Choking under pressure in self-paced sport: Revisiting the effects of attentional interference in preparation and execution

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

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Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed.

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Leo Roberts, September 1, 2018
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The credit (or blame) for this work could never rest entirely with me. I’ve been influenced by others; often covertly. My writing has been infiltrated by words that drew me in, phrases that caught my attention and expressions that I sponged from others. My views, standards and self-belief have been shaped by people who pushed me to do better, challenged my ideas, encouraged my ideas, or simply encouraged. The true list of credits for this production is unwieldy, but there are some stars, and at last, it’s my chance to acknowledge them.

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Abstract

Researchers investigating the nature of expertise in sport have carefully studied psychological processes that occur before a motor action (i.e., in preparation) and psychological processes that occur during a motor action (i.e., in execution). This work has identified a series of preparation advantages that experts hold over novices, such as more efficient visual scanning, superior anticipation and better self-regulation. It has also identified a series of execution advantages that experts hold over novices, such as increased proprioceptive awareness, greater ability to absorb environmental information and superior mid-movement adaptability. A less understood but intrinsically related field, choking under pressure, is concerned with sudden expertise loss, triggered by anxiety, in high-stakes situations. While the study of expertise has closely considered both the preparation and execution phases, this thesis proposes that two influential kinds of choking research – studies based on dual-task experiments and studies based on self-report – have been inattentive to one phase or the other, and accordingly have presented a relatively incomplete picture of the phenomenon. The arguments made throughout the thesis are that a) dual-task experiments have superficially addressed the prospect that mental interference during the preparation phase could cause choking and b) that studies of choking relying on self-report have superficially addressed the prospect that mental interference during the execution phase could cause choking. Accordingly, this PhD research revisited these paradigms with a more detailed focus on information processing during preparation and execution, with the expectation of a new pattern of evidence for the prevailing theories. To this end, two studies were conducted using the self-paced activity of golf. Study 1 addressed how cognitive and perceptual interference during the preparation and execution phases of the golf swing differentially affected skilled motor performance. Study 2 addressed how golfers rationalised choking under pressure when separately considering the preparation and execution phases.
The thesis had a second critical focus: a complementary body of observational research focused on the behavioural correlates of performance, pressure and choking in self-paced sports. The thesis develops the argument that this kind of research has also been incomplete. Some observational studies have considered the relationship between preparation behaviour (e.g., consistency) and performance but without considering pressure. Others have considered the relationship between pressure and preparation behaviour but without directly linking any changes to performance. Finally, some have considered how behaviour under pressure influences performance but without taking a behavioural baseline. In response, Study 3 integrated these elements and addressed how pressure observably influenced golfers’ preparation behaviour, and whether or not any behavioural changes predicted better or worse performance.

In study 1, 24 skilled golfers (handicap≤6) undertook a series of golf approach shots (60m-150m) into a golf simulator while cognitive or perceptual dual-tasks separately interfered with their preparation or execution. The results showed that golfers largely withstood interference, but that distance control of the shortest shots deteriorated when preparation was disrupted. Cluster analysis indicated that interference to short-shot preparation elicited a similar number of cognitive mistakes (e.g., poor decision-making) and execution mistakes (e.g., poor timing). The results suggest that off-task thought during preparation can impair distance control on shots requiring conscious adjustment (e.g., shortening the swing) and further, that several mechanisms may explain this loss of control.

In study 2, 80 golfers of varied skill level (handicap 18 to professional) completed a mixed-methods questionnaire that separately enquired about normal and pressure-affected thinking during the preparation and execution phases. In reflecting on normal thought processes, many golfers, across all skill levels, indicated a technical focus during execution; a finding that sits uncomfortably with the group of choking theories often called self-focus.
When reflecting on the execution phase in past chokes, several forms of conscious processing and irrelevant thought were rated as similarly problematic. Factor analysis of these ratings suggested that golfers often represent choking as an interplay between worry about the outcome (before or during the execution) and unhelpful conscious control during the execution. The results suggest qualification to the prevailing view that overactive conscious processing is an unusual rationalisation for choking in highly-practiced motor skills.

In study 3, 24 golfers (the same as from study 1) were observed as they hit approach shots into a simulator under conditions of lower and higher pressure. The results revealed that golfers collected information about the shot (e.g., target information) over a longer period when experiencing pressure-related worry, when facing a longer shot and when performing relatively well in a condition. While longer information collection periods did not reliably predict superior performance, a secondary analysis suggested that slowing down this component might play a role in saving performance under anxiety. The results further indicated that golfers freely varied their characteristic preparation behaviours (e.g., changing the number of practice swings or settling behaviours like waggling the club). This flexibility was evident regardless of the situation (e.g., the level of pressure or distance from the hole) and did not reliably affect performance. The results suggest qualification to the popular view that preparation in self-paced skills like golf needs to be highly consistent.

In collating these results and other contemporary findings, a model was produced to map how the interplay between compromised information processing in preparation and execution can cause choking. Four pathways between a disrupted preparation and failed motor execution were specified, along with future studies to examine the various predictions. To finish, existing choking interventions were reviewed and new possibilities were offered. In sum, the thesis combined three kinds of research to map how pressure-induced attentional
failures in preparation may set a course for motor skill failures in execution, ways to further test this, and possibilities for mitigation.
Chapter 1 – The colloquial and scientific phenomenon of choking under pressure

‘I count him braver who overcomes his desires than him who conquers his enemies, for the hardest victory is over the self.’

Aristotle

The dual-purpose of this opening chapter is to introduce the phenomenon of choking under pressure and contextualise the rest of the thesis. In the first half of the chapter, discussion is centred on definitions of choking, the reasons why choking might occur, why choking is a worthy topic of study, and the history of its etiological study until now. In the second half of the chapter, the major research gap proposed by the thesis is introduced: that significant sections of the literature on choking have bypassed how misdirected attention in motor preparation and execution could separately or collaboratively contribute to choking. From there, the game of golf is introduced as an example of self-paced sport well suited to the study of choking. Finally, a brief mapping of the chapters to come is presented.

The normal experience of choking

Mastering a sport takes a daunting amount of practice (Ericsson, 2003). Failures are both unavoidable and expected on the long journey from novice to expert – just feedback to refine a method. However, at advanced levels, given the substantial investment and rising expectation, significant failures are inevitably disheartening. In the aftermath of a substandard performance, most athletes will seek answers. Sometimes the failure will be easily externalised: bad luck, a superior opponent, a necessary risk, a technical flaw, an unruly audience or an injury. Yet for almost every sportsperson, some failures are convincingly self-inflicted, and often, these self-defeats occur under pressure. Expertise can be surprisingly fragile (Beilock & Carr, 2001; Lewandowsky & Kirsner, 2000). A skill attained through thousands of hours of practice can unravel unreasonably quickly when the
outcome really matters (e.g., Beilock, Carr, MacMahon, & Starkes, 2002; Christensen, Sutton, & McIlwain, 2015). Even elite athletes prepared by a life of competition can fail dramatically when they approach desired goals or are threatened with embarrassing failure (e.g., Bawden & Maynard, 2001; Gröpel & Beckmann, 2018). Outstanding soccer players, for instance, are more likely to miss penalties when the tournament is more prestigious (e.g., the World Cup) or at a more decisive moment in a shootout (Jordet, Hartman, Visscher, & Lemmick, 2007). When this pressure to perform well is self-evident and the drop in performance (from normal) is obvious, the decline is often branded a *choke* (e.g., Gucciardi, Longbottom, Jackson, & Dimmock, 2010). This dramatic taxonomy is metaphoric (there is no physical choking); not particularly intuitive (think the opposite of flowing) and reflects a highly undesirable event. As flippant as it sounds, *choking* is bona fide scientific terminology. A burst of research in recent decades has progressed understanding of choking greatly (e.g., Mesagno & Mullane-Grant, 2010), nevertheless, the causes remain unclear (Carr, 2015; Christensen et al., 2015; Gröpel & Beckmann, 2018; Payne, Wilson, & Vine, 2018; Toner, Montero, & Moran, 2016; Winter, MacPherson, & Collins, 2014).

Several classic examples of choking are reliably wheeled out in the sport psychology literature. In 1993, Jana Novotna led Steffi Graf 4-1 (40-30) in the final set of the Wimbledon final before losing in a manner that made her ‘unrecognisable’ as an elite player (Gladwell, 2000, p84). In 1996, the golfer Greg Norman entered the final round of the US Masters with a six shot lead – a tournament he had almost won repeatedly – only to lose by five shots. In 1999, Jean Van-de-Velde sacrificed a three shot lead on the final hole of the tournament before eventually losing in a playoff. More recently, the Atlanta Falcons lead the New England Patriots 28-3 in the third quarter of the 2017 Super Bowl. Highlighting that choking can afflict a group, the Falcons gave up 25 unanswered points and lost the ensuing play-off. Choking events at the elite level stand out and attract lasting stigma. Reporters write about
them and the public gossips about them. When Jordan Spieth lost a final round lead in the 2016 US Masters by sending two balls into a water hazard, newspaper headlines were unforgiving. For example, ‘How Jordan Spieth choked away the Masters’ (Gray, 2016) and ‘Was Jordan Spieth's Masters meltdown the major choke of all-time?’ (Murnane, 2016). Donald Trump added ‘Let me tell you, Jordan Spieth choked a little bit’ (Boren, 2016). These landmark instances are relatively scarce, hence the lasting media spotlight when they occur. It is behind the scenes where the problem likely proliferates: the struggling professional golfer near the halfway cut; the amateur basketball player with free-throws to win the game; the grade cricketer ‘needing a score’ to secure team selection. These chances to improve status, gain credibility, get approval, avoid embarrassment, go to the next level, or scratch out a living are the perfect contexts for choking. In this sense, choking might reasonably be viewed as normal experience: just a consequence of moving outside one’s ‘comfort zone’ without knowing how to cope. A step towards better coping is understanding how the breakdown occurs. To that end, the purpose of this thesis is to better understand the causes of choking.

Definitions

Researchers have defined choking differently throughout the sports psychology literature. Most simply, the phenomenon has been defined as a performance decrement under pressure (Baumeister, 1984). Pressure, in the context of performance, has been defined as ‘the presence of situational incentives for optimal, maximal or superior performance’ (Baumeister & Showers, 1986, p362), but is reasonably considered in more negative terms, such as the burden or concern created by an outcome that personally matters (e.g., Carr, 2015). Baumeister’s (1984) basic concept of choking is pragmatic for researchers since any decline under pressure could reasonably count as a choke, thus making the phenomenon relatively easy to study (Gucciardi & Dimmock, 2008). Nevertheless, for several contributors, this benchmark does not adequately capture experience of choking. In the
contemporary discussion, there is broad acceptance that a choke should be specified more
precisely (Gucciardi et al., 2010; Hill, Hanton, Fleming, & Matthews, 2009; Mesagno & Hill,
2013; Mesagno & Mullane-Grant, 2010). To begin, some have argued that a choke can only
occur if performance (under pressure) drops beneath a standard realistically attained in
normal (i.e., low pressure) circumstances (e.g., Beilock & Gray, 2007; Mesagno & Mullane-
Grant, 2010). Others have gone further, proposing that the definition should reflect the view
of the wider sporting public, in which choking is often seen as a fairly disastrous unravelling
of skill (Hill et al., 2009; Mesagno & Hill, 2013). Another definitional layer is that pressure is
matter of perception (Gucciardi et al., 2010). This element reflects that the experience of
pressure is fundamentally personal, affected by, for example, the importance of the outcome
to the individual, past experiences in similar circumstances, and reactivity to stress.

The construct of anxiety has also featured in some definitions of choking (Gucciardi
et al., 2010; Mesagno & Mullane-Grant, 2010). Anxiety refers to the unpleasant conscious
experience of worry, dread, or apprehension (among other labels), often triggered by an
immediate or anticipated threat (LeDoux, 2015). Pressure and anxiety are intuitively related,
given that pressure to perform well (e.g., on the field, in a job interview or when auditioning
for a part) often makes people temporarily anxious. While seminal work on the choking
phenomenon often referred to pressure without referring to anxiety (e.g., Baumeister, 1984;
Beilock & Carr, 2001; Beilock et al., 2002), the two ideas have been largely been intertwined
since (Gucciardi & Dimmock, 2008). For example, researchers focused on choking typically
evaluate their attempts to apply pressure by taking anxiety measurements (e.g., Jackson,
Ashford, & Norsworthy, 2006). Moreover, several contemporary theories used to explain
choking (see chapter 2) fundamentally concentrate on how anxiety impacts attention (e.g.,
Nieuwenhuys & Oudejans, 2012). For this reason, anxiety is an important inclusion in any
precise conceptualisation of choking.
The multiplicity of definitions available in the literature is regarded as problematic because converging the findings makes little sense (Christensen et al., 2015; Hill et al., 2009; Hill, Hanton, Matthews, & Fleming, 2010a). This is primarily because different results in published studies could simply reflect different operationalisations of choking. One fundamental difference is the degree of performance decline accepted as a choke. For example, choking has been published as both a 15% drop in putting accuracy (3cm) and as a 40% drop in shooting scores (Hill et al., 2010a). Another fundamental difference is the skill level of the performers examined, and thus, the extent that inferior performance could really be considered choking. For instance, the pressure-induced failures of national biathlon competitors (Vickers & Williams, 2007) and briefly trained novice golfers (Lewis & Linder, 1997) both take their adjacent place in the literature, even though choking without much skill approaches an oxymoron.

To address the incoherent operationalisations of the phenomenon, calls for a single definition of choking have come from Mesagno, Harvey, and Janelle (2012), Mesagno, Marchant, and Morris (2008), Mesagno, Marchant, and Morris (2009) and Mesagno and Mullane-Grant (2010). Their suggested definition is: ‘a critical deterioration in the execution of habitual processes as a result of an elevation in anxiety levels under perceived pressure, leading to substandard performance’ (e.g., Mesagno & Mullane-Grant, 2010, p131). This definition acknowledges a) a serious drop in performance to subnormal levels, b) the importance anxiety as the trigger and c) the perceived nature of pressure. Although relatively comprehensive, the emphasis on ‘execution of habitual processes’ is arguably problematic. While this element implies (importantly) that choking principally applies to well-rehearsed skills (i.e., motor habits formed with practice), choking could reasonably arise from failures of non-habitual processes (e.g., irrational decisions in challenging environments). The strong focus on habitual (or automatic processes) in the literature on choking will be considered in
depth throughout. To address this issue, a generalised version of Mesagno and Mullane-Grant’s (2010) definition of choking will be adopted, in which the emphasis on habitual processes is removed. This adaptation defines choking as a significant deterioration in the performance of a well-rehearsed skill (to substandard levels) due to elevated anxiety under perceived pressure.

**Why does choking occur?**

An appealing idea is that years of drilling a motor skill would allow future repetition on demand, for example, when it counts. Yet there are obstacles to the easy reproduction of a skill under anxiety and/or pressure. One barrier is that people have imperfect mental control (Wegner, 1994). For instance, telling someone to suppress the thought of a white bear prompts its repeated return to consciousness (Wegner, Schneider, Carter, & White, 1987). When there is competition for attention, mental control can diminish further. For example, asking someone to go to sleep as quickly as possible slows them down if they are listening to an attention-grabbing march, but not if they are listening to new-age background music (Ansfield, Wegner, & Bowser, 1996). The experience of pressure (and related anxiety) in sport also creates a battle for attention between the task at hand and the threat of failing (Beilock & Gray, 2007). As it happens, our brain, by design, may not help us concentrate on the task in these important moments. We have architecture to detect threat (the lateral amygdala) and it has communication lines to cortical attention networks that can railroad our focus towards the threat (LeDoux, 2015). Amidst the ancient threats that humans and their descendants have faced, the consequences of missing an easy putt or serving a ball into the net might seem low on the list. However, there is good evolutionary basis for worrying about being embarrassed in front of peers, or losing social status in general. For our ancestors, living in social groups proved highly adaptive for survival (Emde, 1980) and exclusion from the group or punishment for contravening expectations was worth worrying about (Casimir &
Schnegg, 2002). With worry about performance comes a loss of attentional control (Eysenck, Derakshan, Santos, & Calvo, 2007) and one way or another (to be discussed throughout this thesis), this can overwhelm an athlete. To absorb pressure, athletes need to regulate their attention when it is challenged (e.g., Englert, Zwemmer, Bertrams, & Oudejans, 2015).

