aim was to identify the presence of the tenets of deliberate practice through a novel approach of measuring them *during* the activity. In Chapter 3, the aim of the study was to examine the cognitive processes engaged in

by expert and intermediate players during and between practice sessions. An additional aim was to investigate the role of the relevance of the activity to improving performance on practice and its characteristics. In Chapter 4, the aim of the experiment was to examine the effect of applying the cognitive processes commonly found in expert performers to the practice of intermediate youth performers. In general, this thesis was undertaken to examine some of the misinterpretations, limitations and inconsistencies surrounding research and commentary on the theory of deliberate practice.

Summary of key findings

In Chapter 2, the expert group self-selected to practice the weaker of two kicking skills, whereas the intermediate group chose to practice the stronger of the two skills. The decision to practice a weaker skill by the expert group resulted in them rating the practice greater for mental effort and lower for enjoyment when compared to the intermediate group, in line with deliberate practice theory. The expert group retained their improvement at kicking from pre-test to a retention test, whereas kicking performance of the intermediate group in retention was not significantly different to the pre-test. Participants used a practice schedule involving blocks of five or more trials on one kick-type before switching kicks.

In Chapter 3, an expert and an intermediate group engaged in the deliberate practice of a kicking skill rated as most relevant to overall performance improvement. The expert group rated practice greater for mental effort and lower for enjoyment than the intermediate group, albeit the intermediate group rated practice closer to the tenets of deliberate practice theory when compared to the intermediate group in Chapter 2. In addition, participants rated leisure activity higher for

enjoyment and lower for mental effort when compared to the practice activity, again supporting deliberate practice theory. The expert group engaged in greater amounts of cognitive processing through reflecting on their performance before, during, after and between practice sessions when compared to the intermediate group. The expert group improved kicking performance between the pre-test and retention test. In contrast, the kicking performance of the intermediate group was not significantly different between the pre-test and retention test.

In Chapter 4, two matched groups of youth intermediate level performers practiced a kicking skill they selected as most relevant to overall performance improvement. A training group received an intervention to increase cognitive processing before, during and after practice, whereas the control group engaged in practice without intervention. The training and control group made significant improvements from pre- to post-test and maintained the performance improvement in a retention test. However, the training group demonstrated significantly more accurate kicking in both the post- and retention test when compared to the control group. Moreover, the effect of the intervention was apparent during practice, with the training group having significantly greater accuracy following each session compared to the control group. Both groups rated the practice in line with the tenets of deliberate practice theory, but the training group rated the practice significantly greater for mental effort than the control group. The ratings for effort of the control group matched similar skilled groups in previous chapters. The training group demonstrated greater cognitive processing in terms of reflection and evaluation across the experiment; as evident from the SRL-SRS scores at the retention test compared to the pre-test, whereas the control group did not increase these processes across the experiment. The content of the cognitive processing of the training group

showed they engaged in planning, monitoring and evaluation of their progress before, during, after and between the practice sessions.

This section has provided a synthesis of the key findings from Chapter 2, 3 and 4, with findings showing support for the relevance, effort and enjoyment predictions in deliberate practice theory. The subsequent sections will discuss the theoretical implications of these findings, as well as the potential limitations of this research and future directions.

Theoretical implications

From a theoretical perspective, this thesis investigated the theory of deliberate practice and its ratings of relevance to improving performance, effort, enjoyment, and the cognitive processes that underpin it, as well as applying these characteristics to the development of youth intermediate-level performers.

Ratings of deliberate practice

Deliberate practice is suggested to be rated higher for relevance and effort, yet lower for enjoyment when compared to any other form of practice or activity (Ericsson et al., 1993). Limitations exist in the retrospective recall methodology used in previous research on the theory. Despite its limitations, a number of concepts associated with deliberate practice have been subject to criticism in the literature, such as the enjoyment tenet (Helsen et al., 1998; Young & Salmela, 2002) or the relationship between accumulated deliberate practice and attainment (Tucker & Collins, 2012). Many of the criticisms rely on the retrospective recall methodology not confounding data by, for example, including activities in ratings or accumulated sums that are not deliberate practice. Researchers are yet to measure the tenets of

deliberate practice while it is occurring, which is thought to be a more reliable and valid method compared to retrospective recall (Baker & Young, 2014; Coughlan et al., 2014). In this thesis, the ratings of deliberate practice have been measured during the activity, as opposed to retrospectively. The findings in this thesis showed support for the original tenets in deliberate practice theory proposed by Ericsson et al. (1993).

Ericsson (2003a) has clearly stated that not all practice is deliberate, and that other types of practice exist, such as maintenance practice. In addition, they (Ericsson et al., 1993) have stated that not all performers will be motivated enough to engage in deliberate practice and, therefore, many will not. Chapter 2 provided support for these ideas by demonstrating that not all performers engage in deliberate practice when presented with the opportunity to improve performance of a skill. When two groups of Gaelic football players were required to improve their accuracy of two different kicking skills, the expert group chose to practice the weaker of the two kicks, whereas the intermediate group chose to practice the stronger of the two kicks. The expert players rated the practice greater for effort and lower for enjoyment compared to the intermediate group, in line with the tenets presented in deliberate practice theory (Ericsson et al., 1993). Moreover, expert players demonstrated relatively permanent improvement in their skill, whereas the intermediate players did not retain performance improvement. Findings support the suggestion that not all practice is deliberate (Ericsson, 2003a) and contradicts previous research that has included *all* practice activities when rating deliberate practice (Hodges et al., 2004).

Deliberate practice is an activity engaged in to improve an identified aspect of performance and is more effortful when compared to other activities (Ericsson et

al., 1993). The ratings for mental effort in Chapter 2, 3 and 4 all supported the theory of deliberate practice. In Chapter 2, where both physical and mental effort was rated, the expert group rated practice greater for both physical and mental effort when compared to the intermediate group. In Chapter 3, expert and intermediate groups practiced a kicking skill identified as most relevant to overall improvement. The expert group rated the practice greater for mental effort compared to the intermediate group, and they recorded similar ratings for mental effort compared to the expert group in Chapter 2. The intermediate group in Chapter 3 rated the practice greater for mental effort compared to the intermediate group in Chapter 2, suggesting the relevance of the activity to performance improvement influences this rating. In Chapter 4, two groups of youth intermediate-level Gaelic football players practiced a kicking skill they identified as most relevant to overall improvement. The training group engaged in an intervention to increase cognitive processes during practice and rated the practice sessions greater for mental effort when compared to the control group, who did not engage in additional cognitive processing during practice. The training group rated the practice higher for mental effort when compared to the expert groups in Chapter 2 and 3, whereas the control group rated mental effort similarly to the intermediate group in Chapter 3. Overall, findings support the idea that deliberate practice is a more effortful activity when compared to other activities (Ericsson et al., 1993).

Deliberate practice is predicted to be less enjoyable when compared to other activities (Ericsson et al., 1993). The belief is that the process of attempting to improve an aspect of performance is not an inherently rewarding process, and is less enjoyable when compared to other activities. Ericsson et al. (1993) hold that the motivation to engage in deliberate practice emanates from the desire to improve

future performance, rather than enjoyment during the activity. Findings in this thesis support the proposition from the theory that deliberate practice is not inherently enjoyable (Ericsson et al., 1993) showing that it is rated lower for enjoyment. In Chapter 2 and 3, the expert Gaelic football players rated their practice lower for enjoyment when compared to the intermediate players. The rating for enjoyment by the expert players did not differ between Chapter 2 and 3. In contrast, the ratings for enjoyment by the intermediate players were lower in Chapter 3 compared to Chapter 2, probably because in Chapter 3, they were required to practice the skill that was most relevant to overall improvement, whereas in Chapter 2 they were free to self-select which skill to practice (and chose their stronger skill). In Chapter 4, both youth intermediate groups practiced a kicking skill that was rated high for relevance to overall performance improvement and there was no difference in their ratings for enjoyment. Moreover, their ratings for enjoyment were similar to those for the expert groups in Chapter 2 and 3.

In Chapter 3 and 4, for the first time, enjoyment ratings were compared between leisure and deliberate practice activity. Findings supported deliberate practice theory (Ericsson et al., 1993) because enjoyment was rated lower in practice compared to leisure activity. In Chapter 3 and 4, all groups rated the practice significantly lower for enjoyment when compared to leisure activity. These findings may support the idea that the social aspects of sport and the bio-psychological effects of practice may interfere with the accurate rating of practice enjoyment when done retrospectively (Ericsson, 1996; 2004; 2014). Rating practice during the activity may provide more accurate perceptions compared to retrospective recall. Overall, practice rated as most relevant to improving overall performance was rated lower for

enjoyment compared to other activities, supporting the enjoyment tenet in deliberate practice theory (Ericsson et al., 1993).

Deliberate practice is an activity that requires analysis of current performance and identification of rate-limiting factors to further improvement (Ericsson et al., 1993). Central to this process of analysis is that the aspect identified and practiced is highly relevant to overall performance improvement. The method applied in Chapter 3 and 4 may be the first time participants have been required to select a skill as most relevant to overall improvement before rating it for the tenets of deliberate practice. Findings from these studies support the relevance aspect in the theory of deliberate practice. In Chapter 3 and 4, when participants selected the skill for practice that was most relevant to overall performance improvement, the ratings of practice resembled the expected ratings in deliberate practice theory (Ericsson et al., 1993). In contrast, the intermediate performers in Chapter 2 practiced their stronger, rather than weaker skill, and their ratings were different to those for deliberate practice. In Chapter 3 and 4, not only was the practice selected as being most relevant to improving performance, but significant performance improvement in kicking accuracy was also shown between pre- and post-test measurements, demonstrating the relevance of the practice to improvement. In studies using the retrospective recall methodology, practice activities rated as highly relevant to improving performance (e.g., mat work for wrestlers in Hodges & Starkes, 1996) may not have led to actual performance improvement or been the most relevant to performance improvement. Therefore, the ratings of effort and enjoyment for these activities may be for less relevant activity than is indicated in these studies. In addition, the method of retrospectively rating activities that have been engaged in some time ago into a single aggregate score might lead to changes in perceptions or misperceptions for effort and enjoyment

(Baker & Young, 2014; Coughlan et al., 2014). Overall, in this thesis, when an aspect of performance was rated as most relevant to and led to performance improvement, it was rated as effortful and not inherently enjoyable, supporting the theory of deliberate practice (Ericsson et al., 1993).