Another plausible reason that repeating a skill under pressure is challenging is that athletes often practice their skills in a low-pressure context and perform them in a high-pressure context. Expertise is notoriously domain-specific. Chess experts have outstanding memory for the spatial location of pieces in meaningful chess formations, but not random formations (Chase & Simon, 1973). Tetris experts show enhanced spatial abilities when processing tetris-like arrangements, but not other spatial arrangements (Sims & Mayer, 2002). Pressure is objectively an arbitrary feature of a performance situation since it does not alter the athlete’s task (e.g., pressure does not change the dimensions of the tennis court). Nevertheless, pressure can bring a flurry of uncomfortable thoughts and feelings that can make the task seem different (e.g., Hill et al., 2009). The perception of difference is probably enough. People have trouble transferring their skills from one context to another if they believe they are dissimilar (Lewandowsky, Little, & Kalish, 2007). Presumably, extensive motor rehearsal in pressurised contexts would make coping easier. Studies of motor-skill training under anxiety suggest so (e.g., Oudejans & Pijpers, 2010).

**Why study choking?**

For several reasons, the study of choking is a worthy topic for researchers. For one, its study mirrors an inherent human fascination with public failures (Christensen et al., 2015). These occasions attract a crowd, gossip and excitement. Another reason is that choking is a challenging subject that crosses multiple investigative domains. Its exploration transgresses elusive areas of human experience such as attention, awareness and consciousness; tempting philosophers, cognitive psychologists and neuroscientists to contribute. A third reason is that
choking is a highly negative experience and there remains great scope to devise new intervention solutions or re-evaluate existing approaches. Since the causes of choking are uncertain, the development of theoretically-motivated treatments is sluggish. With little choice, practitioners have moved ahead and recommended strategies thought to mitigate choking without understanding its causes, or relatedly, the reason a treatment might work or not work. For example, the development of a pre-performance routine is a frontline tactic in the management of performance under pressure in sports in which the athlete initiates the action. Nevertheless, how a routine would precisely do this is uncertain and largely untested (Cotterill, 2010). Moreover, a primary goal of the pre-performance routine and other promising treatments of choking (e.g., mindfulness and commitment approaches) is to improve task focus. Yet there is a genuine argument (and evidence) from the aetiology literature that off-task focus is an inadequate explanation of choking in experts (e.g., Hill et al., 2010a). At the rudimentary level, this is because expert athletes can demonstrably perform their skills without thinking much about them (Beilock, Bertenthal, McCoy, & Carr, 2004; Beilock & Carr, 2001; Beilock et al., 2002; Gray, 2004), including when under pressure (Gucciardi & Dimmock, 2008; Jackson et al., 2006; Land & Tenenbaum, 2012). This point is expanded upon in chapter 2. Improved understanding of the causes of choking would present clearer pathways for intervention research and implementation.

**A brief history of choking research**

The origins of choking research are often traced back to arousal (or drive) theories of human performance (see Balk, Adriaanse, De Ridder, & Evers, 2013; Beilock & Gray, 2007; Gucciardi et al., 2010; Hill et al., 2010a). In early work on human performance, Stennett (1957) had participants complete an auditory tracking task, in which they rotated a tracking knob in response to auditory stimuli under conditions of varied incentive. He observed that tracking performance was best when physiological arousal (measured by electromyography
and skin conductance recordings) was at an intermediate level but relatively poor when arousal was very low and high. That is, the arousal-performance function roughly took the shape of an inverted-U. That particular curve was made famous by Yerkes and Dodson (1908) who found that mice habitually avoided medium-strength electric shocks faster than lighter or stronger shocks.

Easterbrook (1959) combined concepts of arousal and attention to also explain inverted-U performance. He proposed that arousal linearly decreases the range of cues attended to in the environment. Arousal initially improves performance because the narrowing attentional field first excludes task-irrelevant cues. Past the optimal arousal level (when all task-irrelevant cues are inhibited), the attentional field keeps narrowing, eventually sacrificing the task-relevant cues as well. This is when the inverted-U takes a downward turn and performance declines. Among others, Hockey (1970) found support for Easterbrook’s hypothesis by examining the effect of noise (a tool to increase arousal) on performance. Under various noise levels, Hockey had participants visually track a central stimulus (the primary task) while identifying the position of lights that occasionally flashed in the periphery. Participants were told that the primary task was the ‘major priority’ (p. 31). At greater arousal levels, Hockey observed a decline in secondary task performance and an improvement in primary task performance – the attentional tunnelling predicted by Easterbrook. On the contrary, more recent research indicates that arousal can lead to attentional expansion when the secondary task is equally important (Eysenck et al., 2007; Shapiro & Johnson, 1987). Current eye movement studies also suggest that attention broadens under anxiety (e.g., Nibbeling, Oudejans, & Daanen, 2012) – a construct that overlaps with arousal. Moreover, the prevailing contemporary view is that the inverted-U (i.e., the arousal-performance the curve that Easterbrook’s hypothesis maintains) is overly simplistic and does not suitably explain cognitive and sports performance (Eysenck & Calvo,
A persistent problem is a lack of evidence that elevated arousal (even to high levels) adequately accounts for declining performance in fine motor skills (Balk et al., 2013; Gardner & Moore, 2004, 2012). For instance, Cohen, Pargman, and Tenenbaum (2003) found that darts players maintained accuracy when their heart rate was at 90% capacity. The issue of attentional change remains relevant.

An important development came when the psychological phenomenon of anxiety was integrated into the study of performance, rather than simply arousal (i.e., the general excitation of the nervous system). Liebert and Morris (1967) proposed that anxiety had two dimensions; a cognitive component (e.g., worry, negative expectations or self-concern) and an emotional component (perception of physiological arousal as unpleasant) – later redescribed as somatic anxiety (Martens, Vealey, & Burton, 1990). In turn, Martens et al. (1990) proposed Multidimensional Anxiety Theory, in which somatic anxiety has an inverted-U relationship with performance, while cognitive anxiety has a negative linear relationship with performance. However, the latter relationship has since been contradicted by evidence that cognitive performance can be maintained at very high levels of cognitive anxiety (Eysenck & Calvo, 1992; Eysenck et al., 2007). More detail came with the introduction of the Catastrophe Cusp Model (Hardy, 1996) and with it, a series of predictions of when cognitive anxiety would harm performance. Among several complex estimations, the model predicts that at low levels of physiological arousal, cognitive anxiety is helpful, but at high levels of physiological arousal, cognitive anxiety is unhelpful. The model also proposes that when anxiety does cause a performance failure, the decline is severe. This notionally fits with the dramatic drop-offs seen in famous choking examples. Even so, the contemporary debate on choking has largely overlooked arousal theories, Multidimensional Anxiety Theory and the Catastrophe Cusp Model. The main justification is that a mechanism of failure is not actually described (Beilock & Gray, 2007; Hill et al., 2010a; Payne et al., 2018). That is, how
excessive arousal, somatic anxiety, cognitive anxiety, or their interaction causes a failure is unstipulated. The favoured theories of choking – the attentional theories – describe mechanisms.

At the most basic level, two feasible attention-based causes of choking have been advanced: insufficient attention to the task (often called distraction) or conscious attention towards the motor action (often called self-focus). Support for distraction comes from studies showing that the amount of task-relevant visual attention (measured by eye fixations) can explain the quality of performance under anxiety or pressure. Further support comes from qualitative studies which indicate that sportspeople usually attribute choking to a lack of concentration on the task. Support for self-focus principally comes from dual-task experiments demonstrating that conscious attention towards the motor action harms expert performance whereas attention towards off-task stimuli does not (e.g., Gray, 2004). This evidence is reviewed in the next chapter. The strongest claim about distraction and self-focus is that they are opposing accounts (e.g., Beilock & Gray, 2007). The argument is that distraction emphasises too little attention to the task while self-focus emphasises too much attention to the task (e.g., Gucciardi & Dimmock, 2008). This is a tidy theoretical position. Echoing Popper (1959), it allows for crucial experiments that can support one theory and falsify the other. Nevertheless, the proposed opposition of the theories has recently been disputed (e.g., Christensen et al., 2015; Nieuwenhuys & Oudejans, 2012) and this thesis supports this contemporary position.

**The reversion model**

An intuitive way to think about choking is as an acute reversal of expertise, in which experts temporarily process information like novices (e.g., Hatfield, 2018; Masters & Maxwell, 2008). Under such a reversion model, understanding the causes of choking requires understanding the nature of expertise, and therefore, the expert characteristics that can be
undone by pressure. As it happens, the study of expertise has identified numerous information processing advantages that experts hold over novices, including many that are evident before the initiation of the movement (e.g., Abernethy, 1990). That is, expertise is apparent during motor preparation and motor execution. Accordingly, under the reversion model, an expert who chokes should exhibit novice-like tendencies in preparation and/or execution.

Broadly speaking, experts prepare better by collecting more task-relevant information, more efficiently (Hatfield, 2018). For instance, experts in various kind of sports typically make fewer preparatory eye fixations than novices, while taking more time at each location (Mann, Wright, & Janelle, 2016). Experts appear to bias their scan towards information-rich areas whereas novices are forced to expend resources searching for these locations (Mann, Williams, Ward, & Janelle, 2007). The target is one information-rich place that experts dwell. Robustly, experts exhibit a relatively long final fixation on their target just before initiating the movement (e.g., Nibbeling et al., 2012; Vickers, 1996; Williams, Singer, & Frehlich, 2002). This portion of their scan, known as the quiet eye period, correlates well with performance in numerous sports and is thought to reflect the input of critical information needed for motor programming (Vickers, 1996, 2016). The importance of the quiet eye seems apparent regardless of the time allowed for execution. For instance, in the slow moving sport of snooker, experts exhibit longer quiet eye fixations on the target than novices (Williams et al., 2002), which might facilitate better organisation of perceptual-motor control networks required for the shot (Vickers, 2016). In the relatively time-limited sport of volleyball, elite players (unlike less skilled counterparts) exhibit a quiet eye fixation on the ball early in flight until their first step, allowing them to meet the ball with fewer steps and in less awkward positions (Vickers & Adolphe, 1997). This kind of foresight is a characteristic of expertise in many sports that demand a rapid response (e.g., rally shots in racquet sports, baseball batting...
or ice hockey goal keeping), and is apparent even before the flight of the stimulus. For example, experts in these time-limited domains extract more information than novices from an opponent’s preceding movements or postures (e.g., Williams, Ford, Eccles, & Ward, 2011). This affords all the benefits of earlier insight into the direction and force of the stimulus (e.g., Abernethy, 1990). Relatedly, baseball experts make probabilistic judgements about the nature of upcoming pitches because the ball moves faster than their eyes can track (Gray, 2002, 2006).

The study of the expert brain also suggests the practice results in more economical neurological processing in motor preparation (Janelle & Hatfield, 2008). Experts of far aiming tasks exhibit a progressive cortical quietening in the lead-up to a motor execution, while novices operate with a relatively noisy brain state (Hatfield, 2018). For example, the use of electroencephalography indicates that expert marksmen reduce cortical activity over regions implicated in verbal-analytic activity before trigger pull (Hatfield, Landers, & Ray, 1984). In contrast, novice shooters show a cortical activation pattern similar to that apparent during a cognitive task (Haufler, Spalding, Santa Maria, & Hatfield, 2000). Expert allocation of resources away from verbal-analytic processing coincides with more relevant processing elsewhere (Mann et al., 2016). For example, Milton, Solodkin, Hluštík, and Small (2007) observed that during preparation, expert golfers activated theoretically useful brain areas thought to process visual and spatial information, whereas novices engaged other seemingly unimportant areas like the amygdala.

In tasks in which the athlete chooses when to initiate the action, experts exhibit more behavioural consistency in their preparations than novices (e.g., Crews & Boutcher, 1986). Among similar themes, this routine behaviour is believed to increase task-relevant focus, promote automated behaviour and assist performance under pressure (Cotterill, 2010). More generally, elite sportspeople are known to develop more advanced self-regulatory strategies
(often contained in routines), used to navigate challenging situations (e.g., Cleary & Zimmerman, 2001), such as when there is pressure. These strategies include kinaesthetic and outcome imagery (Cohn, Rotella, & Lloyd, 1990), thought stopping (Jackson & Baker, 2001), self-monitoring (Kitsantas & Zimmerman, 2002), acceptance of anxiety (Hanton & Jones, 1999) and cognitive restructuring tactics such as the positive reinterpretation of anxiety (Hill, Hanton, Matthews, & Fleming, 2010b). Relatedly, elite performance is characterised by the ability to attain a more relevant focus before and throughout competition (Gould, Dieffenbach, & Moffett, 2002). For example, Gould, Weiss, and Weinberg (1981) found that successful wrestlers spent more time than less successful counterparts focusing on match-related thoughts before competition. Likewise, McPherson (2000) observed that expert tennis players remained more task-oriented between points.

Naturally, extensive practice also yields advantages throughout the execution phase. Experts move more economically, minimising their energy expenditure (Sparrow, 2000). This efficiency manifests in lower metabolic energy output, lower aggregate muscle activity and a reduced feeling of effort, after accounting for work rate (O'Dwyer & Neilson, 2000). For example, Asami, Togari, Kikuchi, Adachi, and Yamamoto (1976) found that skilled soccer players imparted more kinetic energy on the ball per unit of energy expenditure than unskilled players. Likewise, experts minimise their mental resource expenditure during execution. Classic accounts of skill acquisition (e.g., Fitts & Posner, 1967) describe how rehearsal allows a performer to transition from mentally effortful actions reliant on rule-based thought to mentally effortless actions reliant on implicit thought (see chapter 2).

Consequently, due to exhaustive practice, experts can multi-task while executing motor tasks because extra cognitive capacity has opened up (Logan, 1997). For example, expert athletes can successfully execute their skills and simultaneously complete arbitrary cognitive tasks, such listening for target words (e.g., Beilock et al., 2002). More practically, experienced
drivers scan horizontally to process useful environmental cues (e.g., related to potential hazards), while novices (who are short on free capacity) tend to fixate centrally (Underwood, 2007). In a live sporting situation, this freed cognitive capacity has some obvious advantages. For instance, a proficient basketball player can dribble effectively while considering where to pass (Gray, 2004). Relatedly, expert athletes are believed to experience high levels of proprioceptive or kinaesthetic awareness of their movements; (Toner et al., 2016) – that is, they can monitor the interaction of their body and the environment. This is useful for functional movement adaption. For example, Nyberg’s (2015) interviews with elite skiers revealed that they monitored in-flight rotations and adjusted their landing accordingly.

The gaps

While the study of expertise has attended closely to the makeup of superior performance before and during execution, this thesis proposes that two important sections of the choking literature have superficially examined how pressure might differently interfere with preparation and execution, and in doing so, have presented an incomplete account of choking. In focus are dual-task experiments (e.g., Beilock et al., 2002; Gray, 2004) and qualitative studies based on self-report (e.g., Gucciardi et al., 2010; Oudejans, Kuijpers, Kooijman, & Bakker, 2011). The critiques advanced throughout this thesis are that (a) dual-task studies have superficially considered maladaptive thinking during preparation (discussed in chapters 2 and 3) and (b) that self-report studies have superficially considered maladaptive thinking during execution (discussed in chapters 2 and 4). To respond, the first objective of the thesis was to re-consider this work by paying closer attention to the preparation-execution timeline. This was achieved with a) a dual-task experiment (chapter 3) that examined the impact of attentional interference to either the preparation or execution of a well-rehearsed golf action and b) a survey (chapter 4) which required golfers to reflect on mental issues during the preparation or execution phase in past chokes. Both studies were conducted with
the expectation that a new pattern of evidence for the two dominant (attentional) theories would emerge.

To complement the first two studies, the thesis also revisited a third body of choking-related work; research based on observations of preparation behaviour in skills with controllable preparation periods like basketball free throws (Lonsdale & Tam, 2008) or soccer penalty kicks (Jordet, 2009). Studies of this nature have investigated the behavioural correlates of performance, pressure and choking, but arguably, have also done this incompletely. While some studies have considered links between preparation behaviour and performance (e.g., Wrisberg & Pein, 1992) or between pressure and preparation behaviour (e.g., Jackson, 2003), a study (to the author’s knowledge) is yet to comprehensively put these two relationships together. Accordingly, the second objective of the thesis was to examine how pressure observably impacted preparation and if these changes then correlated with performance. To achieve this, an observational study was conducted in which the behaviour and performance of golfers was observed under lower and higher pressure (chapter 5). In addressing gaps in dual-task, self-report and observational work on choking, a logical next step was to compile a more complete account of choking that better accommodated mental events on the preparation-execution timeline. Accordingly, the third objective of the thesis was to map how attentional disturbances in preparation might set a course for eventual performance decline, or alternatively, have no bearing (chapter 6).