Cognitive processing and deliberate practice

Experts engage in more advanced cognitive processing compared to lesser-skilled performers (Ericsson & Kintsch, 1995; Ward et al., 2011) and their acquired domain-specific knowledge enables more efficient planning and evaluation of their actions (Ericsson & Lehmann, 1996). The cognitive processing required to engage in deliberate practice is suggested to be greater than other practice activities (Ericsson et al., 1993). In addition, expert performers are believed to engage in practice-related cognitions *away* from the practice environment (Jonker, Elferink-Gemser, de Roos, & Visscher, 2012). However, researchers have not examined such cognitive processing during and surrounding deliberate practice. Findings from Chapter 2 and 3 confirmed that expert performers engage in the advanced cognitive processing of planning and evaluating performance to a greater degree than lesser-skilled performers. In Chapter 2, evidence for advanced cognitive processing was provided when expert players made more monitoring and planning verbal report statements compared to the intermediate group, whereas there was no difference between groups for evaluation statements. In Chapter 3, the SRL-SRS scale measured the intensity of practice-related cognitive processing engaged in between practice sessions. The SRL-SRS scale scores of the expert group were significantly higher than the intermediate group, indicating they were more cognitively engaged in the process away from the practice environment. The interviews also revealed that cognitive processes between practice sessions were greater for expert compared to

intermediate players. Findings extend the research on deliberate practice theory by providing evidence of advanced cognitive processes during and surrounding deliberate practice in expert performers.

Researchers have shown that the cognitive processes of self-regulation have a positive impact on performance and learning (Cleary et al., 2006, Singer, Flora, & Abourezk, 1989; Singer et al., 1993). For example, Cleary et al. (2006) showed how a group who engaged in a complete cycle of self-regulation experienced greater improvement in shooting accuracy in a basketball free-throw task when compared to groups who did less or no self-regulation. However, the effect of cognitive processing from self-regulation has not been examined during deliberate practice. Findings from Chapter 4 showed significantly greater improvements in accuracy by the training group from pre-test to retention test compared to the control group, who also improved from pre-test to retention test but not to the same degree. These findings support the research of Cleary et al. (2006) and extend it to show that increasing cognitive processing during deliberate practice enhances performance improvement in intermediate performers. Findings extend the theory of deliberate practice by showing a positive effect on performance improvement from implementing a self-regulatory cognitive processing strategy with intermediate performers.

The development and utilisation of advanced cognitive processing may be linked to expanded working memory capacity (Ericsson & Towne, 2010), but researchers have not detailed the content of the cognitive processing of performers during practice. Chapter 4 is the first time that the content of cognitive processing during deliberate practice was examined. Findings show that the cognitions elicited from the evaluation questions for the training group were mainly outcome and

technique-related statements, whereas the cognitions from the planning question were mainly process, routine, and concentration. Findings may provide evidence showing the type of cognitive involvement during deliberate practice outlined by Ericsson & Towne (2010). In their theory, expert performers counteract the development of automaticity by engaging in more complex cognitive processing of the type found in Chapter 4 in order to maintain greater control over performance and learning. It appears that the intervention led to the training group engaging in this processing to a greater degree than the control group, which led to the between-group differences in skill learning, supporting the hypothesis in deliberate practice theory.

The current thesis examined cognitive processing during deliberate practice through verbal reports, SRL-SRS analysis and semi-structured interviews, and for the first time examined the impact of increasing cognitive processing on intermediate performers engaging in deliberate practice. Overall, the current thesis has extended the theory of deliberate practice with its findings relating to cognitive processing and its effect on deliberate practice.

Practice scheduling

Permanent changes in performance are usually greater from random practice schedules compared to blocked practice (Ali, Fawver, Kim, Fairbrother, & Janelle, 2012; Goode & Magill, 1986; Immink & Wright, 2001; Kaefer, Chiviacowsky, Meira Jr., & Tani, 2014; Kitago & Krakauer, 2013; Lee & Magill, 1983, Shea & Morgan, 1979). Researchers are yet to examine the effect of practice scheduling on performers engaging in deliberate practice. Moreover, the theory of deliberate practice refers to repeated repetition of tasks as a performer targets a specific

element of their performance for improvement (Ericsson et al., 1993), which suggests a more blocked practice schedule.

The current thesis is the first time that practice schedule has been linked to the theory of deliberate practice and examined for its effect on performance and learning. The findings from Chapter 2 appear to contradict the research on practice schedule (e.g., Goode & Magill, 1986; Kaefer, et al., 2014). The expert group used a hybrid practice schedule, electing to practice a kick for a set of 5 or more consecutive trials at least once before switching kicks, which was closer to blocked than random practice. In addition, the few intermediate players that experienced improvements in performance and at retention also chose this hybrid practice schedule. In Chapter 3 and 4, participants practiced one skill, and so engaged in a blocked practice schedule. In these chapters, kicking accuracy improved significantly between pre- and retention tests. Findings appear to contradict previous research on practice schedule (e.g., Shea & Morgan, 1979). However, practice schedule was not an independent variable in this thesis that systematically differed based on theory, whereas it was in previous research (e.g., Ali et al., 2012). Therefore, the conclusion about which practice schedule is superior for learning for expert or intermediate performers remains unanswered. One suggestion is that the effect of cognitive processing through self-regulation between trials may be sufficient to induce a form of contextual interference, leading to greater learning when compared to less or no processing between trials (Jelsma & van Merriënboer, 1989).

Limitations and future research

The current thesis explored various concepts related to how experts learn and extended the research on the theory of deliberate practice. As with all research, answers to specific hypotheses were established, but with some limitations, which leaves numerous questions to be investigated by future research. The following section addresses those limitations and suggests directions for future research.

Deliberate practice theory

Some of the concepts associated with deliberate practice have been subject to criticism by other researchers, such as the monotonic benefits assumption (Tucker & Collins, 2012) and the enjoyment tenet (e.g., Hodges & Starkes, 1996). The scientific interrogation of theories and concepts is an important part of their development, and should be encouraged. This thesis has provided valid data to address some criticisms of the theory, such as the enjoyment tenet. However, it has not addressed key criticisms related to the monotonic benefits assumption, such as the idea that accumulated deliberate practice accounts for all of the variance in attained performance. To do so using the method from this thesis would require a longitudinal study in which deliberate practice characteristics and outcomes are measured across an extended time period. Longitudinal research is difficult to conduct given the time constraints of research funding and postgraduate qualifications.

In addition, a central part of deliberate practice theory is its predictions about motivation. It holds that the motivation to engage in deliberate practice emanates from the belief that it will improve future performance, rather than it being immediately rewarding, or inherently enjoyable (Ericsson et al., 1993). The use of

enjoyment as a prediction about and to measure motivation, as was used in this thesis and other research assessing the theory, appears to be less developed as a concept when compared to research on motivation. Researchers examining motivation have considered multiple concepts that contribute to it, including task versus ego orientations and motivational climates (e.g., Duda et al., 1995); basic psychological needs including competence (Vallerand & Reid, 1984), and autonomy and relatedness (e.g., Ryan & Deci, 2000); hierarchical needs including self-actualization, belongingness, and safety (e.g., Maslow, 1943) and intrinsic versus extrinsic motivational factors (e.g., Deci, Koestner, & Ryan, 1999). The development and improvement of expert performance clearly requires high levels of motivation over an extended period of time. However, researchers in this area, including in the theory and in this thesis, have not created well developed theories or testable hypotheses about the motivation of expert performers, beyond those outlined in deliberate practice theory. In future, the motivation of aspiring and current performers should be detailed in a comprehensive theory with testable hypotheses that includes, but is not limited to, those outlined in deliberate practice theory (Ericsson & Charness, 1994; Yeo & Neal, 2004).

Transfer of skill acquisition from practice

The transfer of skill acquisition from practice to improved competition performance should be the key consideration when designing practice. A limitation of this thesis is that the transfer of skill acquisition from practice to competition or competition-like conditions was not assessed. The lack of match-based transfer tests in this thesis limits conclusions about the improvements in performance (Chapter 2 and 3) and the cognitive processes underpinning performance and its acquisition (Chapter 3 and 4). Skill acquisition and the transfer of improved performance from

practice to competition requires measurements of competition performance before and after an intervention. One method in Gaelic football would be to conduct performance analysis on the use and success rate of non-dominant kicks from the hands over the course of a number of competitive matches before and after an intervention. In addition, for example participants could retrospectively recall their thoughts whilst observing video footage of the match to determine the cognitive processes that underpinned the performance. A potential limitation of measuring performance in competition is the confounding effect of contextual factors such as weather conditions, venue, and opposing team characteristics. Therefore, multiple matches or simulated matches would need to be used in measurement to reduce the effect of these contextual factors. Similar ideas have been expressed about the need to transfer skills acquired from perceptual-cognitive skills training using representative tasks to improve real-world performance, such as by researchers examining offside decision making in association football referees and assistant referees (Catteeuw, Gilis, Jaspers, Wagemans, & Helsen, 2010; Catteeuw, Gilis, Wagemans, & Helsen, 2010) and others (Broadbent, Williams, Causer, & Ford, 2015).