**The self-paced sport of golf**

Following a long tradition in research on choking, golf served as the sole applied example in this thesis. The aim of golf is to progress a ball from a designated starting point (the ‘tee’) into a hole some distance away (indicated by a flag or ‘pin’), by striking it with a club (a ‘shot’ or ‘stroke’) as few times as possible. In a standard round, this task is varied 18 times on different parts of the golf course (i.e., there are 18 ‘holes’). A typical competition
round lasts four to five hours. In elite tournaments, golfers complete up to four rounds, usually over four days. In most elite events, there is a ‘halfway cut’. This means that after two rounds, a proportion of the field will be eliminated while the better performers over the first two days go on to complete the final rounds. This is an important moment for professional golfers. Only those making the cut get paid. Accuracy and distance control are key skills that golfers seek to master to minimise the number of shots. Distance control is assisted by a selection of up to 14 clubs which vary in length and club-head loft. These variables influence, respectively, the length and height of shots. Despite this toolkit, golfers still have to exercise considerable control to advance the ball the right distance with each club. More precise control can be achieved, for example, by gripping lower or higher on the club or by shortening or lengthening the swing. Other possibilities include adjusting the setup and/or swing to send the ball higher or lower, or with more or less spin. This kind of functional variability is necessary to play the game well (Langdown, Bridge, & Li, 2012). The issue of distance control is revisited in chapter 3.

Golfers compete against many players in a tournament, yet they play in a small group with very few opponents in sight (usually only two others at the elite level). Additionally, their opponents have no direct influence over their performance (Eysenck & Wilson, 2016), as would be the case in tennis for example. Therefore, a golfer’s score is fundamentally dictated by themselves (ignoring random variables like unlucky bounces). This makes the internalisation of failure especially reasonable, even if maladaptive. Golf falls into a category known as self-paced sport, so named because the performer controls when the action is initiated (Singer, 1988). Numerous other sports have this quality (e.g., archery, shooting, snooker) or contain elements that are self-paced (e.g., serving in tennis, a penalty kick in soccer, bowling in cricket). There are suggestions in the extant expertise/choking literature that self-paced activities lend themselves to maladaptive thought more than other sports. The
proposed reason is that there is an abundance of time to lose concentration on the task (e.g., Jackson, 2003; Jackson & Baker, 2001; Nideffer, 1992). Assuming this is true, self-paced activities are an ideal target for choking research. Golf potentially offers some added interest for applied cognitive psychologists, because at advanced levels, the game requires a mix of numerous cognitive tasks (e.g., forward planning, decision making, pre-shot visualisation) followed by a switch to a relatively instinctive swing of the club (e.g., Marriott & Nilsson, 2011). Furthermore, golfers have a long-standing tradition of developing well-defined preparations (e.g., Cohn et al., 1990; Thomas & Over, 1994). Given the specific interest here in delineating between events of preparation and execution, golf is a fine choice.

**Thesis outline**

The debate about the causes of choking in the published literature is wide-ranging and not entirely within scope. At the highest level, the main question considered here is: when choking occurs, what is the general mechanism that drives the failure? At one level down, the focus is on how a shift in attention under pressure causes choking. Consequently, this thesis does not address a debate that exists about individual predisposition to choking (e.g., Masters, Polman, & Hammond, 1993). Nor does it dwell on possible explanations of choking outside of attention-based mechanisms. For example, there is research focused on how physical changes under pressure (e.g., muscle activity - see Cooke et al., 2014) and emotional changes under pressure (e.g., motivation - see Lazarus, 2000) contribute to choking. There is a further debate about whether or not the ‘yips’ – a chronic loss of smooth motor control in expertly acquired skills – is a psychological problem akin to choking or a separate neuromuscular condition (e.g., Marquardt, 2009). This debate is also bypassed.

The thesis is structured as follows. Chapter 2 presents a critical review of self-focus and distraction theories and their evidence, followed by relatively detailed specifications of how these two mechanisms could operate in externally-paced and self-paced sports. Chapters
3, 4 and 5 describe, respectively, studies designed to address gaps in extant dual-task, qualitative and observational examinations of choking. Finally, chapter 6 unifies the results of these studies, provides novel explanations for choking under pressure in self-paced motor skills, highlights opportunities for new studies and details a series of intervention possibilities.
Chapter 2 - Patterns of evidence for distraction and self-focus

‘It’s just this split second loss of devotion to the task.’

Golfer from this thesis, explaining mental failures during execution

In chapter 1, two attentional mechanisms, distraction and self-focus, were identified as the dominant explanations of choking in sport. In this chapter, these mechanisms are discussed in detail. In the first half of the chapter, the evidence for both mechanisms is reviewed. In the second half, this evidence is critiqued, followed by novel illustrations of how attentional disruptions could trigger motor skill failure in both self-paced and externally-paced sports. In noting several gaps in the extant theoretical literature, the research agenda for chapters 3 and 4 is introduced.

The attentional mechanisms of choking

Theoretical interest in the cause of choking has centred largely on two intuitive kinds of attentional disturbance, often presented in the literature as competing mechanisms of untimely skill failure. On one hand, self-focus theories (e.g., Baumeister, 1984) hold that pressure leads the choking athlete to consciously process the motor skill execution, undermining automaticity and thus expert execution. Broadly speaking, the proposed reason for failure is too much attention directed towards the skill. On the other hand, distraction theories (e.g., Nideffer, 1992) hold that pressure leads the choking athlete to expend attentional resources worrying about the performance outcome and its consequences, leaving a shortage of on-task attention for successful motor skill execution. Broadly speaking, the proposed reason for failure is too little attention directed towards the skill. In this incompatible context, numerous researchers have concluded that self-focus is the more credible explanation (Beilock & Gray, 2007; Gray, 2004; Gray & Cañal-Bruland, 2015; Gucciardi & Dimmock, 2008; Hill et al., 2010a; Mesagno & Mullane-Grant, 2010), armed
with the key evidence that expert motor actions are impaired when an athlete’s attention is
directed towards skill execution (i.e., under self-focus) yet preserved when their attention is
drawn off-task (i.e., under distraction). Several reviewers, largely relying on self-report data
and data from the cognitive performance literature, have hedged that distraction theory
remains relevant to sport, but with little elaboration. Hill et al. (2010a) surmised that ‘The
extant choking literature offers self-focus as the most plausible mechanism of choking in
sport although distraction evidently has an impact’ (p 30), but like a number of other authors
(see Gucciardi et al. (2010) and Beilock and Gray (2007) for similar comments), stop short of
explaining how distraction might actually impair an expert motor skill. This review critically
examines support for both theories then scrutinises how distraction alone, or a combination of
distraction and self-focus could explain motor skill failures under stress. In doing so, the
motivation for chapters 3 and 4 is detailed.

Self-focus theories

Self-focus accounts are closely related to traditional skill learning theories (i.e.,
moment, these learning theories share that skill acquisition requires a progression from
controlled processing to automatic processing. The pervasive view is that controlled
processing is relatively slow, deliberate, mentally expensive, conscious and explicit, among
other similar themes (Singer, 2001). As a result of significant rehearsal, automatic processing
has the opposite characteristics (e.g., Shiffrin & Schneider, 1977). The nature of the
progression from controlled to automatic varies slightly from theory to theory. Fitts and
Posner (1967) proposed three stages of learning; cognitive, associative and autonomous. In
the cognitive stage, verbal rehearsal is necessary to produce an approximate version of the
skill. In the associative stage, errors are slowly removed and verbal rehearsal recedes, before
completely subsiding in the autonomous stage. Anderson (1982) largely accepted the three
stages, but added some details. In his version of the cognitive stage, learners encode facts about how to perform the skill (e.g., from an instructor). This is referred to as declarative knowledge. Anderson proposed that declarative knowledge is converted with rehearsal to a procedural form via a process called knowledge compilation. This is a gradual reduction in the number of processes that have to be recalled from long term memory into a temporary storage facility known as working memory. Once in procedural form, refinement continues to speed-up processing. Logan (1988) had a slightly different perspective. He proposed that novices initially use rules to solve a problem, but upon revisiting the same problem repeatedly, begin to resolve the problem with memory. During transition, there is a competition between modes in which the learner picks the faster mode (rule vs. memory). Automation occurs when performance relies entirely on memory.

Self-focus explains choking as interference to automatic processing with controlled processing. There are three key variations, referred to here as Conscious Control (Baumeister, 1984), Explicit Monitoring (Beilock & Carr, 2001) and Reinvestment (Masters, 1992; Masters & Maxwell, 2008). They vary on the precise nature of the interference. Conscious Control includes these steps: (1) pressure increases self-consciousness, (2) awareness of outcome importance is increased, (3) conscious attention is directed to the internal process of skill execution to better control the outcome and (4) consciousness lacks appropriate knowledge to execute an automated motor skill. (5) Poor execution follows. Explicit Monitoring largely embraces Conscious Control with the modification that the final mechanism of skill breakdown is the monitoring of the ‘step by step’ processes of execution (p701). How monitoring and control affect performance differently remains unclear (Christensen et al., 2015; MacMahon & Masters, 2002; Masters & Maxwell, 2008; Winter et al., 2014).
Reinvestment (Masters, 1992; Masters & Maxwell, 2008) takes the intuitive position that choking occurs when experts (under pressure) regress to (‘reinvest’ in) the explicit rule-based control from the early stages of skill acquisition (i.e., novice-like processing). Under Reinvestment, declarative knowledge is recalled from working memory then consciously applied to the control of the movement. The movement is disrupted because an integrated control structure (something like a compiled computer program) is disaggregated into its component parts. Processing slows because each component is run individually. Automaticity is broken, error becomes more likely and performance declines. According to Reinvestment, choking occurs specifically when attention is directed to the mechanics of a skill (i.e., technique) during motor output (MacMahon & Masters, 2002). This is more specific than Conscious Control or Explicit Monitoring since neither describe the contents of self-focused thought.

While each self-focus account has a different emphasis, they ultimately share the premise that choking is caused by pressure-induced introspection of a normally automatic motor execution, which directly interrupts the long-developed expertise. A further point is that self-focus accounts are specifically concerned with maladaptive information processing during the brief moments of execution.

**Distraction theories**

Distraction theories of choking are based on studies of cognitive performance. Fundamentally, these accounts rely on the capacity model of cognitive psychology, in which humans are assumed to have a limited reserve of mental resources that can be distributed across tasks (e.g., Kahneman, 1973). The simplest version of distraction theory, labelled basic distraction (Christensen et al., 2015), is captured by and regularly attributed to Wine (1971), who reviewed the information processing tendencies of high and low test-anxious persons in cognitive tests. Wine concluded that test-anxious people divide their attention between the
test and self-preoccupation in ego-threatening situations, to the detriment of their performance. The abstraction to choking in sport is usually that pressure causes the diversion of attention from task-relevant information to mentally-expensive alternatives (e.g., worry or self-doubt), leaving insufficient task-focused resources or working memory for successful execution (Beilock, Kulp, Holt, & Carr, 2004; Hill et al., 2009; Hill et al., 2010a; Mesagno et al., 2009; Nideffer, 1992). Working memory is popularly theorised as a multiple component system of temporary information processing that has an exhaustible capacity (e.g., Baddeley, 1986; Baddeley, 2012). The system relies on a central component (the central executive) and two subordinate systems (the phonological loop and the visuo-spatial sketchpad). The central executive is thought responsible for attentional focus, storage and decision making. It relies on the phonological loop to both store sound-based information keep information active via sub-vocal rehearsal and the visuo-spatial sketchpad to store visuo-spatial information. In the context of distraction theory, the central executive is considered especially important given its hypothesised role in attentional focus.

Two other cognitive performance accounts feature in the literature on choking in sport: Processing Efficiency Theory (PET; Eysenck & Calvo, 1992) and its successor, Attentional Control Theory (ACT; Eysenck et al., 2007). Both models hold that worry (i.e., preoccupation with negative consequences or evaluation) reduces the storing and processing capacity of working memory but also motivates compensatory efforts to generate more working memory resources. Compensation is identified when effort-related behaviours increase with anxiety, yet deliver no performance gain. Indicative examples from reading tasks are longer processing times and more regressions to previous text (Calvo, Eysenck, Ramos, & Jiménez, 1994). Indicative examples from motor tasks are more target glances and longer preparation times (e.g., Wilson, Smith, & Holmes, 2007). Elevated subjective mental effort (for no performance gain) has served as a further indicator in both cognitive and motor
domains (e.g., Hadwin, Brogan, & Stevenson, 2005; Nibbeling et al., 2012). If compensatory efforts generate enough resources, effective performance is preserved, but at the cost of processing efficiency (evident in the compensation).

ACT builds on PET by outlining how efficiency is reduced by anxiety. The key elaboration is that anxiety disrupts the balance of a goal-directed system that processes task-relevant stimuli and a stimulus-driven system that processes threatening stimuli (either internal or external). As anxiety increases, more resources are allocated to the stimulus-driven system (i.e., threat is more readily processed), but at the cost of the goal-directed system (i.e., task-relevant processing is reduced). ACT is also specific on how anxiety disrupts attentional control. Eysenck et al. (2007) propose that anxiety primarily disrupts two related functions of the central executive; inhibition and shifting. The inhibition function works to prevent the processing of irrelevant information, whereas the shifting function serves to mobilise attention towards task-relevant information (Miyake et al., 2000).

Given that the predictions of PET and ACT are specific to cognitive tasks (Eysenck et al., 2007), direct application to motor domains may be unwise. The Integrated Model of Anxiety and Perceptual-motor Performance (Nieuwenhuys & Oudejans, 2012) takes the next step and elaborates on ACT, identifying ways that over-resourcing the stimulus-driven system might harm perceptual-motor performance. The Integrated Model is based on evidence that anxiety covertly impacts motor preparation by biasing attention towards threat (affecting perception), encouraging threat-related interpretations (affecting action selection) and encouraging threat-related behavioural responses like avoidance (affecting action). The quality of the movement execution is considered a function of task focus acquired earlier. Under the model, threat-related processing (elevated by anxiety) prevents the athlete from processing task-relevant information needed to adjust and calibrate movements. Three compensatory strategies that might save performance are suggested: forced goal-directed
behaviour (e.g., deliberate task-focused attention); inhibition of stimulus-driven responses (e.g., thought stopping) and self-regulatory activities to reduce feelings of anxiety (e.g., imagery).

The Integrated Model additionally holds that self-focus can be fundamentally explained as distraction. This amalgamation opposes the view that distraction and self-focus are competing mechanisms – a point made on the nebulous distinction that self-focus emphasises too much task-focused attention while distraction emphasises too little task-focused attention (e.g., Beilock et al., 2002; Beilock & Gray, 2007; Gucciardi & Dimmock, 2008; Lewis & Linder, 1997). Defining task-relevance is clearly important. Under the Integrated Model, self-focused attention is considered irrelevant, on the basis that explicit processing of a motor execution is only useful in early skill acquisition. Visual search evidence (findings detailed later) is invoked to posit that with or without self-focus, inadequate task-focused processing will prevent appropriate movement adjustment and calibration.

With the like-minded goal of applying ACT to sports performance, Eysenck and Wilson (2016) recently introduced Attentional Control Theory: Sport (ACTS). Much of ACT is preserved in this version. That is, ACTS also holds that anxiety reduces processing efficiency (inhibition and shifting), draws attention towards threat and stimulates compensatory effort. The first major difference is that ACTS predicts that individual differences will dictate the extent that pressure results in anxiety (and processing inefficiency etc.), and therefore, the likelihood of performance decline. Essential to ACTS is that the level of anxiety experienced depends on a) the performer’s attentional bias towards threat and/or b) the performer’s interpretive bias towards threat. In this context, an attentional bias refers to a disproportionate allocation of attention towards a threatening stimulus over a neutral stimulus. In this context, an interpretive bias refers to a tendency to interpret a neutral
stimulus as threatening. Under ACTS, these biases will increase error monitoring (e.g., assigning significance to mistakes) which increases the threat experienced. The key prediction is that individuals without these biases will typically perform well under pressure. The second major point of difference is that ACTS predicts that problems with attentional control vary from moment to moment in competition. Attentional control is likely to be most challenged after key moments of failure or after key moments of an opponent’s success. Like the Integrated Model, ACTS also considers self-focus a form of distraction. Eysenck & Wilson speculate that the occurrence of self-focus may reflect a breakdown of inhibition system, triggered by anxiety.

Setting aside their various levels of detail, distraction accounts all finally maintain that anxiety-induced performance failure results from inadequate task-focused attention (self-focused or not), even if the failure is after the exhaustion of compensatory efforts. Considering the preparation-execution timeline, distraction theories have a broader scope than self-focus theories. The distraction could occur before and/or during the execution.

**Evidence for self-focus**

A body of dual-task work suggests that self-focus is a better explanation of choking in sport than distraction (Beilock & Gray, 2007; Carr, 2015; Gray, 2004; Gray & Cañal-Bruland, 2015; Hill et al., 2010a; Lewis & Linder, 1997; Mesagno et al., 2009; Mesagno & Mullane-Grant, 2010). The foundation evidence is that experts can effectively execute their skills under simulated distraction but are impaired under simulated self-focus. Novices are impacted in the opposite way, i.e., simulated self-focus is less harmful than simulated distraction. Table 2.1 summarises the evidence.
Table 2.1. Evidence from research attempting to manipulate self-focus and distraction.