In this thesis, the cognitions made during deliberate practice appeared to be relatively explicit in nature and the outcome of an explicit knowledge-base. Other researchers have shown that an implicit knowledge-base leads to more robust motor skill execution compared to an explicit knowledge-base (Masters & Poolton, 2012; Poolton, Masters, & Maxwell, 2006). Typically, the accumulation of implicit or explicit knowledge across practice has been measured in transfer tests that assess the extent to which explicit rules underpin motor skill execution, such as dual-tasks or high anxiety conditions. A limitation of this thesis is that no dual-task or high

anxiety transfer tests were included to assess the accumulation of explicit knowledge. In future, for example, groups could engage in a dual task, such as tone-counting during acquisition, as per Maxwell, Masters, & Eves (2000), to identify whether engaging in intense, task-specific bouts of deliberate practice places different cognitive demands on an individual compared to other forms of practice (Geeves, et., 2014; Toner & Moran, 2014; 2015; in press). Alternatively, Causer, et al. (2011) tested their findings on the kinematics and visual attention of elite-level shotgun shooters using a high anxiety transfer test. High anxiety conditions were created by comparing test scores against other participants, as well as having financial rewards for the top three finishers. The effects of high anxiety can be measured with sensitive equipment, such as positron emission topography (PET scan), functional magnetic resonance imaging (fMRI), electroencephalography, galvanic skin patches, heart rate monitors, pupil dilatometers and blood pressure cuffs to measure the psychophysiological differences of attention, anxiety and focus between performers of varying skill levels (for a review, see Janelle, Duley, & Coombes, 2004). Such transfer tests may reveal the resilience of the cognitive processes occurring during deliberate practice and whether they differ to cognitive processes found in other practice conditions. Overall, there is a need to capture and test the naturally occurring performance, acquisition and cognitive processes of expert performers in realistic ecological settings (Ericsson & Ward, 2007; Ericsson & Williams, 2007; Ford, Coughlan, & Williams, 2009; Williams & Ericsson, 2005).

Practice scheduling

The blocked practice schedule used by participants in this thesis led to effects that contradict practice schedule research showing that blocked practice is more effective during acquisition but the effects of random practice are greater in retention

(Lee, 2012). It seems that when participants are able to self-select their practice schedule, they choose a blocked order, as opposed to a random order (Wu & Magill, 2011), which contradicts the work of those who have shown systematic increases in contextual interference with skill acquisition benefits further acquisition (Porter & Magill, 2010; Post, Fairbrother, & Barros, 2011). Such a finding warrants further investigation to determine whether a random practice group in Chapter 3 and 4 would have resulted in even stronger effects in retention compared to the blocked practice schedule used by the groups. The findings for blocked practice in this thesis may support previous research (Jelsma & van Merriënboer, 1989; Shea & Zimny, 1983) showing that intense engagement in a task causes variations from trial to trial that create a contextual interference effect. Recent neuroscience research using fMRI (Cross, Schmitt, & Grafton, 2007; King, Hartley, Spiers, Maguire, & Burgess, 2005), kinaesthetic imagery (Fourkas, Bonavolonta, Avenanti, & Aglioti, 2008), transcranial magnetic stimulation (Lin, Fisher, Winstein, Wu, & Gordon, (2007), kinematic analysis (Lin, Fisher, Wu, Ko, Lee, & Winstein, 2009) and psychometric testing (Ackerman & Beier, 2006) has advanced understanding of the neural adaptations that occur from different practice schedules. The application of such methods may provide neuroscientific data regarding the brain regions involved in the cognitive processes that underpin deliberate practice.

Ratings of deliberate practice

Chapter 2, 3 and 4 supported and extended the research on the ratings of deliberate practice through the use of a novel method of data collection within the practice environment. This method provided participants with the opportunity to isolate their rating of the practice and prevent other variables such as the outcome of accumulated practice sessions to interfere with the perception of the practice and

counter the suggested interference of retrospective recall (de Bruin et al., 2014). A limitation of the current thesis is that it investigated the ratings of deliberate practice of a kicking skill in Gaelic football and not in any other tasks, sports, or domains. Therefore, the generalizability of the findings from the novel method of data collection used in this thesis has not been examined. Future research should use this method to examine deliberate practice in other sports, tasks and domains. It may be possible to examine how this method differs to retrospective recall by having participants rate the same or similar practice some time later, such as a month or a year later, to determine how the practice is perceived across time-points.

The current thesis examined, supported and extended the enjoyment tenet of the theory of deliberate practice by comparing ratings of it with leisure activity. Findings contradict those who suggest that deliberate practice is inherently enjoyable (Hodges & Starkes, 1996). However, the range of activities chosen by the participants included intense activities such as rugby, as well as some less intense activities such as golf. Future research should control for the intensity of the leisure activities to equate them to the effort of the deliberate practice activity under examination; this may provide a more accurate comparison of the ratings between the deliberate practice activity and the leisure activity.

Importance of the work for other domains

The findings from this thesis may translate to how performers engage in deliberate practice in other domains, such as medicine (Causer, Barach, & Williams, 2014; Ericsson, 2007c), military (Ward, Farrow, Harris, Williams, Eccles, & Ericsson, 2008; Williams, Ericsson, Ward, & Eccles, 2008), education (Ashby-Plan et al., 2005), law enforcement (Ward et al., 2011), pilot training (McKinney &

Davis, 2003), and simulation training (Ward, Williams, & Hancock, 2006). In particular, the medical domain has embraced deliberate practice as a concept that can enhance training and application of skills in areas including surgery (Crochet, Aggarwal, Dubb, Ziprin, et al., 2011; Ericsson, 2011; McGaghie, 2008), medical education for undergraduates (Moulaert, Verwijnen, Rikers, & Scherpbier, 2004), emergency medicine (Wayne, Butter, Siddall, Fudala, et al., 2005) and nursing (Ericsson, Whyte, & Ward, 2007). Findings in this thesis about the cognitive processing of expert performers, as well as the method used of measuring performance before and after deliberate practice bouts, could translate to other domains, such as medicine.

Applied implications

Deliberate practice as a practice tool

The data presented in this thesis show how experts learn, how they continue to improve their performance beyond its current level, and how their practice and learning mechanisms can impact on the performance of youth intermediate performers. Therefore, the applied implications of this thesis impact experts, intermediates, coaches, and mentors.

The theory of deliberate practice states that it plays a significant role in differentiating expert from lesser-skilled performers in a domain (Ericsson et al., 1993). In recent versions of the theory, the notion of "arrested development" has been included to describe the plateau in performance that occurs for many performers (Ericsson, 2003a; 2003c; 2007a). Some performers become competent at a task or domain and are satisfied to remain at that current level of performance. In contrast, current and future expert performers are not satisfied with being merely

competent and, as a consequence, they plan and engage in deliberate practice activities that are highly relevant to improving their current performances and their weaknesses. The domain of sport has many examples of professional athletes who perform to their strengths only and pass through an entire professional career with obvious weaknesses to their game (e.g., a soccer player with the inability to shoot for goal using both feet competently. Findings in Chapter 2 and 3 showed the importance for already established expert performers to continue to engage in deliberate practice to avoid "arrested development", to ensure performance remains superior to competitors, and to potentially achieve eminence (Ericsson et al., 1993).

Researchers had not examined the effect of applying deliberate practice to lesser-skilled performers and this thesis presented novel data in this regard. As Chapter 2 and 3 showed, intermediate Gaelic football players did not practice in a manner that either resembled deliberate practice or maximised the effect of deliberate practice. In the absence of direction, intermediate performers chose less effective practice strategies, such as practicing skills they were already relatively competent at or did not cognitively engage in the task to a sufficient level. Therefore, the findings of Chapter 4 in which a training group engaged in deliberate practice confirms the potential benefits for coaches, athletes and mentors of having intermediate performers engage in structured deliberate practice activities. One of the difficulties in having performers engage in deliberate practice, particularly for multiple bouts across an extended period of time, is ensuring motivation to engage remains high. As this thesis has shown, in support of the theory, deliberate practice is rated lower for inherent enjoyment compared to other activities. Therefore, repeated engagement in deliberate practice activities has the potential to become de-motivating because inherent enjoyment is lower. Coaches and significant others must

apply other strategies to ensure long-term motivation remains high, such as focusing on longer-term goals related to achievement. Such motivational strategies may be particularly important in a deliberate environment (Ford, Hodges, & Williams, 2013) where all of the decisions in a performer's life are goal-directed towards performance improvement and achievement including those within and away from the practice setting. For example, recovery activities between training sessions (Gill, Beaven, & Cook, 2006), video analysis (Helsen, et al., 1998), nutrition (Kerksick, Harvey, Stout, Campbell, Wilborn, Kreider, et al., 2008), and reflective practice (Richards, Collins, & Mascarenhas, 2012). Of course, for younger athletes these activities should be introduced incrementally in line with their increased interest and commitment levels up to and including the elite level (Bullock, Gulbin, Martin, Ross, Holland, & Marino, 2009). This process provides a significant challenge to coaches and mentors to create an environment where individuals are motivated to immerse themselves in goal-directed activities within and away from the training environment.

Findings from this thesis support the construct that not all practice is deliberate (Ericsson, 2003a). Previous research on deliberate practice has included all forms of practice in their accumulations and ratings of deliberate practice, which may have led to overestimations of how much deliberate practice was engaged in (Hodges & Starkes, 1996). These other forms of practice, such as maintenance activities and match-play, are important elements of training sessions but lack the characteristics required to qualify them as deliberate practice (for exceptions, see Catteeuw, et al., 2009; MacMahon et al., 2007). Furthermore, not everyone is suited to or requires engagement in deliberate practice. The monotonic benefits assumption has led to the popular belief that the start of engagement in deliberate practice in a

sport should occur very early in childhood. However, in the theory, Ericsson et al. (1993) explicitly outline a pre-deliberate practice phase of participation. The first phase of participation in a domain was argued to ". . . begin with an individual's introduction to activities in the domain and end with the start of instruction and deliberate practice" (Ericsson et al., 1993, p. 369). It was proposed that ". . . interested individuals need to be engaging in the domain and motivated to improve performance before they begin deliberate practice" (p. 371). Therefore, novice and child performers do not need to engage in deliberate practice. Play activities that are engaged in for fun and enjoyment are more suited to novice performers to increase skill acquisition and the likelihood of their participation in the sport for an extended period of time (Côté, Baker, & Abernethy, 2007).