<table>
<thead>
<tr>
<th>Manipulation Type</th>
<th>Study</th>
<th>Participants</th>
<th>Task</th>
<th>Key Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directed</td>
<td>Gucciardi &amp; Dimmock (2008)</td>
<td>Golfers (handicap 0-12)</td>
<td>Putting task (lower and higher pressure) while processing (1) task-irrelevant thought (e.g., colours); (2) holistic swing thought (e.g., 'smooth'); (3) self-focused thought (e.g., 'arms, weight, head')</td>
<td>Under higher pressure: only self-focused putting deteriorated</td>
</tr>
<tr>
<td>Directed and task-induced</td>
<td>Mullen and Hardy (2000)</td>
<td>Golfers (handicap 12-18)</td>
<td>Putting task (lower and higher pressure) under (1) self-focus: verbalise explicit instructional cues; (2) distraction: random letter generation; (3) single task</td>
<td>Under higher pressure: 'better' putters less accurate under self-focus yet maintained performance under distraction</td>
</tr>
<tr>
<td>Directed and task-induced</td>
<td>Mullen, Hardy &amp; Tattersall (2005)</td>
<td>Golfers (handicap 10-21)</td>
<td>Putting task (lower and higher pressure) under (1) self-focus: process explicit instructional cues ; (2) distraction: count higher pitched tones; (3) Single task</td>
<td>Under higher pressure: putting less accurate under both self-focus and distraction</td>
</tr>
<tr>
<td>Task-induced</td>
<td>Beilock, Carr, MacMahon, &amp; Starkes (2002) Experiment 1</td>
<td>Golfers (handicap &lt;8) or high school varsity experience (&gt; 2 years)</td>
<td>Putting task under (1) self-focus; say 'stop' at conclusion of putting stroke; (2) distraction; identify target word</td>
<td>Distraction easier than self-focus</td>
</tr>
<tr>
<td>Task-induced</td>
<td>Beilock, Carr, MacMahon, &amp; Starkes (2002) Experiment 2</td>
<td>Soccer players (8+ years experience) and novices</td>
<td>Soccer dribbling task (1) self-focus: identify side of contacting foot upon tone; (2) distraction: identify target word</td>
<td>For the dominant foot (i.e., the expert foot): experts: distraction faster than self-focus novices: self-focus faster than distraction</td>
</tr>
<tr>
<td>Manipulation Type</td>
<td>Study</td>
<td>Participants</td>
<td>Task</td>
<td>Key Results</td>
</tr>
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<tr>
<td>Task-induced</td>
<td>Beilock, Bertenthal, et al. (2004) Experiment 1</td>
<td>Experienced golfers (handicap &lt;8) or school varsity experience (&gt; 2 years) and novices</td>
<td>Putting task under (1) self-focus: say 'straight' at impact; (2) distraction: identify target tone</td>
<td>Experts: distraction easier than self-focus Novices: self-focus easier than distraction</td>
</tr>
<tr>
<td>Task-induced</td>
<td>Gray (2004) Experiment 1</td>
<td>College baseball players and novices</td>
<td>Baseball hitting task under (1) self-focus: identify bat direction when tone played; (2) distraction: auditory discrimination; (3) single task</td>
<td>Relative to control: expert batting worse under self-focus; expert batting maintained under distraction; (novices showed the reverse pattern)</td>
</tr>
<tr>
<td>Task-induced</td>
<td>Jackson, Ashford, &amp; Norsworthy (2006) Experiment 1</td>
<td>Club, county, or regional hockey players</td>
<td>Hockey dribbling task (lower and higher pressure) under (1) self-focus: identify hand position upon tone; (2) distraction: random letter generation; (3) single task</td>
<td>Relative to control (in both pressure conditions): dribbling slower under self-focus; dribbling faster under distraction</td>
</tr>
<tr>
<td>Task-induced</td>
<td>Wilson, Chattington, Marple-Horvat &amp; Smith (2007)</td>
<td>Drivers (&gt;1 year of experience)</td>
<td>Driving simulation task (lower and higher pressure) under (1) self-focus: identify hand position upon tone; (2) distraction: auditory discrimination; (3) single task</td>
<td>No self-focus/distraction performances differences</td>
</tr>
</tbody>
</table>
Expert tolerance of extraneous tasks fits with traditional skill learning theories because automatic skills should require few working memory resources, leaving capacity to perform an extra task (Gray, 2004). Expert tolerance of extraneous tasks fits with self-focus theories because the extraneous thought can prevent the more damaging attention to skill execution, preserving automaticity (Gucciardi & Dimmock, 2008; Lewis & Linder, 1997; Mesagno et al., 2009). Expert tolerance of extraneous tasks runs against distraction theories since off-task attention appears harmless to motor skill execution. Without evidence that task-irrelevant thought impairs performance, a critical step is missing: there is no clear distraction-based route to motor skill failure. This does not preclude that a clear distraction-based route exists. More promising evidence is introduced shortly (e.g., from visual search data) as well other novel possibilities (e.g., effects of cognitive interference outside the execution phase).

Transfer of training studies have also supported self-focus. Training under self-awareness appears to protect against choking, whereas training with extraneous tasks appears to offer no benefit. Lewis and Linder (1997) trained novice golfers to a set standard on a simple putting task. A self-focus group trained under video surveillance while believing that the recording would receive expert evaluation. A distraction group trained while counting backwards in twos. The self-focus group maintained putting performance under a contingent-reward pressure manipulation (reward for improvement beyond baseline), whereas the distraction group deteriorated (see Beilock and Carr (2001) Study 3 for a corroborated effect). Given many expert-novice dissociations in the field, this evidence is not necessarily applicable to experts. However, Reeves, Tenenbaum, and Lidor (2007) obtained comparable results with a skilled soccer population. Participants practiced while attending to the foot’s contact point (self-focus) or by verbally describing crowd noise (e.g., as ‘annoying’). Only self-focus training assisted performance under pressure. Preservation of performance could be explained by specificity. Training under anxiety-provoking conditions is thought to
facilitate performance when revisiting similar conditions in competition (e.g., Oudejans & Pijpers, 2009; Oudejans & Pijpers, 2010). This implies that self-focused training mirrored the attentional threats created by the pressure condition (e.g., fear of negative evaluation). It also implies that extraneous attention (or its effect; depleted attentional resources) did not mirror the attentional threats created by the pressure condition.

Reinvestment theory draws some support from studies of implicit skill learning. Masters (1992) prevented one group of novice golfers (the implicit learning group) from developing verbal rules (i.e., reinvestable rules) by having them practice 400 putts while carrying out a simultaneous cognitive task (random letter generation). A second explicit learning group took the 400 putts after receiving technical instructions and without cognitive interference. The implicit learning group accumulated little declarative knowledge and (unlike the explicit learning group) showed improvement under pressure (see Maxwell, Masters, & Eves, 2000 for similar results). Learning by analogy also appears to obstruct declarative knowledge compilation and deliver similar protective qualities. For example, learning to shoot free throws guided only by the instruction ‘shoot as if you are trying to put cookies into a cookie jar on a high shelf” appears to limit verbal knowledge and protect against choking (Lam, Maxwell, & Masters, 2009, p344). The results suggest that choking (for near-novices at least) is less likely when reinvestment is not possible.

Self-focus models assume that pressure triggers conscious motor processing when choking occurs. This assumption has no direct experimental support (Christensen et al., 2015; Nieuwenhuys & Oudejans, 2012), but Gray (2004) offers indirect evidence. In his Experiment 3, expert baseball players swung at a simulated pitch while low or high frequency tones were played. After each swing, players were cued to make an extraneous tone judgment (discriminate the tone as high or low) or a self-focused tone judgement (identify the bat as moving up or down when the tone was sounded). Accordingly, players had to consider the
tone’s frequency and bat position throughout execution. When pressure was increased, self-focused judgment improved but extraneous judgement was unaffected, implying that pressure enhanced skill-focused processing. Gray and Cañal-Bruland (2015) replicated the effect with golfers and a putting task; only self-focused judgement improved with the experience of pressure. However, Wilson, Chattington, Marple-Horvat, and Smith (2007) obtained conflicting results using a driving simulator and similar dual tasks. Higher pressure led to inferior self-focused judgment (identifying hand position on the steering wheel upon hearing a tone) and inferior extraneous judgement (tone discrimination). Directly comparing the results to Gray’s studies is problematic because Wilson et al’s drivers knew the nature of the secondary task up front, hence could distribute their attention more decisively. Moreover, the attentional requirements of the primary tasks are appreciably different. Driving and baseball batting have different complexity and occur on different timescales. A driving study examining cued secondary tasks or a baseball study examining known secondary tasks would help to clarify the effects in each context. This issue is revisited in chapter 6.

In summary, four key lines of evidence support self-focus. First, expert skills are uniquely sensitive to manipulated introspection of motor execution (with or without pressure), yet uniquely tolerant to off-task thought. Second, training under ego-threat appears to protect later performance under pressure, whereas training with extraneous distraction does not. Third, choking appears unlikely without reinvestable knowledge. Fourth, pressure appears to encourage biased processing of secondary tasks related to motor execution and not extraneous tasks. Assuming that self-focus and distraction oppose each other the evidence also forms a case against the general distraction mechanism. This assumption is reflected on shortly.
Evidence for distraction

A relatively recent set of qualitative data is generally thought to favour distraction theory (Englert & Oudejans, 2014; Gucciardi et al., 2010; Hill et al., 2010b; Hill & Shaw, 2013; Oudejans et al., 2011). The key finding is that descriptions of past choking episodes often mention task-irrelevant preoccupations but seldom mention conscious monitoring or conscious control during execution. For example, Oudejans et al. (2011) analysed the verbal reports of 70 athletes (across numerous sports) prompted to recall thought processes under pressure. Only four percent of statements featured movement execution. In contrast, 26% of statements were related to worries while another five percent related to external distractors. The remaining statements indicated adaptive thinking. Gucciardi et al. (2010) interviewed skilled golfers about recent choking episodes and found that fear of failure and reduced ability for task-focus outweighed discussion of explicit control or monitoring. Likewise, Hill et al.’s (2010b) interviews with choking-resistant and choking-susceptible golfers suggested that choking could be largely attributed to evaluation apprehension and accompanying loss of perceived control. For Hill et al.’s golfers, explicit attention during execution only concluded with choking when co-occurring with distractions, suggesting both mechanisms are at play. Sport psychology practitioners, interviewed by Hill et al. (2009), also advised the involvement of both mechanisms.

Quantitative evidence for distraction theories is found in the visual search literature. Researchers in the area have explored gaze behaviour to assess visual attention and processing efficiency in aiming tasks and related the findings to PET and ACT. Investigators have often concentrated on the onset and duration of the ‘Quiet Eye’ (QE; Vickers, 1996, 2016), which refers to final eye fixation towards a target before a motor action is initiated. Longer QE periods are associated with greater expertise and accuracy in numerous motor tasks, including basketball free-throws (Vickers, 1996), volleyball serving (Vickers &
Adolphe, 1997), ice hockey (Panchuk, Vickers, & Hopkins, 2017) and darts (Nibbeling et al., 2012). Relatedly, expert snooker players exhibit longer QE durations with increasing shot difficulty (Williams et al., 2002). The QE period may be especially important for skill execution because it is the final uninterrupted chance for motor programming (Vickers, 1996, 2016; Vickers & Williams, 2007). Accordingly, reductions in the QE duration are taken as a lost opportunity to perform optimally (e.g., Vine & Wilson, 2011).

The gaze behaviour of experts and novices reacts to pressure and anxiety. Nibbeling et al. (2012) examined the visual attention and performance of expert and novice darts players under low anxiety (throwing on the ground) and high anxiety (throwing from height). At height, both groups collected visual information less efficiently (shorter QE, a higher rate of scanning and longer visual drifts from the target), yet only novice performance declined. Experts appeared to retain a threshold level of visual attention prior to dart release that allowed them to maintain performance under anxiety. Vine and Wilson (2010) obtained similar evidence with novice golfers trained to have longer QE periods before putting stroke initiation. The QE-trained group reduced their average QE duration under pressure, yet maintained putting performance. Despite reduced visual attention, the QE-trained group still retained durations far longer than a control group, and at levels known to predict accurate performance in other aiming tasks. Adding further detail, Englert, Zwemmer, et al. (2015) showed that depleting the self-control strength of non-expert darts players before throwing (with a transcription task requiring conscious override of writing habits) resulted in shorter final fixations and decreased performance under high anxiety. By contrast, non-depleted controls maintained visual attention and performance under anxiety. The transcription task might have suppressed the ability to produce compensatory effort, thus preventing the maintenance of performance when resources were strained by anxiety.
Researchers also have specific evidence for visual bias towards threatening stimuli under stress. Wilson, Wood, and Vine (2009) observed soccer players making earlier onset and longer fixations towards the goal-keeper before penalty shots, at the expense of the target (e.g., the corner of the goal). This resulted in more shots within keeper reach. Likewise, Nieuwenhuys and Oudejans’ (2011) study of police shooting revealed that a visual bias towards threat (the head and gun of an opponent) in a high anxiety condition accompanied fewer target hits. Taken together, the evidence suggests that anxiety (and pressure) reduces attentional efficiency; biases attention off-target (including towards threat) and impairs perceptual-motor performance when visual attention is sub-threshold or when compensatory efforts are hampered. These are all effects accommodated by ACT and the Integrated Model. Numerous studies indicating compensatory effort under anxiety are an additional line of support (e.g., Nibbeling et al., 2012; Nieuwenhuys & Oudejans, 2011; Wilson, Chattington, et al., 2007; Wilson, Smith, et al., 2007). The visual search evidence offers a relatively complete account of distraction-based choking in aiming tasks, since there a clear route to motor skill failure. Figure 2.1 displays the steps.

![Figure 2.1. A distraction-based pathway to choking suggested by visual search evidence.](image)
In summary, two categories of evidence support a distraction-based explanation of choking in sport. First, several qualitative studies indicate that athletes usually attribute their choking experiences to the dysfunctional thinking emphasised by distraction accounts (e.g., fear of failure). To complement this, self-focused attention appears a rare complaint. More precise support for distraction comes from the study of covert measures of visual attention. These findings connect pressure to task-irrelevant thought and then task-irrelevant thought to motor skill failure. The findings also suggest that compensatory effort may have a role in saving performance.

Domain Specificity

Outside the motor skill domain, there is a convincing case for choking by distraction in cognitively-demanding tasks (unrelated to sport) that burden the working memory system. For example, performance of mathematical computation (Beilock, Kulp, et al., 2004) and fluid intelligence tests (Gimmig, Huguet, Caverni, & Cury, 2006) are only susceptible to pressure when working memory demands are elevated – suggesting that exceeded attentional capacity is the likely problem. The findings inform the view that distraction affects cognitive skills relying on working memory and that self-focus affects skills that run outside working memory (Beilock & Gray, 2007). From here on, this position is referred to as Domain Specificity because distraction and self-focus are assigned difference domains of relevance. Under Domain Specificity, not all sporting skills are immune to distraction. The clarification is that skills involving ‘strategizing, problem solving and decision making’ are susceptible to choking by distraction, whereas automated skills like ‘a highly practiced golf putt or a baseball swing’ are susceptible to self-focus (Beilock & Gray, 2007, p434). Domain Specificity is a popular reconciliation of self-focus and distraction (Carr, 2015; Gucciardi et al., 2010; Hill et al., 2010a; Hill & Shaw, 2013; Reeves et al., 2007).
Challenges to the evidence for self-focus

Given that self-focus theories blame choking on explicit thought during the execution phase, these accounts do not easily accommodate the possibility that explicit thought during execution could be tolerable or beneficial (Christensen, Sutton, & McIlwain, 2016; Toner et al., 2016; Winter et al., 2014). However, there are suggestions that expert athletes can (and willingly do) engage in some explicit thought during the execution of motor actions without detriment. For example, some performers use part-process cues, in which certainly bodily features are brought to the conscious foreground, while other automated elements work in the background (Toner et al., 2016). In one study, Maurer and Munzert (2013) found that 18 of 23 skilled basketball players preferred to concentrate on body movements (e.g., snapping the wrist) in free-throw execution; a focus that resembles reinvestment. Likewise, Toner and Moran (2011) showed that golfers could make technical changes to their putting stoke without losing proficiency. Controlled explicit thought might also have value as a coping strategy. Hill et al. (2010b) reported that some golfers focused on technique to mitigate poor scoring mid-round – a deliberately suboptimal (but reportedly effective) strategy. Self-focus accounts lack detail on which explicit thoughts are harmful and which are harmless (or helpful). This issue is revisited in chapters 4 and 6.

Recent theoretical discussions of expertise contend that skilful motor execution is more complex than thoughtless automaticity. The nuanced position is that elite sportspeople rapidly modulate between controlled and autonomous processes (in accordance with task requirements) and resist full automaticity (Christensen et al., 2015; Christensen et al., 2016; Eysenck & Wilson, 2016; Toner et al., 2016). Earlier expertise work has a similar theme. Deliberate Practice Theory holds that experts avoid automaticity because it represents the conclusion of motor skill learning (Ericsson, 2003). Consistent with this more complex view of motor expertise, Christensen et al. (2015) dispute that existing dual-task data is valid.
evidence against distraction theories. They reason that the primary tasks employed (e.g., swinging a baseball bat at a simulated pitch) have been so simple and monotonous that a secondary task could not overwhelm working memory sufficiently to affect performance, especially post compensatory effort (like that described by PET and ACT). They propose that a genuinely challenging primary task, approximating a true competitive situation, might elicit distraction-based choking. This position awaits evidence since examinations of cognitive interference upon motor tasks with suitable difficulty manipulations are missing from the literature.

Self-focus might just be a debilitative kind of distraction and not a special form of interference (Nieuwenhuys & Oudejans, 2012). If so, the self-focus-based secondary tasks that typically degrade expert performance (i.e., those in Table 2.1) must be more resource-taxing than the corresponding extraneous secondary tasks. This remains as speculation because the cognitive load burden imposed by self-focus and extraneous tasks have rarely been compared. Furthermore, when Wilson, Chattington, et al. (2007) produced self-focus and distraction tasks with demonstrably comparable resource requirements (similar effort and performance under low threat), self-focused attention and extraneous distraction were similarly harmful to driving times under pressure. The issue of task comparability prevents the safe conclusion that existing dual-task experiments support self-focus. Nevertheless, some have noted that the easily overwhelmed attention (and performance) of novices has often tolerated induced self-focus while suffering under extraneous distraction (Beilock & Gray, 2007; Hill et al., 2010a). If it is true that novice performance is dictated by the amount of imposed cognitive load, these results suggest that the self-focus manipulations used so far have not been more cognitively demanding. It would be useful for future dual-task research examining distraction and self-focus to demonstrate resource equivalence of secondary tasks. Indices of gaze behaviour might be one way to do this. For example, the relative disruption to
efficient gaze behaviour under self-focus and extraneous dual-tasks could inform their relative distractibility.

**Challenges to the evidence for distraction**

Qualitative study of past choking experiences has indicated that task-irrelevant worry is a frequent concern and that explicit processing is a rare concern. The findings have been used to give renewed weight to distraction theory (Gucciardi et al., 2010; Hill et al., 2010b; Hill & Shaw, 2013), cast doubt over self-focus theory (Oudejans et al., 2011) and challenge the natural frequency of self-focused attention under pressure (Nieuwenhuys & Oudejans, 2012). Three challenges to these interpretations are offered here. First, self-report data reflects athletes’ rationalisations of past choking episodes and is not clear theoretical evidence. While likely insightful for practitioners, submitting verbal reports of choking experiences as theoretical evidence sits beside a history of doubt over human ability to reflect accurately on cognitive processes (e.g., Nisbett & Wilson, 1977). An agreed concern is the potential inaccuracy of verbal report that is neither concurrent nor immediately retrospective (Ericsson & Simon, 1980; Williams & Ericsson, 2005) – i.e., the type of report most easily obtained by choking researchers. Inferential bias is a key risk (Ericsson, 2006), especially since the recall of emotional content (like that experienced in choking) is shaped by the current feelings and a desire to preserve current self-beliefs (Ochsner & Schacter, 2000). While authors of qualitative choking studies have recognised inaccurate self-report as a potential limitation, some demonstration that athletes can judge the nature of their attention would improve the theoretical validity of the evidence. Verification of some aspects of existing qualitative data certainly seems achievable. For example, some of Gucciardi et al.’s (2010) and Hill et al.’s (2010b) golfers recalled being disturbed by pre-shot rushing during choking, which is a perception that could be tested. As it stands, only the opposite finding is
available. Jackson and Baker’s (2001) case study discredited an elite rugby goal kicker’s perception that his pre-kick routine was highly consistent.

Second, differences in investigation scope might explain the conflicting results between dual-task and self-report studies. The experimental studies trying to simultaneously assess the relative viability of the two theories (Table 2.1) have fixated on simulating the effects of distraction and self-focus during motor output (Nieuwenhuys & Oudejans, 2012). Beilock et al.’s (2002) soccer players and Jackson et al.’s (2006) hockey players listened for target words or self-focused while dribbling; Gray’s (2004) baseball players listened for tones while their bat was moving and Gucciardi and Dimmock’s (2008) golfers were asked to process self-focused or irrelevant thoughts during the putting stroke. Only one study – Gray (2006); discussed shortly – has specifically tested the effects of cognitive interference during motor skill preparation. Qualitative studies trying to assess both mechanisms have been relatively holistic, concerned with thoughts preceding, during and following the execution. For example, Oudejans et al. (2011) asked athletes: ‘When the pressure you feel is at a peak, and you are failing, or you have the feeling you are about to fail, where is your attention focused and what do you think about during these decisive moments?’ (p62), but did not target the preparation phase or the execution phase. For dual-task experiments, the execution focus has been pragmatic. Attempts to induce self-focus can only, by definition, target the execution. Accordingly, any experiment that directly compares self-focus and distraction must confine its manipulations to the execution phase. Qualitative explorations have not constrained their scope equally. No qualitative choking study has enquired about thoughts specifically during execution or specifically during preparation in high pressure situations. The consequence is that the dual-task and qualitative results are not directly comparable. The fact that athletes seldom report self-focused attention when recalling choking experiences
could be because a description of skill processing during execution requires recall of the fastest moving and most cognitively elusive part of the process.

The third concern with the interpretation of the qualitative evidence is that reports of distractions to date have not implicated the mechanism of skill-failure hypothesised by distraction theories – a shortage of mental resources to adequately process the task. Self-report of ego-threatening distractions means that distractions were observed and perceived as important but does implicate compromised information processing as the reason for failure. Self-focus (or other mechanisms) could still be the final reason for execution problems. Moreover, the presence of distractions is consistent with self-focus theories. Conscious Control embraces the idea that pressure increases worrying about the outcome (step 2 of the model), but proposes that this triggers the damaging conscious motor skill processing. Qualitative data targeting focus during the execution period would be useful to better understand athletes’ position on the matter of self-focus versus distraction.

Studies of gaze-behaviour provide a clear distraction-based route to choking. However, this work has not addressed self-focus theory. This is reasonable because the QE and other fixation measures do not index explicit processing. Nevertheless, self-focus is not disqualified because increased conscious processing and compromised visual search could co-occur. For example, QE founder Vickers (2016) notes the possibility of ‘closed-loop control’ (i.e., controlled processing) coinciding with maladaptive visual search strategy (p8). This is feasible because several other covert events, presumably co-occurring with the QE period, are thought to signal an increase or decrease in verbal/analytical processing (i.e., the kind of processing expected under self-focus). For example, electroencephalogram (EEG) studies tend to show left hemispheric quietening just before experts initiate motor action in aiming tasks (Hatfield et al., 1984; Janelle & Hatfield, 2008; Janelle et al., 2000). This is believed to indicate that skilled performance relies on cortical resource allocation away from
analytical processing (Mann et al., 2016). Furthermore, there is some evidence of stress-induced cortical noise over the left temporal lobe (T3) in intermediate shooters just prior to trigger pull – believed to signal increased verbal activity (Hatfield et al., 2013). In light of this evidence, it seems reasonable that an increase in analytical processing (potentially skill-focused) and a decrease in theQE could simultaneously occur under pressure.

There are challenges to the significance of the QE that encourage continued scrutiny of the evidence. The first is that there is a conceptual mismatch between relatively long QE periods and the efficient processing normally observed among experts. QE findings suggest that experts invest more task-relevant resources than novices (e.g., longer target processing times). This is an unusual because experts typically display more economic information processing (Hatfield, 2018). The inconsistency is known as the efficiency paradox (Mann et al., 2016). The returning argument is that longer processing times at key moments could create later efficiencies. For example, a longer QE fixation early in the flight of a hockey puck may allow a more efficient attempt to protect the goal (Panchuk et al., 2017; Vickers, 2016). That is, dwelling on an information-rich location for longer is not necessarily inefficient.

A second challenge is that the QE can continue into the execution period, yet few researchers have examined this post-initiation component (Gallicchio, Cooke, & Ring, 2018). In doing so, Vine, Lee, Moore, and Wilson (2013) found that skilled golfers had longer post-initiation QEs on holed putts but similar pre-execution QEs on holed and missed putts. This suggests that the QE during movement is the more important part. Using an occlusion paradigm, Vine, Lee, Walters-Symons, and Wilson (2017) showed that blocking golfers’ vision during the putt was more detrimental that blocking it before the putt – also indicating the relative importance of the later component. In explaining the results, Vine et al. (2017) argued that obtaining task-relevant information throughout execution could be more
important than obtaining task-relevant information earlier. However, there is an alternative explanation. Gallicchio et al. (2018) posited that a longer QE might simply reflect more stable movement properties (e.g., greater postural stability) rather than more complete movement programming. Given that the QE is only correlated with performance, it seems plausible that in some situations (e.g., a golf putt or a snooker shot) poor performance might trigger a short (post-movement) QE and not the other way around. If this is so, shorter QEs under pressure could reflect self-focus as much as distraction. Explicit attention is thought to disrupt movement kinematics (e.g., Gray, 2004), which in turn, might manifest in unstable gaze patterns throughout execution. One way to integrate the study of self-focus into the gaze-behaviour paradigm is conduct an eye-tracking experiment investigating gaze behaviour under induced self-focus (e.g., a manipulation in the vein of Gray, 2004). This could serve as an initial assessment of what happens to visual search immediately before and during self-focused attention. This idea is taken up in chapter 6.

**Challenges to domain specificity**

The first assumption of Domain Specificity is that sports’ cognitive elements (e.g., strategy, problem solving and decision-making) are susceptible to choking by distraction. The claim is intuitive, but there is minimal sport-specific evidence. Tests of the distraction mechanism have largely ignored the thoughtful aspects of sports performance, including strategy, problem solving and decision-making, but also prediction, anticipation, visualisation, and psychological attempts to achieve an appropriate mental state for execution (e.g., cognitive components of a pre-performance routine). As a point of difference, the expertise acquisition literature has long-considered cognitive aspects of expert performance outside execution (e.g., Abernethy & Russell, 1987), so it seems remiss that a field concerned with the untimely collapse of expertise would be less thorough. The lack of relevant studies forces authors maintaining domain specificity (e.g., Gucciardi & Dimmock, 2008; Gucciardi
et al., 2010; Hill & Shaw, 2013) to cite examples outside of the sporting domain, like mathematics, and assume applicability. A second concern with Domain Specificity is that it suggests a separation between the execution of an automatic skill and the preceding cognitive processes (referred to as the independence assumption here), excluding the possibility that compromised task-focused attention in preparation could affect the quality of execution. Figure 2.2 illustrates how choking could occur under Domain Specificity if distraction interfered with strategy, problem solving, or decision making.

![Figure 2.2. Routes to choking suggested by Domain Specificity.](image)

Performance could suffer from (a) a poor strategy implemented well or (b) a poor strategy implemented poorly, but whichever the case, faulty cognition and faulty implementation would be unrelated. This explanation is plausible for some occasions. For
example, an ill-considered club selection in golf could leave the ball far from the pin. However, there are reasons to think that the quality of cognitive processes before execution would usually impact the execution. More efficient visual scanning prefacing better aiming performance (e.g., Wilson, Vine, & Wood, 2009), associations between neurological changes and putting performance (e.g., Babiloni et al., 2008), and impaired baseball batting execution after suppression of expert anticipation (Gray, 2006) suggest more cognition-execution dependence than Domain Specificity accommodates. The latter two effects also suggest that putting and baseball hitting – Beilock and Gray’s (2007) examples of automated skills susceptible to self-focus – are sensitive to a compromised preparation. A way to test the independence assumption is introduced in chapter 3.

The independence assumption is contested by more recent models of motor performance. The Integrated model (described earlier) details how threat-related bias in preparation can directly affect the motor action via inadequate movement adjustment and calibration. Christensen et al.’s (2016) Meshed Cognition and Action (called Mesh) makes alternative challenges, with particular reference to more difficult motor tasks. Mesh holds that cognitive control directly influences motor execution by informing situation awareness and developing action gist. An action gist, under Mesh, is an explicit understanding of the desired action type and the way of executing it in a specific context. Mesh holds that the importance of situation awareness and action gist diminishes as tasks become less challenging. Accordingly, when the task is very simple, Mesh accepts that experts can execute thoughtlessly, and thus that self-focus could explain choking in these basic executions. Mesh shares with Domain Specificity that strategic decisions could be compromised by pressure-induced distraction and that basic motor tasks could be compromised by self-focus (i.e., independence is possible), but also advocates that failed cognitive processes could impair the quality of the execution in complex tasks via poor action gist specification. Therefore, Mesh
allows a relatively complete account of choking by distraction in challenging tasks (see Figure 2.3) but not in simplistic tasks. There are ways, however, that impaired cognitive processes in preparation could interact with the execution in normally easy motor tasks. How preparatory cognition and execution interact could depend on the nature of the skill and its attentional requirements.

**Figure 2.3.** Distraction-based pathway to choking according to MESH in a high difficulty task

**Choking by distraction in externally-paced skills**

The sports science literature distinguishes externally-paced skills (alternatively, open skills) and self-paced skills (alternatively, closed skills). Externally-paced skills, like baseball batting, ground strokes in tennis, or catching in cricket, demand rapid anticipation, decision-making, and reaction to a moving stimulus (Jackson, 2003). Self-paced skills, like golf shots, basketball free-throws, and rugby penalty kicks, allow the performer to decide within context-specific limits when to initiate action (Singer, 2000).

It is well established that experts of fast-ball skills use non-verbal cues available before the flight of the stimulus, allowing a time advantage over novices, who rely solely on
the in-flight information (Abernethy, 1990; Abernethy & Russell, 1987; Magill, 1998; Weissensteiner, Abernethy, Farrow, & Müller, 2008). Lost attentional resources due to worry could impact expert anticipation, forcing a more novice-like preparation. Gray (2006) reported a relevant experiment with expert and novice baseball players. Using simulation technology (the same as Gray, 2004), participants swung a bat at an approaching electronic baseball while completing auditory discrimination either during execution or during the period between swings (i.e., in preparation). Expert performance was predictably robust to interference during execution but was impaired by interference during preparation. Novices exhibited the reverse pattern. Gray reasoned that the pre-performance secondary task interfered with the experts’ more advanced anticipation; an ability to make probabilistic judgements about characteristics of the next pitch, given the previous pitches received. By contrast, novices’ relatively improvised approach made distraction during preparation inconsequential. Although Gray does not draw a link to choking, the findings are applicable. Distraction in preparation (e.g., due to worry) could prevent expert-like anticipation, forcing novice-like processing reliant on later information, causing choking. Figure 2.4 displays the steps.

Figure 2.4. A distraction-based pathway to choking in externally-paced skills.


**Choking by distraction in self-paced skills**

One challenge of self-paced skills is the abundant opportunity for task-irrelevant thought as the time to act approaches (Boutcher & Rotella, 1987) and consequently, the effort required to stay on task (Jackson & Baker, 2001). A pre-performance routine (PPR) is one strategy that athletes employ to manage the ‘thinking time’ in self-paced actions, and is achieved with a systematic sequence of task-relevant cognitions and behaviours leading up to skill execution (Moran, 1996). PPRs are typical for elite self-paced skill performers (Boutcher & Crews, 1987; Jackson, 2003), are widely believed (although, with little experimental evidence) to improve task-specific focus (Cotterill, 2010) and may help to control choking (Mesagno & Mullane-Grant, 2010).

There is little dispute that an effect of state anxiety (i.e., temporary anxiety triggered by a situation) is some redistribution of attention away from the task (Beilock & Gray, 2007; Eysenck & Wilson, 2016). Athletes experiencing anxiety under pressure will certainly be forced to cope with depleted mental resources or instigate strategies to replenish them (i.e., compensatory effort). In that environment, routine tasks are likely to be perceived as more difficult and the available resources are less likely to be perceived as sufficient. Anxious athletes are unlikely to be comfortable in their compromised mental situation and this may trigger further processing issues. Along with strategy and decision-making, self-paced performers may devote considerable energy to acquiring appropriate mental states to facilitate execution with a ‘quiet mind’ (Singer, 2000), especially when confronted with pressure. Cognitive strategies performed by self-paced athletes, often within pre-performance routines, in pursuit of ideal execution states include imagery (Arvinen-Barrow, Weigand, Thomas, Hemmings, & Walley, 2007; Singer, 2000), thought-stopping (Jackson & Baker, 2001) and cognitive restructuring (Hill et al., 2010b). Achieving a mental state that allows automatic execution in a high-pressure situation is probably effortful. Successful rugby goal
kickers take more thinking time (motionless, looking at the goals) readying themselves for execution when the game score is close (Jackson, 2003). Likewise, elite soccer players who take longer over high-pressure penalty shots seem more successful (Jordet, 2009), implying that additional cognitive effort in preparation adds value. Preparatory efforts in high stakes situations may be significantly compromised if attention is drawn elsewhere. The compromised attention could manifest in strategic errors, but also it could facilitate unhelpful thinking throughout the execution. One scenario is that a distracted mental preparation opens the door to explicit interjection in execution (i.e., self-focus). This idea is explored further in the following chapters.