Concluding remarks

In conclusion, this thesis provided an in-depth examination of the theory of deliberate practice, showing how experts learn and how their mechanisms and strategies impact the practice efficacy of lesser-skilled performers. Research on expertise and in particular deliberate practice has received considerable attention in the last 20 years (Baker & Young, 2014). The current thesis addressed some of the limitations in that literature, such as the ratings of relevance, effort, and enjoyment of deliberate practice. The thesis used a novel method of data collection to determine the presence of the tenets of deliberate practice *during* practice, as opposed to retrospectively. In Chapter 2 and 3, the expert performers improved a skill highly relevant to overall performance improvement and rated the practice higher for effort and lower for enjoyment, when compared to intermediate performers. In addition, the thesis extends previous research from the deliberate practice literature concerning the cognitive processes of expert performers (Ericsson & Towne, 2010), showing

their greater engagement in planning, monitoring, and evaluation of performance. Moreover, in Chapter 4, when intermediate performers were required to engage in these cognitive processes during deliberate practice they improved performance beyond that of a group who engaged only in deliberate practice. This thesis will hopefully act as a catalyst for future research in several different areas from both a theoretical and applied perspective. For example, the link between practice schedule and deliberate practice must be investigated as it could have theoretical and applied implications for researchers and practitioners. Overall, the findings in this thesis have corroborated and extended the literature on the theory of deliberate practice and how experts learn.

Chapter 6: References

Abrahams, J. (2001). And the winner is . . . you. *Golf Magazine*, *43*, 92-100.

Ackerman, P. L., & Beier, M. E. (2006). Methods for studying the structure of expertise: Psychometric approaches. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman (Eds.), *Cambridge handbook of expertise and expert performance* (pp. 147-165). Cambridge, UK: Cambridge University Press.

Ali, A., Fawver, B., Kim, J., Fairbrother, J., & Janelle, C. M. (2012). Too much of a good thing: Random practice scheduling and self-control of feedback lead to unique but not additive learning benefits. *Frontiers in Psychology*, *3*, 1-9. doi: 10.3389/fpsyg.2012.00503

Anshel, M. H., & Porter, A. (1996). Self-regulatory characteristics of competitive swimmers as a function of skill level and gender. *Journal of Sport Behavior*, *19*, 91-110.

Ashby-Plant, E., Ericsson, K. A., Hill, L., & Asberg, K. (2005). Why study time does not predict grade point average across college students: Implications of deliberate practice for academic performance. *Contemporary Educational Psychology*, *30*, 96-116. doi: 10.1016/j.cedpsych.2004.06.001

Baker, J., Côté, J., & Abernethy, B. (2003). Sport specific practice and the development of expert decision-making in team ball sports. *Journal of Applied Sport Psychology*, *15*, 12-25. doi: 10.1080/10413200305400

Baker, J., Côté, J., & Deakin, J. M. (2005). Expertise in ultra-endurance triathletes early sport involvement, training structure, and the theory of deliberate practice. *Journal of Applied Sport Psychology, 17*, 64-78. doi:10.1080/10413200590907577

Baker, J. & Young, B. (2014). 20 years later: Deliberate practice and the development of expertise in sport. *International Review of Sport and Exercise Psychology, 7*, 135-157. doi: 10.1080/1750984X.2014.896024

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Prentice-Hall, Inc.

Bernier, M., Codron, R., Thienot, E., & Fournier, J. F. (2011). The attentional focus of expert golfers in training and competition: A naturalistic investigation. *Journal of Applied Sport Psychology*, *23*, 326-341. doi: 10.1080/10413200.2011.561518

Boekaerts, M., & Cacallar, E. (2006). How far have we moved toward the integration of theory and practice in self-regulation? *Educational Psychology Review*, *18*, 199-210. doi: 10.1007/s10648-006-9013-4

Borg, G. (1985). *An introduction to Borg's RPE Scale*. Ithaca NY: Movement Publications.

Boudreau, M-C., Gefen, D., & Straub, D. W. (2001). Validation in information systems research: A state-of-the-art assessment. *Management Information Systems Quarterly, 25*, 1-16. doi: 10.2307/3250956.

Boutin, A., & Blandin, Y. (2010a). Cognitive underpinnings of contextual interference during motor learning. *Acta Psychologica*, *135*, 233-239. doi: 10.1016/j.actpsy.2010.07.004

Boutin, A., & Blandin, Y. (2010b). On the cognitive processes underlying contextual interference: Contributions of practice schedule, task similarity and amount of practice. *Human Movement Science*, *29*, 910-920. doi: 10.1016/j.humov.2010.07.011

Boyce, B. A. (1992). The effects of goal proximity on skill acquisition and retention of a shooting task in a field-based setting. *Journal of Sport & Exercise Psychology*, *14*, 298-308.

Brashers-Krug, T., Shadmehr, R., & Bizzi, E. (1996). Consolidation in human motor memory. *Nature*, *382*, 252-255. doi: 10.1038/382252a0

Broadbent, D. P., Causer, J., Williams, A. M., & Ford, P. R. (2015). Perceptual-cognitive skill training and its transfer to expert performance in the field: Future research directions. *European Journal of Sport Science*, *15*, 322-331. doi: 10.1080/17461391.2014.957727

Bullock, N., Gulbin, J. P., Martin, D. T., Ross, A., Holland, T., & Marino, F. (2009). Talent identification and deliberate programming in skeleton: Ice novice to Winter Olympian in 14 months. *Journal of Sports Sciences, 27*, 397-404. doi: 10.1080/02640410802549751

Campitelli, G., & Gobet, F. (2011). Deliberate practice: Necessary but not sufficient. *Current Directions in Psychological Science*, *20*, 280-285. doi: 10.1177/0963721411421922

Carson, H. J., & Collins, D. (2011). Refining and regaining skills in fixation/diversification stage performers: The Five-A Model. *International Review of Sport and Exercise Psychology*, *4*, 146-167. doi: 10.1080/1750984X.2011.613682

Catteeuw, P., Gilis, B., Jaspers, A., Wagemans, J., & Helsen, W. (2010). Training of perceptual-cognitive skills in offside decision making. *Journal of Sport & Exercise Psychology*, *32*, 845-861.

Catteeuw, P., Gilis, B., Wagemans, J., & Helsen, W. (2010). Perceptual-cognitive skills in offside decision making: Expertise and training effects. *Journal of Sport & Exercise Psychology*, *32*, 828-844.

Catteeuw, P., Helsen, W. F., Gilis, B., & Wagemans, J. (2009). Decision-making skills, role specificity, and deliberate practice in association football refereeing. *Journal of Sports Sciences*, *11*, 1125-1136. doi: 1080/02640410903079179

Causer, J., Barach, P., & Williams, A. M. (2014). Expertise in medicine: Using the expert performance approach to improve simulation training. *Medical Education*, *48*, 115-123. doi: 10.1111/medu.12306

Causer, J., Holmes, P. S., Smith, N. C., & Williams, A. M. (2011). Anxiety, movement kinematics, and visual attention in elite-level performers. *Emotion, 11*, 595–602. doi: 10.1037/a0023225

Charness, N. (1981). Search in chess: Age and skill differences. *Journal of Experimental Psychology: Human Perception and Performance*, *7*, 467-476. doi: 10.1037/0096-1523.7.2.467

Charness, N., Tuffiash, M., Krampe, R., Reingold, E., & Vasyukova, E. (2005). The role of deliberate practice in chess expertise. *Applied Cognitive Psychology*, *19*, 151-165. doi: 10.1002/acp.1106

Chase, W. G., & Ericsson, K. A. (1980). Skilled memory. In J. R. Anderson (Ed.), *Cognitive Skills and their Acquisition*, (pp. 141-190). Psychology Press.

Chase, W. G., & Ericsson, K. A. (1982). Skilled and working memory. In G. W. Bower (Ed.), *The Psychology of Learning and Motivation*, Vol. *16,* Academic Press.

Chen, M. J., Fan, X., & Moe, S. T. (2002). Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: A meta-analysis. *Journal of Sports Sciences, 20,* 873-899. doi: 10.1080/026404102320761787

Cleary, T. J., & Zimmerman, B. J. (2001). Self-regulation differences during athletic practice by experts, non-experts, and novices. *Journal of Applied Sport Psychology, 13,* 185-206. doi: 10.1080/104132001753149883

Cleary, T. J., Zimmerman, B. J., & Keating T. (2006). Training physical education students to self-regulate during basketball free throw practice. *Research Quarterly for Exercise and Sport, 77,* 251-262. doi: 10.1080/02701367.2006.10599358

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Côté, J., Baker, J., & Abernethy, B. (2007). Practice and play in the development of sport expertise. In R. Eklund & G. Tenenbaum (Eds.) *Handbook of sport psychology* (184-202, 3rd Edition). Hoboken, NJ: Wiley.

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,* 51-64. doi: 10.1080/10413200903403216

Coughlan, E. K., Williams, A. M., McRobert, A. P., Ford, P. R. (2014). How experts practice: A novel test of deliberate practice theory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40,* 449-458. doi: 10.1037/a0034302

Crochet, P., Aggarwal, R., Dubb, S. S., Ziprin, P., Rajaretnam, N., Grantcharov, T., Ericsson, K. A., & Darzi, A. (2011). Deliberate practice on a virtual reality

laparoscopic simulator enhances the quality of surgical technical skills. *Annals of Surgery, 253,* 1216-1222. doi: 10.1097/SLA.0b013e3182197016

Cross, E. S., Schmitt, P. J., & Grafton, S. T. (2007). Neural substrates of contextual interference during motor learning support a model of active preparation. *Journal of Cognitive Neuroscience*, *19,* 1854-1871. doi: 10.1162/jocn.2007.19.11.1854

Davids, K. & Baker, J. (2007). Genes, environment and sport performance: Why the nature-nurture dualism is no longer relevant. *Sports Medicine, 37,* 961-980. doi: 0112-1642/07/0011-0961

Day, E. A., Arthur Jr., W., & Gettman, D. (2001). Knowledge structures and the acquisition of a complex skill. *Journal of Applied Psychology*, *86,* 1022-1033. doi: 10.1037//0021-9010.86.5.1022

Deakin, J. M., & Cobley, S. (2003). A Search for Deliberate Practice – An Examination of the Practice Environments in Figure Skating and Volleyball. In J. L. Starkes, & K. A. Ericsson (Eds.), *Expert performance in sports: Advances in research on sport expertise* (pp. 115-136), Champaign: IL, Human Kinetics.