The next steps

Traditional examinations of choking under pressure have used dual-task manipulations to identify if self-focus or distraction is a better explanation of choking. A common reading of this research is that self-focus is the more likely mechanism in automated motor skills while distraction is the more likely mechanism in cognitive activities (e.g., Hill et al., 2010a), including the thoughtful aspects of sports performance (Beilock & Gray, 2007). Two concerns with this proposition are a) that dual-task work has not yet thoroughly addressed the thoughtful aspects of sports performance, probably occurring during preparation and b) that confining distraction theory to sport’s most cognitive elements (e.g., strategy) assumes that the quality of thought processes in preparation does not affect the quality of the motor execution. To generate a more complete picture, future dual-task research could assess the extent that cognitive interference affects strategy and decision-making as well as the diverse mental preparations that experts engage in. If interference to preparatory activities does affect performance, identifying the nature of the failure would be relevant (e.g., as compromised strategy or compromised motor coordination). This would allow assessment of the independence assumption. Given that evidence for distraction
theories may be more likely in high-difficulty tasks (Christensen et al., 2016), assessing the impact of cognitive interference in more challenging situations is another important step. These issues are examined in the next chapter when an experiment is introduced that compares how a distracted preparation or execution affects the golf swing (while considering task difficulty). In examining performance under these conditions, the independence assumption is also tested.

Studies of covert visual attention have produced detailed evidence for a distraction-based account of choking. Principally, the research demonstrates visual deviations from relevant targets under anxiety (including towards external threats), accompanied by sub-optimal aiming performance (e.g., Wilson, Wood, et al., 2009). Further work supports that a strain on compensatory effort can explain declining performance under anxiety (Englert, Zwemmer, et al., 2015) and that there is an attentional threshold for the maintenance of performance under anxiety (Nibbeling et al., 2012). The findings clarify the potential harm of task-irrelevant processing in aiming tasks, and given the attentional threshold evidence, suggest that self-focus can be fundamentally explained as distraction (Nieuwenhuys & Oudejans, 2012). Notwithstanding, the potential co-occurrence of self-focus with sub-optimal visual input has received little attention. Observing the eye movements of athletes under a self-focus manipulation would be a useful step towards addressing this gap. While this work falls outside the scope of this thesis, a research idea in this space is developed in chapter 6.

The turn to qualitative research has revealed data widely interpreted as supportive of distraction theory (e.g., Hill & Shaw, 2013) and unsupportive of self-focus theory (Oudejans et al., 2011). The key finding is that athletes typically note distractions in higher frequency than self-focused attention when recalling choking experiences. However, there is reason to believe that the current qualitative evidence remains in the scope of self-focus theory, which recognises that distractions are part of the context of choking, but not the final trigger.
Qualitative support for distraction theory alone would have to indicate that task-irrelevant thought was considered the reason for failure and not just part of the context. Additionally, it is plausible that athletes do consider self-focus an important problem but have not carefully reflected on the execution phase in past studies. Given that self-focus occurs in execution, future research seeking to understand the frequency of self-focused thought should clarify to athletes that the execution phase is the point of interest. These issues are addressed in chapter 4 when a qualitative study is introduced which examines golfers’ rationalisations of choking during preparation and execution. As a point of comparison, this study also considered golfers’ normal thought processes. In doing so, the typicality of explicit thought during execution was also addressed.

Research Declaration

Much of the content of this chapter is found (often in modified form) in the reference below. The author wrote the review article below, with some editorial input from the two co-authors.

Chapter 3 – Study 1. The effect of perceptual and cognitive interference during the preparation and execution of the golf swing

‘Being overwhelmed with negative thoughts prior to executing a golf shot when put under a self-perceived pressure situation.’

Golfer from this thesis, defining choking a pre-execution problem.

Chapter 2 highlighted the extensive use of the dual-task experiment as a method to test self-focus and distraction. One gap identified in this literature was a lack of studies considering the impact of task-irrelevant thought during motor preparation (especially in self-paced skills). Accordingly, in this chapter, a dual-task experiment is described in which the impact of attentional interference upon golfers’ preparations and executions was separately tested. Chapter 2 also described the popular but largely untested view that only high-level cognitive activities in sport (e.g., strategic considerations) are impacted by extraneous off-task thought (i.e., Domain Specificity). The underlying assumption of this position is that interference to high-level cognitive activities (presumably occurring in preparation) would not influence the quality of the execution (e.g., timing). In this chapter, a method is introduced and applied to test this assumption.

Holding a task-relevant focus in sport

There is consensus that an athlete’s attentional regulation affects their motor skill performance (Beilock & Gray, 2007; Eysenck & Wilson, 2016; Wulf, 2013). A logical perspective on this matter, shared by numerous researchers and athletes, is that superior sports performance requires exclusive attention to task-relevant elements (e.g., Gucciardi et al., 2010; Vickers, 1996; Wilson, Wood, et al., 2009). Equally, holding such a focus in competitive sport is frequently challenged by distractions that are internal, such as worry, or external, such as noise in the environment (Singer, 2000). Furthermore, several key theories
of choking under pressure are centred on the idea that inadequate task-focused attention under anxiety causes motor skill failure (e.g., Nideffer, 1992). The most detailed of these explanations – PET (Eysenck & Calvo, 1992), ACT (Eysenck et al., 2007) and related accounts (e.g., Nieuwenhuys & Oudejans, 2012) – add that performers can boost their task-focus with additional cognitive effort but ultimately maintain that failure (when it occurs) is caused by sub-threshold task-relevant attention.

To test how distraction affects motor performance, many researchers have had performers execute their skills and a simultaneous extraneous task that consumes attention (e.g., Beilock et al., 2002; Gray, 2004; Mullen & Hardy, 2000). Reliably, this approach has revealed that experts can maintain performance under cognitive load whereas novices suffer; implying that extraneous thought is inconsequential to motor skills that have reached expert-level autonomy (Beilock & Gray, 2007). A curious feature of this dual-task work is that researchers have predominantly occupied the attention of athletes during the brief moments of execution (Nieuwenhuys & Oudejans, 2012), and similarly, given little consideration to misdirected attention during preparation (see chapter 2). This is surprising given that skilled performers are often absorbed in task-focused cognitive activities during preparation (e.g., Gray, 2006; Singer, 2000), yet probably have some cognitive capacity for a secondary task during execution (e.g., Logan, 1997). To address the bias, the present study offered a novel assessment of task-irrelevant thought by separately examining the effects of interference upon the preparation and execution of golf shots.

**Dual task simulation of attentional interference**

Given the hypothesised role of attention in motor skill failures, the dual-task experiment has been useful to assess how its misallocation affects performance. The standard method is to direct a performer’s attention to perceptual or cognitive stimuli (a secondary task) while a motor task is simultaneously executed (the primary task). To assess the effects
of extraneous distraction, thought has been directed away from skill execution by requiring a
verbalised decision about perceptual stimuli, such as the nature of tones (Gray, 2004), or the
expression of cognitive activity, such as counting (Lewis & Linder, 1997). In equal measure,
investigators have also used dual-tasks to study the impact of another form of interference:
conscious processing of the execution. According to self-focus theories of choking, it is this
kind of attention (i.e., self-focused attention), triggered by pressure, that causes motor skill
failure (Baumeister, 1984; Beilock & Carr, 2001; Masters, 1992). To assess the self-focus
mechanism, attention has been directed towards skill execution by requiring verbalisation of
a physical aspect of the execution, such as the positioning of hands (Wilson, Chattington, et
al., 2007) or an implement used (Gray & Cañal-Bruland, 2015). Using secondary tasks is
advantageous because researchers can verify the direction of an athlete’s attention.

Some investigators have used dual-task methods to assess the effects of mental
interference (extraneous or self-focus) on expert and novice motor performance. Others have
also manipulated pressure to assess if this makes extraneous or self-focused attention more
problematic. Regardless of the approach, the results indicate that experts can maintain motor
performance under extraneous attention yet suffer under self-focused attention (Hill et al.,
2010a). Novices, when tested, have shown the reverse pattern. This configuration has been
observed without a pressure manipulation in golf putting (Beilock, Bertenthal, et al., 2004;
Beilock et al., 2002), baseball batting (Gray, 2004) and soccer dribbling (Beilock et al.,
2002). Applying pressure to skilled performers has returned the same pattern in hockey
dribbling (Jackson et al., 2006) and golf putting (Mullen & Hardy, 2000). Collectively, the
findings fit nicely into a classic skill acquisition framework (e.g., Fitts & Posner, 1967).
Expert motor actions require so little attention, due to skill automation, that overcoming a
secondary task is simple unless the secondary task disturbs the automation.
Expert ability to tolerate extraneous distraction implies that off-task thought is an unlikely explanation for expert motor skill failure. However, two potentially important factors have received little consideration: primary task complexity and the timing of distraction. Regarding the first, Christensen et al. (2015) have argued that the primary tasks used (e.g., short-range indoor putting) have lacked the complexity or variability found in competitive sport and that more difficult versions could reveal effects of distraction. In follow-up work, Christensen et al. (2016) have proposed that situation awareness and action gist (an explicit representation of a desired action type and how to execute it) are the elements that are potentially susceptible to task-irrelevant thought in challenging tasks. These assertions aside, the relationship between task complexity, task-irrelevant thought and performance remains uncertain since complex primary tasks or manipulations of primary task difficulty are scarce. The second issue, the timing of interference, is returned to shortly.

**Domain Specificity**

In chapter two, the concept of Domain Specificity was introduced. To briefly recap, while heavily rehearsed motor skills appear unaffected by co-opted working memory resources, the performance of purely cognitive tasks (outside the sporting domain) seems vulnerable to pressure only when working memory demands are high (e.g., Beilock, Kulp, et al., 2004). This implies that choking in cognitive tasks is caused by a resources shortage (as predicted by distraction theories). Given the cross-domain results, Beilock and Gray (2007) proposed that task-irrelevant distraction harms skills dependent on working memory and that self-focused attention harms skills that can run autonomously. They clarified that in sport, ‘strategizing, problem solving and decision making’ are probably susceptible to extraneous distraction whereas autonomous motor skills such as ‘a highly practiced golf putt or a baseball swing’ are probably susceptible to self-focused attention (p434).
The suggestion that task-irrelevant thought will only affect strategising, problem solving or decision making brings up three key issues. First, there is an absence of sport-related studies which have demonstrated that these high-level activities are harmed by task-irrelevant thought. Second, Beilock & Gray’s (2007) domain specific account implies that failed cognition would not influence execution quality (the Independence Assumption from chapter 2). Independence is certainly possible. For example, in the 2018 US Masters Golf tournament, Sergio Garcia (the defending champion) hit five similar shots into a water hazard, ending his tournament run. Each shot appeared excellent, landing close the hole before spinning backwards into the water. Garcia noted afterwards that he ‘kept hitting good shots with the sand wedge’ (Both, 2018). Repeated strategic errors caused the failure while execution quality remained high. Nevertheless, more complicated failures seem inevitable. In support, numerous studies suggest that distracted visual attention in preparation harms later execution quality (e.g., Vickers, 1992; Vickers & Adolphe, 1997; Wilson, Wood, et al., 2009). The third issue with the domain-specific view is that experts perform numerous sport-specific cognitive activities other than strategy, decision making, or problem solving that could be also affected by task-irrelevant interference. For example, distraction could affect expert-level anticipation (Abernethy, 1990), prediction (Gray, 2006), or intricate self-regulatory cognitions contained in pre-performance routines like visualisation (Cohn et al., 1990), cognitive restructuring (Hill et al., 2010b), thought stopping (Jackson & Baker, 2001) or cue focus (Singer, 2000). Assessing the impact of task-irrelevant disturbances during preparation would help to understand the relationship between cognitive failures and motor skill failures.

Past study of interference in preparation

To the author’s knowledge, only one published study has assessed the impact of cognitive load upon the mental preparation of athletes. Gray (2006) had expert and novice
baseball players discriminate the pitch of tones either (a) while they executed a baseball swing or (b) during the period between swings (i.e., in preparation). Expert performance was resistant to interference during execution but was impaired by interference during preparation. Novices showed the reverse pattern. Gray argued that the secondary task during preparation disturbed the experts’ ability to predict characteristics of the next pitch, on the basis of pitches already received. Gray’s study indicates a connection between insufficient task-focused attention and motor-skill failure not observed in other dual-task work.

   Baseball is an externally-paced skill; a class of activity demanding rapid anticipation, reaction and decision-making to a moving stimulus (e.g., Jackson, 2003). Externally-paced skills can be distinguished from self-paced skills (e.g., golf shots) in which the performer decides when to initiate action (e.g., Singer, 2000). Self-paced skills afford ample opportunity for task-irrelevant thought and efforts are often undertaken to improve focus before execution (e.g., Jackson & Baker, 2001; Singer, 2001). These efforts are usually contained in a systematic sequence of task-relevant cognitions and behaviours leading up to skill execution; a PPR (Moran, 1996). PPRs are normal for self-paced athletes (Boutcher & Rotella, 1987), are highly consistent at expert levels (Thomas & Over, 1994), are believed to improve task focus (Cotterill, 2010) and may help to prevent choking (Mesagno & Mullane-Grant, 2010). While Gray’s (2006) experiment shows how extra cognitive load during expert preparation could harm an externally-paced skill, there are no comparable examinations in self-paced sport. The present study addressed this gap by manipulating interference during the preparation and execution of a self-paced activity. Furthermore, the study responded to calls for challenging and varied primary tasks by using a relatively complex golf task.

   The approach shot in golf

   Most dual-task golf studies have used short-range putting as the primary task, typically undertaken on a flat indoor surface (e.g., Beilock, Bertenthal, et al., 2004). The
present study used a longer and more difficult shot, between 60 and 150 metres – the *approach shot* to the green. The approach shot requires more preparatory consideration than a flat putt and has a more complex execution. The golf swing requires full body coordination whereas a putt requires a simple shoulder rocking motion. Golfers approaching the green choose a club (clubs vary in length and loft, which affects, respectively, shot length and height) and evaluate shot parameters (e.g., factors of height, spin, shot shape and force), given distance information and anticipation of the ball’s behaviour (e.g., Langdown et al., 2012). As mentioned, better golfers also typically employ PPRs. While expert preparation certainly has deliberate elements, theorists debate the extent that complex motor actions are automatically executed (Christensen et al., 2016; Toner et al., 2016). For example, some golfers use part-process cues for swing execution (Toner et al., 2016), in which technical aspects of their swing fill the conscious foreground, while other aspects run automatically in the background. Given its relative complexity, golf swing execution could be more sensitive to interference than putting.

**Secondary task selection**

Past dual-task studies concerned with the effects of extraneous distraction in sport have either employed secondary tasks that a) demand cognitive operations on a perceptual stimuli (described as perceptual tasks here) or b) demand internal operations without an external stimulus (described as cognitive tasks here). Examples of perceptual secondary tasks include judging the orientation of tones (Gray & Cañal-Bruland, 2015) and monitoring a series of tones for a specific frequency (Beilock et al., 2002). Examples of cognitive secondary tasks include counting backwards by two (Lewis & Linder, 1997) and generating random letters (Jackson et al., 2006; Mullen & Hardy, 2000). Using Baddeley’s (1986) working memory framework (see chapter two), perceptual tasks like tone frequency judgement should occupy the phonological loop, given this system’s involvement in the
temporary storage of sounds (Schulze, Gaab, & Schlaug, 2009). Perceptual tasks like tone orientation discrimination should also occupy the visuo-spatial sketch pad, given this system’s role in the storage of spatial information (Repovš & Baddeley, 2006). As a point of difference, cognitive tasks (without a perceptual component) are believed to principally occupy the central executive (Baddeley, 2012; Eysenck, Payne, & Derakshan, 2005; Jackson et al., 2006). The present study employed one perceptual task (tone orientation discrimination) and one cognitive task (counting backwards in twos). This allowed a thorough revisitation of dual-task distraction (using the novel preparation/execution framework) using known secondary tasks with different impacts on the working memory system.

Aims/hypotheses

The study examined the impact of perceptual interference (tone orientation discrimination) and cognitive interference (counting backwards) applied separately during skilled golfers’ preparation or execution. The research question was: does cognitive/perceptual interference applied in golf shot preparation or execution differentially affect approach shot performance? Considering the cognitive nature of expert golf shot preparation (e.g., decision making, self-regulation, shot planning etc.), the hypothesis was that interference to preparation would impair performance more than interference to execution (and no interference at all). Distance was varied to force golfers to make decisions before each shot. Simultaneously, distance served as a difficulty manipulation with the expectation that performance would decrease as distance increased (see Hunt, 2014).

Method

Design

A repeated-measures design was employed, using a Balanced Latin Square to control for carry-over and practice effects. All golfers completed five conditions (described shortly).
In each, golfers prepared and executed 10 different shots towards a simulated target. Ten shot distances were randomly ordered without replacement in each condition.

**Participants**

Twenty-four skilled golfers (Golf Australia handicap <=6) were recruited. Mean golf experience was 20 years (standard deviation =12.2). Mean age was 37 years (standard deviation =11.0). The study included 23 males and one female.

**Apparatus**

The experimental apparatus was a commercially available indoor golf simulator (SportsCoach GPS golf simulator, version 3.85). The device allows participants to hit golf balls from a synthetic grass mat towards a projected image of a golf course (see Figure 3.1 and Figure 3.2). The simulator monitors the club (from 0.5m before impact) and the ball launch (for 3m of flight) with an overhead camera (IDS uEye CP high speed USB 3; 100fps) then calculates the following performance measures: swing speed (kph), ball speed (kph), horizontal angle of the swing path (degrees from target), horizontal angle of the clubface at impact (degrees from target), horizontal launch angle (degrees from target), vertical launch angle (degrees from ground), side-spin rate (rpm), back-spin rate (rpm), predicted maximum height of the shot (m), predicted carry (to the nearest metre), predicted distance travelled (to the nearest metre) and predicted radial error from target (to the nearest metre). The ball is hit into the screen, then drops to the floor, after which a simulation of the predicted-flight is generated, followed by presentation of the diagnostics.

Using a simulator strikes a balance between ecological validity and controlling nuisance variables (e.g., changing daily conditions). A simulator (and its housing) allows golfers to go through the normal on-course experiences of a) studying shot distance (and receiving visual distance cues, b) choosing a club and c) deciding on the style of execution.
This is an advance in ecological validity when compared to related studies in which golfers have performed short (and flat) putts on carpet (e.g., Beilock, Bertenthal, et al., 2004; Beilock et al., 2002; Gray & Cañal-Bruland, 2015). Further general support for the use of the simulator comes from research showing that golfers exhibit similar preparations behaviours in a simulator and on the course (Cotterill et al., 2010). Additionally, the use of similar simulation devices has precedent in perceptual-motor research focused on golf (e.g., An, Wulf, & Kim, 2013).

Figure 3.1. An image of the golf simulator. Golfers hit the ball from the synthetic grass mat into the screen (where the target is represented). An overhead high-speed camera calculated the results of the shot.
Figure 3.2. A view of the simulated green from the golfer’s perspective. The shot distance is visible in the top left corner. An overhead image of the green is at the bottom right.

To account for baseline state anxiety in the analysis, Somatic and Cognitive subscales of the Competitive State Anxiety Inventory 2 Revised (CSAI-2R; Cox, Martens, & Russell, 2003) were administered at the beginning of the study. The CSAI-2R measures anxiety intensity with a four-point Likert scale (‘not at all’ to ‘very much so’) against seven somatic items and five cognitive items. Several alternative state anxiety instruments exist that are suitable for the present research, such the Mental Readiness Form (Krane, 1994). The CSAI-2R was selected on the basis of a precedent in relevant research (e.g., Bell & Hardy, 2009; Jackson et al., 2006) and credible internal reliability on both subscales (α >0.8; Cox et al., 2003).

Procedure

Prior to data collection, ethics approval was obtained from the RMIT College Human Ethics Advisory Network (Appendix XV). Written consent was obtained at study commencement, followed by completion of the CSAI-2R. Participants then warmed up for 10 minutes and checked the simulator’s output against their usual on-course results. Given an
appreciable difference, the simulator’s distance calculations were scaled up or down to better suit the golfers’ expectations. Most golfers elected to make no change (18 of 24), indicating that the default estimations were regarded as appropriate. Among the remaining golfers, the maximum change implemented was two percent. Given that skilled golfers have a well-developed knowledge of the distances achievable with each club (a key component of their skill), the minimal overall adjustment supports the face validity of the simulator’s output. Likewise, the minor adjustments that were undertaken should only serve to improve the simulator’s face validity.

In all conditions, golfers hit 10 shots towards the same virtual flag in the centre of a green. Shots were taken from different virtual distances (i.e., the target appeared further away), indicated numerically on the screen. Virtual distances were 60-150m in 10m increments. In each condition, participants were asked to prepare and execute each shot as they would in competition; with the goal of minimising the distance from the target. Golfers were free to view the results of each shot. After viewing their results, golfers were instructed to look away from the screen until prompted to turn around for the next trial. Audio and video was taken throughout to record, respectively, secondary task responses and simulator diagnostics. The experiment was completed over approximately one hour, with short breaks as required to manage fatigue. Participants received $15 to support travel/parking expenses. Each condition is described below.

**Single task condition.** Golfers prepared and executed 10 shots with no interference.

Figure 3.3 is a diagrammatic representation of one trial.
**Perceptual dual-task in preparation.** Golfers made a series of tone discrimination judgements during preparation. The first tone (500 Hz for 150ms) was initiated at trial commencement and then repeated every three seconds. Tones randomly varied in origin (left of target or right of target). Participants indicated location with an audible ‘left’ or ‘right’ response. Tones were stopped just before execution. Tones were generated with MATLAB software (R2015a). Figure 3.4 is a diagrammatic representation of one trial.

![Figure 3.4. Schematic of a trial perceptual dual-task in preparation condition.](image)

**Perceptual dual-task in execution.** Golfers prepared uninterrupted then performed the same tone discrimination task during execution. A single tone was played in the participant’s club takeaway (i.e., backswing). Participants responded immediately after completing their shot. Takeaway presentations were favoured because attentional sensitivity is thought greatest during this component (Beilock & Gray, 2012). A burst of white noise was played from both speakers immediately after each tone to prevent participants from using echoic memory. Figure 3.5 is a diagrammatic representation of one trial.

![Figure 3.5. Schematic of a trial in the perceptual dual-task in execution condition.](image)

**Cognitive dual-task in preparation.** Golfers prepared while audibly counting backwards in twos\(^1\) from a random number (range 100-1000). Participants began counting

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\(^1\) Counting backwards in threes was piloted but proved too difficult/time-consuming for use in the study.
once given the starting number (at trial beginning) and ceased when ready to hit. Figure 3.6 is a diagrammatic representation of one trial.

![Diagram of a trial in the cognitive dual-task in preparation condition.](image)

**Figure 3.6.** Schematic of a trial in the cognitive dual-task in preparation condition.

**Cognitive dual-task in execution.** Golfers prepared uninterrupted, before audibly counting backwards in twos during execution (two calculations) from a random number (range 10-100). Typical swing initiation behaviours from practice guided the experimenter to cue counting. Golfers were encouraged to feedback if the cue was early or late. Figure 3.7 is a diagrammatic representation of one trial.

![Diagram of a trial in the cognitive dual-task in execution condition.](image)

**Figure 3.7.** Schematic of a trial in the cognitive dual-task in execution condition.

**Data Analysis**

**Missing data.** The simulator occasionally produced implausible diagnostics (misreads); for example, an obviously impossible shot distance, unlikely ball flight or unusually large swing path angle. Additionally, there were occasional errors in the manipulation (early or late prompt or participant response). Trials were repeated given awareness of the error and sufficient time. Ultimately, 75 trials were missed (6%) and not rerun. The remaining 1125 trials (94%) were submitted for analysis.

**Key Measures: Vertical and Horizontal error.** Radial error has traditionally served as the dependent variable in dual-task work with golfers (e.g., Mullen & Hardy, 2000).
However, vertical and horizontal errors were considered the more theoretically salient measurements and were calculated for each shot (see Figure 3.8). The vertical error (VE) reflects a distance control problem whereas the horizontal error (HE) reflects a direction control problem. VE suggests poor club choice (e.g., choosing a club that sends the ball too far), inadequate determination of force (e.g., hitting the ball too hard), or inadequate motor coordination (e.g., mis-hitting the ball). Hence, aggregate VE represents a mixture of cognitive mistakes (decision/force calibration) and execution mistakes (coordination/timing). By contrast, HE suggests imprecise orientation and path of the clubface through impact and likely only reflects an execution mistake. Poor aim could also explain HE, but target guidelines on the mat protected against this.
Figure 3.8. Overhead diagram of the key measures of the experiment. Vertical error (VE) and horizontal error (HE) were derived from simulator output (RE to the nearest metre, SD in metres and DT to the nearest metre) using standard geometry.

**Modelling of vertical and horizontal error.** Mixed-effects linear regression was used to estimate the difference in VE and HE under the different manipulations, while considering individual differences. The ‘mixed’ refers to the simultaneous modelling of fixed and random effects. Random effects are parameter estimates that are themselves modelled, whereas fixed effects are not (Gelman & Hill, 2007). Random effects can be modelled with a varied intercept, a varied slope or both. This means that batches of parameters (slopes, intercepts or both) are produced for each level of the variable modelled (for example, a different intercept for each participant). Mixed-effects regression is a recommended treatment of repeated-measures data (see Baayen, Davidson, & Bates, 2008; Pinheiro & Bates, 2000). There were several advantages to taking a mixed-modelling approach to the present data over

\[
K(\text{Radians}) = \arccos \frac{(RE^2 - SD^2 - DT^2)}{-2SD \times DT}
\]

\[
\text{HE} = DT \times \sin K
\]

\[
\text{VE} = |(DT \times \cos K) - SD|
\]
a more traditional approach (e.g. a repeated measures ANOVA). Principally, missing data was well handled. Because trials were missed in different patterns across conditions and participants, the experiment became slightly unbalanced. For example, participant A’s average error in a given condition might be reflect performance on a different set of shots to participant B’s average error in the same condition – an imbalance hidden by aggregating data and using a repeated measures ANOVA or similar. The mixed-modelling negotiated missing data without list-wise deletion of participants or data imputation (i.e., all available observations were considered). Additionally, the analysis modelled individual performance via different regression intercepts for each golfer and conveniently accounted for other potentially important factors (distance to target, handicap, condition order, cognitive anxiety and somatic anxiety were trialled). Modelling was conducted with R’s *lme4* package (Bates, Maechler, Bolker, & Walker, 2015), which calculates effects using a restricted maximum likelihood estimation. In arriving at the reported models (see results), several models were trialled (by varying potentially useful fixed and random factors) then evaluated for fit using the Bayesian Information Criteria (BIC). This piloting approach has precedent elsewhere in cognitive psychology (e.g., Little, Lewandowsky, & Craig, 2014).

In considering modelling assumptions, Gelman and Hill’s (2007) approach (p47) was followed, in which residuals are plotted against fitted values and inspected for patterns. An uncorrelated cloud of dots indicates no systematic problems with the model fit. Plots for reported models are in Appendix I. Two VE models were produced (explained shortly). No clear pattern was observed in fitted/residual plots for either model. However, some linearity was evident in the HE plot, caused by a collection of zero HE values. The zero values were a by-product of lost resolution from deriving the HE from rounded quantities (Appendix II explains this issue). Two alternative approaches were explored. First, HE was modelled with zero cases removed and second, a proxy for HE was modelled (Appendix III details this
Both methods improved the fitted values/residual plot, but delivered highly similar results (and the same interpretation); hence, the original HE results are reported.

**Secondary task performance.** Secondary task performance (e.g., whether or not the tone in execution was correctly identified) was not incorporated into the modelling because there was no easily interpretable value for control trials. Additionally, performance was at ceiling in the two counting conditions. Only five counting trials (considering both conditions) contained mistakes. Tone recognition performance was more variable: 93% in preparation (i.e., the average percentage correct in each trial) and 76% in execution. Five participants had difficulty in identifying tones correctly during execution (i.e. performed at <65% correct across the condition), possibly due to a) the sound bouncing unpredictably off surfaces, b) the difficulty created by the following white noise, c) individual hearing acuity, or a combination of those issues. Affected participants appeared to both try and believe that their responses were correct. Given that their attention was still co-opted, their results were retained. Tone recognition performance was correlated with VE and HE to assess any impact.

**Large vertical error classification.** A large VE could indicate a cognitive mistake (e.g., poor club selection) or an execution mistake (e.g., a mis-hit). To obtain the extra detail, exploratory work using cluster analysis was conducted to group large VEs as cognitive or execution mistakes and obtain the probability of an execution or cognitive mistake across conditions. First, each shot was classified as a low or high quality execution using measures that could theoretically discriminate this (see below). Then, low quality shots with large VE were classified as execution mistakes (i.e., poor execution leading to poor distance control) and high quality shots with large VE were classified as cognitive mistakes (i.e., a good execution leading to poor distance control). Additional data from higher pressure condition completed at the end of the study (described in chapter 5) was added to the current data to enhance the classifications. Furthermore, trials excluded from HE and VE analysis because
the manipulation was applied incorrectly were included in the clustering process because the flight characteristics of these shots were credible. Separate cluster analyses were performed on shots stopping before the target (under-shot analysis) and shots stopping past the target (over-shot analysis), because the ball behaved differently (over-shot hits tended to roll further). Large errors were defined as those outside a golfer’s median VE at each distance (i.e., larger than usual). Measures selected to capture shot quality were back spin, height, carry, roll (distance travelled minus carry), flight time and vertical launch angle. The choices reflected ideal launch and flight characteristics for a simulated green surface that was both small and firm. Each measure was standardised to account for natural variation across individuals and club choice. Accordingly, z scores were taken at each distance for each golfer (e.g., shot height for golfer A at 100m relative to the mean and standard deviation height for all shots taken by golfer A at 100m). Distance was used as a proxy for club choice (which was not collected). The z scores were entered into a two-cluster K-means cluster analysis.

Results

Descriptive statistics for VE and HE (all distances) are displayed in Table 3.1. The aggregate data suggests broad maintenance of performance under the various secondary tasks. The general impact of interference appears larger on VE than HE.
Table 3.1. Means and standard deviations (in parenthesis) of key performance measures across conditions.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Vertical Error</th>
<th>Horizontal Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-task</td>
<td>7.32 (5.65)</td>
<td>3.68 (4.57)</td>
</tr>
<tr>
<td>Tone in preparation</td>
<td>8.22 (6.32)</td>
<td>3.72 (5.24)</td>
</tr>
<tr>
<td>Count in preparation</td>
<td>8.01 (5.4)</td>
<td>3.55 (4.56)</td>
</tr>
<tr>
<td>Tone in execution</td>
<td>8.07 (7.38)</td>
<td>3.85 (4.73)</td>
</tr>
<tr>
<td>Count in execution</td>
<td>7.77 (5.62)</td>
<td>3.76 (4.52)</td>
</tr>
</tbody>
</table>

Secondary task performance

Successful tone recognition in preparation was not associated with VE or HE (Pearson’s rVE=0.06; rHE=0.03). Successful tone recognition in execution was not associated with VE (point biserial rVE=-0.04) but did signal a small improvement in HE (point biserial rHE=-0.18). Performance in the counting conditions approached ceiling.

Shot difficulty

The expectation was that VE and HE would linearly increase with distance (i.e., distance would signal difficulty). However, a more complex relationship was observed (Figure 3.9). For HE (left panel), a linear relationship is clear. For VE (right panel), distance control on 60-70m shots looks anomalously challenging, while at greater distances, the relationship appears relatively constant. Given the non-linearity, incorporating distance into a linear regression on the VE would be problematic, hence separate VE models were produced for 60-70 metre shots and longer shots.
Modelling results

Three models are reported in Table 3.2: short shot VE (60-70m; $VE_{ss}$), longer shot VE (80-150m; $VE_{ls}$) and HE (all distances). Each include a by-participant random intercept (i.e., the random effect) along with condition and condition order as fixed factors. Condition order (e.g., first, second, third etc. in the sequence of conditions) was brought into the model to account for the level of practice that golfers had experienced to a given point. Note that this is helpful on top of the counterbalancing achieved via the balanced Latin square. While counterbalancing neutralises the practice effect as an overall explanation of the results, it does not account for the influence of practice when estimating the effects (Baayen et al., 2008). Distance improved the fit of the HE model and somatic anxiety improved the fit of the $VE_{ls}$
model, so both were retained as additional fixed factors. Significance testing on fixed-effects coefficients in mixed-model regression is often critiqued because the number of degrees of freedom is undefined (e.g., Baayen et al., 2008; Gelman & Hill, 2007). Accordingly, significance is not reported. Coefficients more than twice the size of the standard error are treated as credible predictors in the model and their size is interpreted.