Deakin, J. M., Starkes, J. L., & Allard, F. (1998). *The microstructure of practice in sport*. Ottawa, Canada: Sport Canada Technical Report.

de Bruin, A. B. H., Rikers, R. M. J. P., Schmidt, H. G. (2007). The influence of achievement motivation and chess-specific motivation on deliberate practice. *Journal of Sport & Exercise Psychology*, *29,* 561-583.

de Bruin, A. B. H., Smits, N., Rikers, R. M. J. P., & Schmidt, H. G. (2008). Deliberate practice predicts performance over time in adolescent chess

players and drop-outs: A linear mixed models analysis. *British Journal of Psychology*, *99*, 473-497. doi: 10.1348/000712608X295631

de Bruin. A. B. H., Kok, E. M., Leppink, J., & Camp, G. (2014). Practice, intelligence, and enjoyment in novice chess players: A prospective study at the earliest stage of a chess career. *Intelligence*, *45*, 18-25. doi: 10.1016/j.intell.2013.07.004

Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiements examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin*, *125*, 627–668. doi: 10.1037/0033-2909.125.6.627

Dishman, R. K., Farquhar, R. P., & Cureton, K. J. (1994). Responses to preferred intensities of exertion in men differing in activity levels. *Medicine and Science in Sports and Exercise, 26*, 783-790. doi: 10.1249/00005768-199406000-00019

Duda, J. L., Chi, L., Newton, M. L., Walling, M. D., & Catley, D. (1995). Task and ego orientation and intrinsic motivation in sport. *International Journal of Sport Psychology*, *26*, 40-63.

Duffy, L. J., Baluch, B., & Ericsson, K. A. (2004). Dart performance as a function of facets of practice amongst professional and amateur men and women players. *International Journal of Sport Psychology*, *35*, 232-245.

Eccles, D. W. (2010). Verbal reports of cognitive processes. In G. Tenenbaum, R. C. Eklund, & A. Kamata (Eds.), *Handbook of measurement in sport and exercise psychology* (pp. 103-117). Champaign, IL: Human Kinetics.

Elferink-Gemser, M. T., Jordet, G., Coelho-E-Silva, M. J., & Visscher, C. (2012). The marvels of elite sports: How to get there? *British Journal of Sports Medicine, 45,* 683-684. doi: 10.1136/bjsports-2011-090254

Ericsson, K. A. (Ed.) (1996). The acquisition of expert performance: An introduction to some of the issues. In K. A. Ericsson (Ed.), *The road to excellence: The acquisition of expert performance in the arts and sciences, sports and games* (pp. 1-50). Hillsdale, NJ: Lawrence Erlbaum.

Ericsson, K. A. (2003a). Development of elite performance and deliberate practice: an update from the perspective of the expert performance approach. In J. L. Starkes & K. A. Ericsson (Eds.), *Expert Performance in Sports: Advances in Research on Sport Expertise* (pp. 49-84). Champaign: IL, Human Kinetics.

Ericsson, K. A. (2003b). Exceptional memorizers: made, not born. *Trends in Cognitive Sciences, 7,* 233-235. doi: 10.1016/S1364-6613(03)00103-7

Ericsson, K. A. (2003c). The acquisition of expert performance as problem solving: Construction and modification of mediating mechanisms through deliberate practice. In J. E. Davidson & R. J. Sternberg (Eds.), *The Psychology of Problem Solving* (pp. 31-83). New York: Cambridge University Press.

Ericsson, K. A. (2004). Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. *Academic Medicine, 10,* S70-S81.

Ericsson, K. A. (2006a). The influence of experience and deliberate practice on the development of superior expert performance. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman (Eds.), *Cambridge handbook of expertise and expert performance* (pp. 683-703). Cambridge, UK: Cambridge University Press.

Ericsson, K. A. (2006b). Protocol analysis and expert thought: Concurrent verbalizations of thinking during expert's performance on representative tasks. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman (Eds.), The *Cambridge handbook of expertise and expert performance* (pp. 223-242). Cambridge: Cambridge University Press.

Ericsson, K. A. (2007a). Deliberate practice and the modifiability of body and mind: toward a science of the structure and acquisition of expert and elite performance. *International Journal of Sport Psychology*, *38*, 4-34.

Ericsson, K. A. (2007b). Toward a science of expert and exceptional performance in sport: a reply to commentaries. *International Journal of Sport Psychology*, *38*, 109-123.

Ericsson, K. A. (2007c). An expert-performance perspective of research on medical expertise: The study of clinical performance. *Medical Education*, *41*, 1124-1130. doi: 10.1111/j.1365-2923.2007.02946.x

Ericsson, K. A. (2008). Deliberate practice and acquisition of expert performance: A general overview. *Academic Emergency Medicine*, *15*, 988-994. doi: 10.1111/j.1553-2712.2008.00227.x

Ericsson, K. A. (2011). The surgeon's expertise. In *Surgical Education* (pp. 107-121). Springer Netherlands.

Ericsson, K. A. (2012). Training history, deliberate practise and elite sports performance: an analysis in response to Tucker and Collins review – what makes champions? *British Journal of Sports Medicine*, *47*, 533-535. doi: 10.1136/bjsports-2012-091767

Ericsson, K. A. (2014). Why expert performance is special and cannot be extrapolated from studies of performance in the general population: A

response to criticisms. *Intelligence, 45,* 81-103. doi: 10.1016/j.intell.2013.12.001

Ericsson, K. A., & Charness, N. (1994). Expert performance: Its structure and acquisition. *American Psychologist, 49,* 725-747. doi: 10.1037/0003-066X.49.8.725

Ericsson, K. A., & Chase, W. G. (1982). Exceptional memory: Extraordinary feats of memory can be matched or surpassed by people with average memories that have been improved by training. *American Scientist, 70,* 607-615.

Ericsson, K. A., Chase W. G., & Faloon, S. (1980). Acquisition of a memory skill. *Science, 208,* 1181-1182. doi: 10.1126/science.7375930

Ericsson, K. A., & Delaney, P. F. (1999). Long-term working memory as an alternative to capacity models of working memory in everyday skilled performance. In A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 257-297). New York: Cambridge University Press.

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review, 102,* 211-245. doi: 10.1037/0033-295X.102.2.211

Ericsson, K. A. and Kirk, E. (2001). *Instructions for giving retrospective verbal reports*. Department of Psychology, Florida State University. Unpublished manuscript.

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100,* 363-406. doi: 10.1037/0033-295X.100.3.363

Ericsson, K. A., & Lehmann, A. C. (1996). Expert and exceptional performance: Evidence of maximal adaptation to task constraints. *Annual Review of Psychology, 47,* 273-305. doi: 10.1146/annurev.psych.47.1.273

Ericsson, K. A., Prietula, M. J., & Cokely, E. T. (2007). The making of an expert. *Harvard Business Review, 85,* 1-14.

Ericsson, K. A. & Simon, H. A. (1980). Verbal reports as data. *Psychological Review, 87,* 215-251. doi: 10.1037/0033-295X.87.3.215

Ericsson, K. A. & Simon, H. A. (1993). *Protocol analysis; Verbal reports as data, revised edition*. Cambridge, MA: Bradford books/MIT Press.

Ericsson, K. A. & Towne, T. J. (2010). Expertise. *Wiley Interdisciplinary Reviews Cognitive Science, 1,* 404-416. doi: 10.1002/wcs.47

Ericsson, K. A., & Ward, P. (2007). Capturing the naturally occurring superior performance of experts in the laboratory: Toward a science of expert and exceptional performance. Current Directions in Psychological Science, *16,* 346-350. doi: 10.1111/j.1467-8721.2007.00533.x

Ericsson, K.A., Whyte, J., & Ward, P. (2007). Expert performance in nursing: Reviewing research on expertise in nursing within the framework of the expert-performance approach. *Advances in Nursing Science, 30,* 58-71.

Ericsson, K. A., & Williams, A. M. (2007). Capturing naturally occurring superior performance in the laboratory: Translational research on expert performance. *Journal of Experimental Psychology: Applied, 13,* 115-123. doi: 10.1037/1076-898X.13.3.115

Ertmer, P. A., & Newby, T. J. (1996). The expert learner: Strategic, self-regulated, and reflective. *Instructional Science, 24,* 1-24. doi: 10.1007/BF00156001

Everitt, B. S., & Skrondal, A. (2002). *The Cambridge dictionary of statistics*. Cambridge: Cambridge.

Fitts, P. M. & Posner, M. I. (1967). *Human performance*. Belmont, CA: Brookes/Cole.

Ford, P. R., Carling, C., Garces, M., Marques, M., Miguel, C., Farrant, A., Stenling, A., et al. (2012). The developmental activities of elite soccer players aged under-16 years from Brazil, England, France, Ghana, Mexico, Portugal and Sweden. *Journal of Sports Sciences, 30*, 1653-1663. doi: 10.1080/02640414.2012.701762

Ford, P. R., Coughlan, E. K., Hodges, N. J., & Willaims, A. M. (2015). Deliberate practice in sport. In J. Baker & D. Farrow. (Eds.) *Routledge Handbook of Sport Expertise* (pp. 347-362). UK: Routledge.

Ford, P. R., Coughlan, E. K., & Williams, A. M. (2009). The expert performance approach as a framework for understanding and enhancing coaching performance, expertise and learning. *International Journal of Sports Science & Coaching*, *4*, 451-463. doi: 10.1260/174795409789623919

Ford, P. R., Yates, I., & Williams, A. M. (2010). An analysis of practice activities and instructional behaviours used by youth soccer coaches during practice: Exploring the link between science and application. *Journal of Sports Sciences*, *28*, 483-495. doi: 10.1080/02640410903582750

Ford, P. R., Hodges, N. J., & Williams, A. M. (2013). Creating champions: The development of expertise in sports. In S. B. Kaufman (Ed.), *Beyond talent: The complexity of greatness* (pp.391-414). Oxford: Oxford University Press.

Ford, P. R., Ward, P., Hodges, N. J., & Williams, A. M. (2009). The role of deliberate practice and play in career progression in sport: the early

engagement hypothesis. *High Ability Studies*, *20*, 65-75. doi: 10.1080/13598130902860721

Fourkas, A. D., Bonavolonta, V., Avenanti, A., Aglioti, S. M. (2008). Kinesthetic imagery and tool-specific modulation of corticospinal representations in expert tennis players. *Cerebral Cortex*, *18*, 2382-2390. doi: 10.1093/cercor/bhn005

Fox, M. C., Ericsson, K. A., & Best, R. (2011). Do procedures for verbal reporting of thinking have to be reactive? A meta-analysis and recommendations for best reporting methods. *Psychological Bulletin*, *137*, 316-344. doi: 10.1037/a0021663

Geeves, A, McIlwain, D. J. F., Sutton, J., & Christensen, W. (2014). To think or not to think: The apparent paradox of expert skill in music performance. *Educational Philosophy and Therapy*, *46*, 674-691. doi: 10.1080/00131857.2013.779214

Gill, N. D., Beaven, C. M., & Cook, C. (2006). Effectiveness of post-match recovery strategies in rugby players. *British Journal of Sports Medicine*, *40*, 260-263. doi:10.1136/bjsm.2005.022483

Goode, S., & Magill, R. A. (1986). Contextual interference effects on learning three badminton serves. *Research Quarterly for Exercise and Sport*, *57*, 308-314. doi: 10.1080/02701367.1986.10608091

Guadagnoli, M. A. & Lee, T. D. (2004). Challenge point: framework for conceptualizing the effects of various practice conditions in motor learning. *Journal of Motor Behavior*, *36*, 212-224. doi: 10.3200/JMBR.36.2.212-224

Hambrick, D. D., Altmann, E. M., Oswald, F. L., Meinz, E. J., & Gobet, F. (2014). Facing facts about deliberate practice. *Frontiers in Psychology*, *5*, 164-165. doi: 10.3389/fpsyg.2014.00751

Hambrick, D. Z., Oswald, F. L., Altman, E. M., Meinz, E. J., Gobet, F., & Campitelli, G. (2014). Deliberate practice: Is that all it takes to become an expert? *Intelligence, 45*, 34-45. doi: 10.1016/j.intell.2013.04.001

Hansman, C. A. (2001). Context-based adult learning. *New Directions for Adult and Continuing Education, 89*, 43-52. doi: 10.1002/ace.7

Hardy, L., Jones, G., & Gould, D. (1996). *Understanding psychological preparation for sport: Theory and practice of elite performers*. Wiley, England.

Helsdingen, A.S., van Gog, T., & van Merrienboer, J. J. G. (2011). The effects of practice schedule on learning a complex judgment task. *Learning and Instruction, 21*, 126-136. doi:10.1016/j.learninstruc.2009.12.001

Helsen, W. F., Hodges, N. J., Van Winckel, J. & Starkes, J. L. (2000). The roles of talent, physical precocity and practice in the development of soccer expertise. *Journal of Sports Sciences, 18***,** 727-736. doi: 10.1080/02640410050120104

Helsen, W. F., Starkes, J. L., & Hodges, N. J. (1998). Team sports and the theory of deliberate practice. *Journal of Sport and Exercise Psychology*, *20*, 12-34.

Hendry, D. T., Crocker, P. R. E., & Hodges, N. J. (2014). Practice and play as determinants of self-determined motivation in youth soccer players. *Journal of Sports Sciences, 32*, 1091-1099. doi: 10.1080/02640414.2014.880792

Hill, N. M., & Schneider, W. S. (2006). Brain changes in the development of expertise: Neuroanatomical and neurophysiological evidence about skill-based adaptations. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman (Eds.), *Cambridge handbook of expertise and expert performance* (pp. 653-682). Cambridge, UK: Cambridge University Press.

Hodge, T., & Deakin, J. (1998). Deliberate practice and expertise in the martial arts: The role of context in motor recall. *Journal of Sport and Exercise Psychology, 20,* 260-279.

Hodges, N. J., Edwards, C., Luttin, S., & Bowcock, A. (2011). Learning from the experts: Gaining insights into best practice during the acquisition of three novel motor skills. *Research Quarterly for Exercise and Sport, 82,* 178-187. doi: 10.5641/027013611X13119541883546

Hodges, N. J., Kerr, T., Starkes, J. L., Weir, P. L., & Nananidou, A. (2004). Predicting times from deliberate practice hours for triathletes and swimmers: What, when, and where is practice important? *Journal of Experimental Psychology: Applied, 10,* 219-237. doi: 10.1037/1076-898X.10.4.219

Hodges, N. J., & Starkes, J. L. (1996). Wrestling with the nature of expertise: A sport-specific test of Ericsson, Krampe and Tesch-Römer's (1993) theory of "deliberate practice". *International Journal of Sport Psychology, 27,* 400-424.

Hodges, N. J., Starkes, J. L., MacMahon, C. (2006). Expert performance in sport: A cognitive perspective. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman (Eds.), *Cambridge handbook of expertise and expert performance* (pp. 471-488). Cambridge, UK: Cambridge University Press.

Holladay, C. L., & Quiñones, M. A. (2003). Practice variability and transfer of training: The role of self-efficacy generality. *Journal of Applied Psychology, 88,* 1094-1103. doi: 10.1037/0021-9010.88.6.1094

Howard, B. C., McGee, S., Sia, R., & Hong, N. S. (2000). *Metacognitive self-regulation and problem-solving: Expanding the theory base through factor*

analysis. Paper presented at the Annual Meeting of the American Educational Research Association.

Hyllegard, R., Radlo, S. J., & Early, D. (2001). Attribution of athletic expertise by college coaches. *Perceptual and Motor Skills*, *92*, 193-207. doi: 10.2466/pms.2001.92.1.193

Hyllegard, R., & Yamamoto, M. (2005). Testing assumptions of deliberate practice theory, relevance, effort, and inherent enjoyment of practice on a novel task. *Perceptual and Motor Skills*, *101*, 283-294. doi: 10.2466/pms.101.1.283-294.

Immink, M. A., & Wright, L. D. (2001). Motor programming during practice conditions high and low in contextual interference. *Journal of Experimental Psychology: Human Perception and Performance*, *27*, 423-437. doi: 10.1037//0096-1523.27.2.423

Janelle, C. J., Duley, A. A., & Coombes, S. A. (2004) Psychophysiological and related indices of attention during motor skill acquisition. In A. M. Williams, & N. J. Hodges (Eds.), *Skill acquisition in sport: Research theory and practice* (pp. 282-308), Routledge.

Jelsma, O., & van Merriënboer, J. J. G. (1989). Contextual interference: Interactions with reflection-impulsivity. *Perceptual Motor Skills*, *68*, 1055-1064. doi: 10.2466/pms.1989.68.3c.1055

Jones, C. (2012, July 4). How Andy Murray turned a second serve into his lethal weapon. *The London Evening Standard*. Retrieved from http://www.standard.co.uk/sport/wimbledon

Jonker, L., Elferink-Gemser, M. T., & Visscher, C. (2010). Differences in self-regulatory skills among talented athletes: The significance of competitive

level and type of sport. *Journal of Sports Sciences*, *28*, 901-908. doi: 10.1080/02640411003797157

Jonker, L., Elferink-Gemser, M. T., de Roos, I. M., & Visscher, C. (2012). The role of reflection in sport expertise. *The Sport Psychologist*, *26*, 224-242.

Kaefer, A., Chiviacowsky, S., Meira Jr., C. de M., Tani, G. (2014). Self-controlled practice enhances motor learning in introverts and extroverts. *Research Quarterly for Exercise and Sport*, *85*, 226-233. doi: 10.1080/02701367.2014.893051

Keetch, K. M., & Lee, T. D. (2007). The effect of self-regulated and experimenter-imposed practice schedules on motor learning for tasks of varying difficulty. *Research Quarterly for Exercise and Sport*, *78*, 476-486. doi: 10.1080/02701367.2007.10599447.

Kellmann, M. (2010). Preventing overtraining in athletes in high-intensity sports and stress/recovery monitoring. *Scandinavian Journal of Medicine & Science in Sports, 20*, 95-102. doi: 10.1111/j.1600-0838.2010.01192.x

Kendzierski, D., & DeCarlo, K. J. (1991). Physical Activity Enjoyment Scale: Two Validation Studies. *Journal of Sport & Exercise Psychology*, *13*, 30-64.

Kerksick, C., Harvey, T., Stout, J., Campbell, B., Wilborn, C., Kreider, R., Kalman, D., Ziegenfuss, T., Lopez, H., Landis, J., Ivy, J. L., & Antonio, J. (2008). International society of sports nutrition position stand: Nutrient timing. *Journal of the International Society of Sports Nutrition, 5*, 1-12. doi: 10.1186/1550-2783-5-17

King, J. A., Hartley, T., Spiers, H. J., Maguire, E. A., & Burgess, N. (2005). Anterior prefrontal involvement in episodic retrieval reflects contextual interference. *NeuroImage*, *28*, 256-267. doi: 10.1016/j.neuroimage.2005.05.057

Kitago, T., Krakauer, J. W. (2013). Motor learning principles for neurorehabilitation. In M. P. Barnes, D. C. Good (Eds.), *Handbook of Clinical Neurology, 110,* 93-103. Elsevier Netherlands.

Kitsantas, A., & Zimmerman, B. J. (1998). Self-regulation of motoric learning: A strategic cycle view. *Journal of Applied Sport Psychology, 10,* 220-239. doi: 10.1080/10413209808406390

Kitsantas, A., & Zimmerman, B. J. (2002). Comparing self-regulatory processes among novice, non-expert, and expert volleyball players: A microanalytic study. *Journal of Applied Sport Psychology, 14,* 91-105. doi: 10.1080/10413200252907761

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice Hall.

Krampe, R. Th., & Ericsson, K. A. (1996). Maintaining excellence: Deliberate practice and elite performance in young and older pianists. *Journal of Experimental Psychology: General, 125,* 331-359. doi: 10.1037/0096-3445.125.4.331

Law, M., Côté, J. & Ericsson, K. A. (2007). Characteristics of expert development in rhythmic gymnastics: A retrospective study. *International Journal of Sport and Exercise Psychology, 5,* 82-103. doi: 10.1080/1612197X.2008.9671814

Lee, T. D. (2012). Contextual interference: Generalizability and limitations. In N. J. Hodges & A. M. Williams (Eds.), *Skill Acquisition in Sport: Research, Theory and Practice,* (pp. 79-93). Routledge.

Lee, T. D., & Magill, R. A. (1983). The locus of contextual interference in motor skill acquisition. *Journal of Experimental Psychology: learning, memory and cognition, 9,* 730-746. doi: 10.1037/0278-7393.9.4.730

Lee, T. D., Swinnen, S. P., & Serrien, D. J. (1994). Cognitive effort and motor learning. *Quest, 46,* 328-344. doi: 10.1080/00336297.1994.10484130

Lin, C-H., Fisher, B. E., Winstein, C. J., Wu, A. D., & Gordon, J. (2008). Contextual interference effect: Elaborative processing or forgetting-reconstruction? A post hoc analysis of transcranial magnetic stimulation-induced effects on motor learning. *Journal of Motor Behavior, 40,* 578-586. doi: 10.3200/JMBR.40.6.578-586

Lin, C-H., Fisher, B. E., Wu, A. D., Ko, Y-A., Lee, L-Y., & Winstein, C. J. (2009). Neural correlate of the contextual interference effect in motor learning: A kinematic analysis. *Journal of Motor Behavior, 41,* 232-242. doi: 10.3200/JMBR.41.3.232-242

MacIntyre, T. E., Igou, E. R., Campbell, M. J., Moran, A. P., & Matthews, J. (2014). Metacognition and action: a new pathway to understanding social and cognitive aspects of expertise in sport. *Frontiers in Psychology, 5,* 220-231. doi: 10.3389/fpsyg.2014.01155

MacMahon, C., Helsen, W. F., Starkes, J. L., & Weston, M. (2007). Decision-making skills and deliberate practice in elite association football referees. *Journal of Sports Sciences, 25,* 65-78. doi: 10.1080/02640410600718640

Macnamara, B. N., Hambrick, D. Z., & Oswald, F. L. (2014). Deliberate practice and performance in music, games, sports, education, and professions: A meta-analysis. *Psychological Science, 25,* 1608-1618. doi: 10.1177/0956797614535810

Magill, R. A., & Hall, K. G. (1990). A review of the contextual interference effect in motor skill acquisition. *Human Movement Science, 9,* 241-289. doi: 10.1016/0167-9457(90)90005-X

Maslow, A. H. (1943). A theory of human motivation. *Psychological Review*, *50*, 370-396. doi: 10.1037/h0054346

Masters, R. S. W., & Poolton, J. M. (2012). Advances in implicit motor learning. In N. J. Hodges & A. M. Williams (Eds.), *Skill Acquisition in Sport: Research, Theory and Practice*, (pp. 59-75). Routledge.

Maxwell, J. P., Masters, R. S. W., Eves, F. F. (2000). From novice to no know-how: A longitudinal study of implicit motor learning. *Journal of Sports Sciences*, *18*, 111-120. doi: 10.1080/026404100365180

McGaghie, W. C. (2008). Research opportunities in simulation-based medical education using deliberate practice. *Academic Emergency Medicine*, *15*, 995-1001. doi: 10.1111/j.1553-2712.2008.00246.x

McKinney Jr., E. H., & Davis, K. J. (2003). Effects of deliberate practice on crisis decision performance. *Human Factors*, *45*, 436-444. doi: 10.1518/hfes.45.3.436.27251

McPherson, S. L., & Thomas, J. R. (1989). Relation of knowledge and performance in boys' tennis: Age and expertise. *Journal of Experimental Psychology*, *48*, 190-211. doi: 10.1016/0022-0965(89)90002-7

Meinz, E. J., & Hambrick, D. Z. (2010). Deliberate practice is necessary but not sufficient to explain individual differences in piano sight-reading skill: The role of working memory capacity. *Psychological Science*, *21*, 914-919. doi: 10.1177/0956797610373933

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits of our capacity for processing information. *Psychological Review*, *63*, 81-97. doi: 10.1037/0033-295X.101.2.343

Moulaert, V., Verwijnen, M. G. M., Rikers, R., Scherpbier, A. J. J. A. (2004). The effects of deliberate practice in undergraduate medical education. *Medical Education, 38,* 1044-1052. doi: 10.111/j.1365-2929.2004.01954.x

Newell, A., & Rosenbloom, P. S. (1981). Mechanisms of skill acquisition and the law of practice. In: *Cognitive skills and their acquisition*. Ed: Anderson, J. R., Hillsdale, NJ: Erlbaum, 1-55.

Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice Hall.

Notebaert, W., & Verguts, T. (2008). Cognitive control acts locally. *Cognition, 106,* 1071-1080. doi: 10.1016/j.cognition.2007.04.011

Paris, S. G., & Paris, A. H. (2001). Classroom applications of research on self-regulated learning. *Educational Psychologist, 36,* 89-101. doi: 10.1207/S15326985EP3602_4

Perdue, B. C. & Summers, J. O. (1986). Checking the success of manipulations in marketing experiments. *Journal of Marketing Research, 23,* 317-326. doi: 10.2307/3151807.

Poolton, J. M., Masters, R. S. W., & Maxwell, J. P. (2006). The influence of analogy learning on decision-making in table tennis: Evidence from behavioural data. *Psychology of Sport and Exercise, 7,* 677-688. doi: 10.1016/j.psychsport.2006.03.005

Porter, J. M., & Magill, R. A. (2010). Systematically increasing contextual interference is beneficial for learning sport skills. *Journal of Sports Sciences, 28,* 1277-1285. doi: 10.1080/02640414.2010.502946

Post, P. G., Fairbrother, J. T., & Barros, J. A. C. (2011). Self-controlled amount of practice benefits learning of a motor skill. *Research Quarterly for Exercise and Sport, 82*, 474-481. doi: 10.1080/02701367.2011.10599780

Richards, P., Collins, D., & Mascarenhas, D. R. D. (2012). Developing rapid high-pressure team decision-making skills. The integration of slow deliberate reflective learning within the competitive performance environment: A case study of elite netball. *Reflective Practice, 13*, 407-424. doi: 10.1080/14623943.2012.670111

Rohrer, D., & Taylor, K. (2007). The shuffling of mathematics problems improves learning. *Instructional Science, 35*, 481-498. doi: 10.1007/s11251-007-9015-8

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology, 25*, 54-67. doi: 10.1006/ceps.1999.1020

Schneider, W. (1985). Training high performance skills: Fallacies and guidelines. *Human Factors, 27*, 285-300. doi: 10.1177/001872088502700305.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York: Basic Books.

Schwarzer, R. (1993). *Measurement of perceived self-efficacy: Psychometric scales for cross-cultural research*. Berlin: Forschung an der Freien Universität Berlin.

Shea, C. H., Lai, Q., Black, C., Park, J-H. (2000). Spacing practice sessions across days benefits the learning of motor skills. *Human Movement Science, 19*, 737-760. doi: 10.1016/S0167-9457(00)00021-X

Shea, J.B. and Morgan, R.L. (1979). Contextual interference effects on the acquisition, retention, and transfer of a motor skill. *Journal of Experimental Psychology: Human Learning and Memory*, *5*, 179-187. doi: 10.1037/0278-7393.5.2.179

Shea, J. B., & Zimny, S. T. (1983). Context effects in memory and learning movement information. In R. A. Magill (Ed.), *Memory and control of action* (pp. 345-366). Amsterdam: North-Holland.

Singer, R. N., Flora, L. A., & Abourezk, T. L. (1989). The effect of a five-step cognitive learning strategy on the acquisition of a complex motor task. *Applied Sport Psychology, 1*, 98-108. doi: 1041-3200/89/0098-0108

Singer, R. N., Lidor, R., & Cauraugh, J. H. (1993). To be aware or not aware? What to think about while learning and performing a motor skill. *The Sport Psychologist, 7*, 19-30.

Sonnentag, S. (1998). Expertise in professional software design: A process study. *Journal of Applied Psychology, 83*, 703-715. doi: 10.1037/0021-9010.83.5.703

Starkes, J. L. (2000). The road to expertise: Is practice the only determinant? *International Journal of Sport Psychology*, *31*, 431-451.

Starkes, J. L., Deakin, J., Allard, F., Hodges, N. J., & Hayes, A. (1996). Deliberate practice in sports: What is it anyway? In K. A. Ericsson (Ed.), *The road to excellence: The acquisition of expert performance in the arts and sciences, sports, and games* (pp. 81-106). Mahwah, NJ: Erlbaum.

Ste-Marie, D. M., Clark, S. E., Findlay, L. C., & Latimer, A. E. (2004). High levels of contextual interference enhance handwriting skill acquisition. *Journal of Motor Behavior, 36*, 115-126. doi: 10.3200/JMBR.36.1.115-126

Sutton, J., McIlwain, D., Christensen, W., & Geeves, A. (2011). Applying intelligence to the reflexes: embodied skills and habits between Dreyfus and Descartes. *Journal of the British Society for Phenomenology*, *42*, 78-103. doi: 10.1080/00071773.2011.11006732

Thayer, J. F., Hansen, A. L., Saus-Rose, E., Johnsen, B. J. (2009). Heart rate variability, prefrontal neural function, and cognitive performance: The neurovisceral integration perspective on self-regulation, adaptation, and health. *Annals of Behavioral Medicine, 37*, 141-153. doi: 10.1007/s12160-009-9101-z

Thomas, J. R., & Nelson, J. K. (2001). *Research methods in physical activity*. Champaign, IL: Human Kinetics.

Toering, T. T., Elferink-Gemser, M. T., Jonker, L., Van Heuvelen, M. J. G., & Visscher, C. (2012). Measuring self-regulation in a learning context: Reliability and validity of the Self-Regulation of Learning Self-Report Scale (SRL-SRS). *International Journal of Sport and Exercise Psychology*, *10*, 24-38. doi: 10.1080/1612197X.2012.645132

Toering, T. T., Elferink-Gemser, M. T., Jordet, G., Jorna, C., Pepping, G-J., & Visscher, C. (2011). Self-regulation of practice behaviour among elite youth soccer players: An exploratory observation study. *Journal of Applied Sport Psychology*, *23*, 110-128. doi: 10.1080/10413200.2010.534544

Toering, T. T., Elferink-Gemser, M. T., Jordet, G., & Visscher, C. (2009). Self-regulation and performance level of elite and non-elite youth soccer players. *Journal of Sports Sciences, 27*, 1509-1517. doi: 10.1080/02640410903369919

Toering, T. T., Jordet, G., & Ripegutu, A. (2013). Effective learning among elite football players: The development of a football-specific self-regulated learning questionnaire. *Journal of Sports Sciences, 31*, 1412-1420. doi: 10.1080/02640414.2013.792949

Toner, J., Montero, B. G., & Moran, A. (2014). Considering the role of cognitive control in expert performance. *Phenomenology and the Cognitive Sciences,* (online version). doi: 10.1007/s11097-014-9407-6

Toner, J., & Moran, A. (2014). In praise of conscious awareness: a new framework for the investigation of "continuous improvement" in expert athletes. *Frontiers in Psychology, 5*, 232-236. doi: 10.3389/psyg.2014.00769

Toner, J., & Moran, A. (2015). Enhancing performance proficiency at the expert level: Considering the role of 'somaesthetic awareness'. *Psychology of Sport & Exercise, 16*, 110-117. doi: 10.106/j.psychsport.2014.07.006

Toner, J., & Moran, A. (in press). Toward an explanation of continuous improvement in expert athletes: The role of consciousness in deliberate practice. *International Journal of Sport Psychology*.

Tucker, R., & Collins, M. (2012). What makes champions? A review of the relative contribution of genes and training to sporting success. *British Journal of Sports Medicine, 46*, 555-561. doi:10.1136/bjsports-2011-090548

Vallerand, R. J., & Reid, G. (1984). On the causal effects of perceived competence on intrinsic motivation: A test of cognitive evaluation theory. *Journal of Sport Psychology, 6*, 94-102.

Ward, P., Ericsson, K. A., & Williams, A. M. (2013). Complex perceptual-cognitive expertise in a simulated task environment. *Journal of Cognitive Engineering and Decision Making, 7*, 231-254. doi: 10.1177/1555343412461254

Ward, P., Farrow, D., Harris, K. R., Williams, A. M., Eccles, D. W., & Ericsson, K. A. (2008). Training perceptual-cognitive skills: Can sport psychology research inform military decision training? *Military Psychology, 20*, S71-S102. doi: 10.1080/08995600701804814

Ward, P., Hodges, N. J., Starkes, J. L., & Williams, A. M. (2007). The road to excellence: deliberate practice and the development of expertise. *High Ability Studies*, *18*, 119-153. doi: 10.1080/13598130701709715

Ward, P., Hodges, N. J., Williams, A. M., & Starkes, J. L. (2004). Deliberate practice and expert performance: Defining the path to excellence. In A. M. Williams, & N. J. Hodges (Eds.), *Skill acquisition in sport: Research theory and practice* (pp. 231-258), Routledge.

Ward, P., Suss, J., Eccles, D. W., Williams, A. M., & Harris, K. R. (2011). Skill-based differences in option generation in a complex task: A verbal protocol analysis. *Cognitive Processing*, *12*, 289-300. doi: 10.1007/s10339-011-0397-9

Ward, P., Williams, A. M., & Hancock, P. A. (2006). Simulation for performance training. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman (Eds.), *Cambridge handbook of expertise and expert performance* (pp. 243-262). Cambridge, UK: Cambridge University Press.

Wayne, D. B., Butter, J., Siddall, V. J., Fudala, M. J., Wade, L. D., Feinglass, J., & McGaghie, W. C. (2005). Mastery learning of advanced cardiac life support skills by internal medicine residents using simulation technology and deliberate practice. *Journal of General Internal Medicine*, *21*, 251-256. doi: 10.1111/j.1525-1497.2006.00341.x

Weissensteiner, J., Abernethy, B., Farrow, D., & Müller, S. (2008). The Development of Anticipation: A Cross-Sectional Examination of the Practice Experiences Contributing to Skill in Cricket Batting. *Journal of Sport & Exercise Psychology, 30***,** 663-684.

Williams, A. M., & Ericsson, K. A. (2005). Perceptual-cognitive expertise in sport: Some considerations when applying the expert performance approach. *Human Movement Science, 24*, 283-307. doi: 10.1016/j.humov.2005.06.002

Williams, A. M., & Ericsson, K. A. (2005). From the guest editor: How do experts learn? *Journal of Sport & Exercise Psychology*, *30*, 653-662.

Williams, A. M., Ericsson, K. A., & Ward, P. (2008). Research on expertise in sport: Implications for the military. *Military Psychology*, *20*, S123-S145. doi: 10.1080/08995600701804863

Wu, W. F. W., & Magill, R. A. (2011). Allowing learners to choose: Self-controlled practice schedule for learning multiple movement patterns. *Research Quarterly for Exercise and Sport*, *82*, 449-457. doi: 10.1080/02701367.2011.10599777

Wulf, G. (2013). Attentional focus and motor learning: A review of 15 years. *International Review of Sport and Exercise Psychology*, *6*, 77-104. doi: 10.1080/1750984X.2012.723728

Wulf, G., Raupach, M., & Pfeiffer, F. (2005). Self-controlled observational practice enhances learning. *Research Quarterly for Exercise and Sport, 76*, 107-111. doi: 10.5641/027013605X13076330976948

Wulf, G., & Schmidt, R. A. (1997). Variability of practice and implicit motor learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*, 987-1006. doi: 10.1037/0278-7393.23.4.987

Wulf, G., & Su, J. (2007). An external focus of attention enhances golf shot accuracy in beginners and experts. *Research Quarterly for Exercise and Sport, 78,* 384-389. doi: 10.1080/02701367.2007.10599436

Yarrow, K., Brown, P., & Krakauer, J. W. (2009). Inside the brain of an elite athlete: The neural processes that support high achievement in sports. *Nature Reviews Neuroscience, 10,* 585-596. doi: 10.1038/nrn2672

Yeo, G. B., & Neal, A. (2004). A multilevel analysis of effort, practice, and performance: Effects of ability, conscientiousness, and goal orientation. *Journal of Applied Psychology, 89,* 231-247. doi: 10.1037/0021-9010.89.2.231

Young B. W., & Salmela, J. H. (2002) Perceptions of training and deliberate practice of middle distance runners. *International Journal of Sport Psychology, 33,* 167-181.

Zijlstra, F.R. H., & van Doorn, L. (1985). *The Construction of a Scale to Measure Perceived Effort*. Delft University of Technology, The Netherlands.

Zimmerman, B. J. (1986). Becoming a self-regulated learner: Which are the key subprocesses? *Contemporary Educational Psychology, 11,* 307-313. doi: 10.1016/0361-476X(86)90027-5

Zimmerman, B. J. (1989). A social cognitive view of self-regulated academic learning. *Journal of Educational Psychology, 81,* 329-339. doi: 10.1037/0022-0663.81.3.329

Zimmerman, B. J. (1998). Academic studying and the development of personal skill: A self-regulatory perspective. *Educational Psychologist, 33,* 73-86.

Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. Pintrich, & M. Zeidner (Eds.), *Handbook of self-*

regulation, research, and applications (pp. 13-39). Orlando, FL: Academic Press.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory into Practice*, *41*, 64-70. doi: 10.1207/s15430421tip4102_2

Zimmerman, B. J. (2006). Development and adaptation of expertise: The role of self-regulatory processes and beliefs. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 705-722). New York: Cambridge University Press.

Zimmerman, B. J. (2008). Investigating self-regulation and motivation: historical background, methodological developments, and future prospects. *American Educational Research Journal*, *45*, 166-183. doi: 10.3102/0002831207312909.

Zimmerman, B. J., & Campillo, M. (2003). Motivating self-regulated problem solvers. In J. E. Davidson & R. J. Sternberg (Eds.), *The Psychology of Problem Solving* (pp. 233-262). New York: Cambridge University Press.

Zimmerman, B. J., & Kitsantas, A. (1996). Self-regulated learning of motoric skill: The role of goal-setting and self-monitoring. *Journal of Applied Sport Psychology*, *8*, 60-75. doi: 1041-3200/96/0060-0075

Zimmerman, B. J., & Kitsantas, A. (1997). Developmental phases in self-regulation: Shifting from process goals to outcome goals. *Journal of Educational Psychology*, *89*, 29-36. doi: 10.1037/0022-0663.89.1.29

Chapter 7: Appendix