Table 3.2. Mixed-effects modelling results. For fixed-effects coefficients, standard errors are reported in parenthesis. Bold coefficients are credible predictors in the model (>=2 times the standard error). Condition coefficients should be interpreted as relative to the single-task condition.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Vertical Error (Short Shots)</th>
<th>Vertical Error (Longer shots)</th>
<th>Horizontal Error</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed Effects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>9.31 (1.15)</td>
<td>7.85 (0.54)</td>
<td>4.21 (0.42)</td>
</tr>
<tr>
<td>Tone in preparation</td>
<td>2.65 (1.23)</td>
<td>0.37 (0.62)</td>
<td>0.04 (0.41)</td>
</tr>
<tr>
<td>Count in preparation</td>
<td>2.57 (1.26)</td>
<td>0.15 (0.61)</td>
<td>-0.21 (0.41)</td>
</tr>
<tr>
<td>Tone in execution</td>
<td>1.44 (1.23)</td>
<td>0.64 (0.61)</td>
<td>0.20 (0.41)</td>
</tr>
<tr>
<td>Count in execution</td>
<td>1.47 (1.23)</td>
<td>0.21 (0.61)</td>
<td>0.11 (0.40)</td>
</tr>
<tr>
<td>Distance (centred)</td>
<td>0.05 (0.00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Somatic (centred)</td>
<td></td>
<td>0.32 (0.09)</td>
<td></td>
</tr>
<tr>
<td>Condition order</td>
<td>-0.8 (0.28)</td>
<td>-0.30 (0.14)</td>
<td>-0.25 (0.09)</td>
</tr>
<tr>
<td><strong>Random Effects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept variance (standard deviation)</td>
<td>6.55 (2.56)</td>
<td>0.76 (0.87)</td>
<td>1.45 (1.21)</td>
</tr>
<tr>
<td>Diagnostics (BIC)</td>
<td>1500.2</td>
<td>5793.1</td>
<td>6543.7</td>
</tr>
</tbody>
</table>

Condition order was a credible predictor in each model, indicating that practice helped golfers to reduce their error, regardless of the nature or timing of interference. In practical terms, the effect is small (0.80m, 0.30m and 0.25m of improvement per attempted
condition, other factors being equal). A condition-based effect emerged only in the VE_{ss} model, where both preparation conditions stably predicted more VE than no interference. The model estimated that a disturbed preparation added approximately 2.5 metres of VE, compared to no interference, given the constancy of other factors. The VE_{ls} and HE models showed no condition effect – the standard error exceeded condition estimates for each manipulation.

**Large vertical error classification**

Mean z scores are shown in Table 3.3 for the diagnostics entered into the over-shot and under-shot cluster analyses. In the over-shot analysis, one cluster tended to have relatively low back spin (~ one standard deviation below the mean, on average), low height, low flight time, low vertical launch, and high roll; suggesting poor execution (labelled the *mis-hit cluster*). The other cluster exhibited the opposite characteristics; suggesting good execution (labelled the *well-hit cluster*). A similar pattern was evident in the under-shot analysis.

**Table 3.3. Mean z-scores for mis-hit and well-hit clusters.**

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Cluster</th>
<th>Mean z scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Backspin  Carry  Roll  Height  Flight time  Vertical launch  Cases</td>
</tr>
<tr>
<td>Over-shot</td>
<td>Mis-hit</td>
<td>-1.03  -0.25  1.21  -0.92  -0.89  -1.16  247</td>
</tr>
<tr>
<td></td>
<td>Well-hit</td>
<td>0.63   0.86  -0.42  0.75   0.79   0.50   388</td>
</tr>
<tr>
<td>Under-shot</td>
<td>Mis-hit</td>
<td>-0.70  -0.87  0.43  -0.83  -0.86  -0.54  344</td>
</tr>
<tr>
<td></td>
<td>Well-hit</td>
<td>0.59   0.06  -0.66  0.51   0.49   0.65   427</td>
</tr>
</tbody>
</table>

To further examine the short-shot effect (Table 3.2), over-shot and under-shot analyses were combined to compare the probability of classifications (well-hit or mis-hit) across preparation, execution and control conditions, for short and longer shots (Table 3.4).
Large VEs in the well-hit cluster are probably driven by poor decision making or force calibration, hence they were called cognitive errors. Large VEs in the mis-hit cluster are probably driven by poor coordination or timing, hence they were called execution errors. Cognitive errors were more frequent for short shots, regardless of condition. This was confirmed by a Chi-Square test of independence, $\chi^2 (1, N=547) = 8.78, p<0.05$. The balance of short-shot cognitive and execution mistakes was highly similar across the preparation and control conditions ($\chi^2<1$). The error rate for the short shot (Table 3.4, far right column) was higher under preparation interference, indicating that more mistakes generally were made in those conditions. This pattern simply reflects the results in Table 3.2 and was not examined further.

Table 3.4. Probability of mis-hit cluster membership (execution error) and well-hit cluster membership (cognitive error) for large vertical errors.

<table>
<thead>
<tr>
<th>Distance</th>
<th>Interference timing</th>
<th>p(cognitive error)</th>
<th>p(execution error)</th>
<th>N Errors (error rate$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-150m</td>
<td>Control</td>
<td>0.49</td>
<td>0.51</td>
<td>93 (0.51)</td>
</tr>
<tr>
<td></td>
<td>Execution</td>
<td>0.50</td>
<td>0.50</td>
<td>172 (0.47)</td>
</tr>
<tr>
<td></td>
<td>Preparation</td>
<td>0.51</td>
<td>0.49</td>
<td>174 (0.49)</td>
</tr>
<tr>
<td>60-70m</td>
<td>Control</td>
<td>0.65</td>
<td>0.35</td>
<td>17 (0.39)</td>
</tr>
<tr>
<td></td>
<td>Execution</td>
<td>0.71</td>
<td>0.29</td>
<td>43 (0.46)</td>
</tr>
<tr>
<td></td>
<td>Preparation</td>
<td>0.62</td>
<td>0.38</td>
<td>51 (0.57)</td>
</tr>
</tbody>
</table>

$^2$ The error rate refers to the number of mistakes (i.e., the number of shots with a VE greater than a golfer’s median VE at a given distance) divided by the number of shots taken.
Discussion

The present study revisited dual-task examination of task-irrelevant interference by separately challenging the preparation and execution of the golf swing with perceptual and cognitive distractions. The results showed that a disturbed preparation impaired distance control on the shortest shots (60-70m). Further analysis suggested that interference to short-shot preparation did not influence the mix of cognitive and execution errors. Instead, distraction during short-shot preparation appeared to just trigger more mistakes in general. Golfers maintained distance control on longer shots and direction control at any distance, regardless of the timing or nature of interference.

Distance control on short shots

The attentional demands of the short shot may have been elevated because a skilled golfer’s full swing (i.e., the most automated swing) would typically send the ball beyond 70m with any club. Consequently, golfers were probably forced to think more and/or behaviourally adjust more to restrict the distance. Useful calibrations could include setup changes (e.g., gripping the club lower to shorten the lever), shortening the swing or slowing the swing speed. The latter two occur in the execution, but their successful implementation could be determined by the quality of the preparation, when golfers set their execution thoughts. Various findings support that preparatory indicators signal execution quality in aiming tasks. For example, visual attention efficiency in preparation (e.g., Vickers, 1996), neurological changes leading up to execution (e.g., Babiloni et al., 2008), and the length of preparation under pressure (Jackson, 2003; Jordet, 2009) have been associated with performance. The shortage of cognitive resources in the planning phase may have negated golfers’ ability to make the subtle adjustments for the 60-70m shots. Similar calibrations are presumably necessary whenever golfers find themselves at distances unsuited to a full swing (golfers know this situation as ‘in between clubs’). Calibration from the full swing was
almost certainly necessary at other distances in the experiment, but perhaps not with the same consistency as the 60-70m shot, which probably affected everyone.

The results are consistent with Christensen et al. (2016) to the extent that shots with more complicated distance control requirements were most affected by co-opted attention. Using Christensen et al.’s (2016) framework, action gist is presumably especially important for shots requiring conscious tweaking to the automatic swing, which could explain the impact of interference on these occasions. Playing shots ‘in between clubs’ might also necessitate the application of the part-process cues (Toner et al., 2016), which involves bringing explicit thoughts to the foreground of attention. For an approach shot, this might involve considering the position of the club and ceasing the backswing earlier than usual (e.g., ¾ of the way). This need for extra conscious involvement presumably increases the chance of failure (either due to attentional exhaustion or self-focus). Considering the present data, access to cognitive resources during preparation could dictate how effectively this explicit control is implemented.

**Cognitive and execution errors**

The launch and flight characteristics of large vertical errors were useful because they allowed classification of probable cognitive mistakes and probable execution mistakes. The clustering solution indicated that large vertical errors on shorter shots (regardless of condition) were usually cognitive, suggesting that the challenging aspect (in general) was making useful choices rather than timing the shot. This fits with the accepted notion that shorter iron shots are easier to hit than longer iron shots (Hunt, 2014). By contrast, large vertical errors on longer shots were an even mix of cognitive and execution mistakes. Interestingly, cognitive interference during short-shot preparation did not consistently generate cognitive problems. Instead, the interference promoted short-shot mistakes of either kind. This suggests that a straightforward model that cognitive interference will lead to a
cognitive mistake is inadequate. A disrupted preparation presumably prevents the golfer from organising their thoughts well. On some occasions, this might elicit a poor choice. On others, it might encourage a rushed execution or difficult on-the-fly adjustments (e.g., self-focused attention), creating a timing problem. These results extend Beilock and Gray’s (2007) model, which does not specify the relationship between disturbed cognition and execution quality.

**Broad tolerance to interference**

Previous observations of expert tolerance to task-irrelevant interference during execution were replicated (e.g., Beilock et al., 2002; Gray, 2004). General maintenance of performance with a disturbed preparation was unexpected. One possibility is that golfers increased their cognitive effort to preserve performance. This is consistent with PET (Eysenck & Calvo, 1992) and ACT (Eysenck et al., 2007), which both hold that performers can withstand losses of processing efficiency (e.g., off-task processing) by engaging in compensatory efforts (e.g., additional target glances or longer preparation times). Future research may wish to consider if dual-task interference has this behavioural effect (in chapter 5, the behavioural effect of pressure is considered). A related explanation is that in a novel, low pressure setting, the need to prepare (beyond noting the distance and choosing a club) may have been relatively low. Consequently, disruption to cognitive processes during players’ routine preparations may have been largely inconsequential to this self-paced task. The different preparation requirements of externally-paced and self-paced skills could be relevant. Gray’s (2006) baseball players seemed to need all their resources during their brief preparation to anticipate and guide the events of externally-paced execution. Time to organise their thoughts was neither abundant nor under their control, with the pitch soon on its way. Golfers’ relatively luxurious and controlled preparation timing probably facilitated their tolerance to interference.
Limitations and future research

To balance creating a challenging primary task and maintaining control over environmental variables (e.g., different daily conditions), a commercial golf simulator was utilised. The choice was advantageous because numerous measurements were efficiently obtained (e.g., back spin) beyond traditional collections of radial error. However, some limitations were also introduced. In particular, discretisation of the radial error and distance travelled measurements increased the noise in the estimation of VE and HE effects – although presumably evenly across conditions. Additionally, while a stronger difficulty manipulation was preferable to increase external validity, the features available (e.g., the addition of ‘wind’) were known to negate the measurement quality and were avoided. Researchers seeking to conduct similar research with putting might consider a range of slopes and distances in the primary task. Strong difficulty manipulations remain a useful choice for future dual-task examinations of interference during preparation or execution.

Several measures obtained from the simulator were used to assess the quality of the shot. However, alternative indicators of execution quality may be more suitable. For example, the time to maximum club-head speed is thought to distinguish expert and novice putters (Beilock & Gray, 2012). Similarly, experts characteristically achieve near maximal putter velocity near or after ball impact (Paradisis & Rees, 2000; Sim & Kim, 2010) – implying efficient energy transfer. Regarding the full golf swing, the rotation of the shoulder relative to the pelvis at the top of the golf swing is thought critical to generating maximum acceleration (An et al., 2013). An indication of where the club strikes the ball would also be informative (i.e., to assess middling the shot). In a low-tech manner, stickers placed on the clubface to show the strike point (often used by golf coaches) could be utilised. A comprehensive kinematic analysis is needed to directly assess execution quality, define cognitive and
execution mistakes, and therefore better understand how cognitive interference converts to motor skill failure.

The current findings could have ramifications for understanding choking under pressure. Cognitive resources compromised by pressure could similarly impact the preparation of golfers seeking to calibrate distance. Furthermore, off-task thought is presumably most destructive when cognitive interference is unwelcome, such as when performance matters (i.e., under pressure). Accordingly, a useful next step would be a study that tested the effects of dual-task interference in preparation with and without a pressure manipulation (e.g., the addition of incentives and/or threat). If the pressure/distraction combination is more destructive than pressure alone, then the argument that sub-threshold attention causes motor skill failure would be supported (e.g., Lewis & Linder, 1997).

Making interference more disconcerting to the performer would also enhance simulation of the distractions experienced in competitive sport. One option is to increase the unpredictability of the interference. For example, perceptual stimuli (e.g., tones) could be played randomly and/or rarely, leaving athletes uncertain about the occurrences to come (see Herrebrøden, Sand Sæbø, & Hystad, 2017). Another option is to increase the rate or intensity of distraction during a pressure condition, appearing unfair to the participant. Tailoring primary tasks to the individual is another way forward. For example, a further study using golf approach shots could identify golfers’ ‘in-between’ distances up-front, then compare the effect of distraction upon more and less comfortable shots. Post-hoc survey of the extent that athletes were troubled by interference, followed by sample division on this basis, would also make for a helpful analysis.
Concluding remarks

The study holds value in that it is the first to compare the effects of cognitive load during the preparation and execution of a self-paced activity. The data indicates that extraneous thought during preparation can harm golfers’ distance control when the task has unusually complex attentional requirements. The analysis further suggests that interference may encourage multiple routes to failure, rather than just strategic or decision-related problems. Evidently, the detail of the sporting task is important in assessing the impact of distraction. Where a minor task-irrelevant disturbance to the preparation of a baseball player might debilitate their performance, a larger disturbance is probably necessary to derail a self-paced skill (given opportunity to compensate), unless the task has advanced attentional requirements.

In true competitive situations, off-task thought could be widely damaging. In tournaments, attention to irrelevant features (e.g., threat) might escalate to levels not attempted in experimental research, causing discomfort and spiralling irrelevant thought. This could cause the destructive resources shortage hypothesised by distraction-based choking theories; derailing useful action planning, negating self-regulation, or even overwhelming autonomous action. Dual-task research has the rare advantage of verifying an athlete’s attention, but this is coupled with a novelty that detracts from the importance of the situation. Thorough difficulty manipulations, along with the creative introduction or post-hoc identification of discomfort, are necessary to make further strides in the area.

In this chapter, a gap in dual-task examinations of distraction theory was addressed. In the next chapter, the focus shifts onto a gap in qualitative examinations of choking based on self-report. The argument is developed that studies of this nature have given superficial consideration to disrupted processing during the short intense moments of execution. To
close this gap, a study is introduced that gives specific consideration to normal and pressure-affected thought processes during golfers’ preparations and executions.

Research Declaration

The content of this chapter was presented as a poster at a conference (reference listed first below). The author made and presented this poster, after some editorial input from the two co-authors. Additionally, the content of this chapter (in a modified form) has been submitted for publication in the International Journal of Sport and Exercise Psychology (reference listed second below). The author wrote this submission, with some editorial input from the two co-authors.


Chapter 4 – Study 2. Rationalisations of choking under pressure in golf: Disrupted processing in preparation and execution.

‘The introduction of self-doubt and subsequently removing my focus from the target and introducing technical swing thoughts and images of the different ways that I could fail to execute the shot, which in turn overrides my natural ability and makes for a negative, tight, un-rhythmic and un-athletic swing (a steer!).’

A golfer from this thesis, putting together the numerous elements of a choke.

In chapter 2, several qualitative studies of choking were reviewed. To date, the dominant reading of these studies is that they a) support a distraction-based mechanism and b) reflect the improbability of a self-focus-based mechanism. One criticism of these studies (raised in chapter 2) is that they did not address in any detail the unhelpful thought processes that might occur during skill execution. Given that self-focus occurs only during execution and that these moments are so brief relative to the length of the overall experience, it was posited in chapter 2 that asking athletes to consider thought processes during the execution phase might reveal a different pattern of rationalisation. Accordingly, this chapter describes a study that required golfers to report on thinking during the preparation and execution phases in past chokes, via a mixed-methods questionnaire. To contextualise these pressure-affected responses, information was also collected about normal preparation and execution thought processes during competitive situations.

A shift in the literature on choking to qualitative research

Researchers studying the phenomenon of choking under pressure have long-suspected that the cause is attentional interference under pressure. Two intuitive mechanisms have been advanced: self-focus and distraction. The general proposal of the self-focus mechanism is that pressure causes the athlete to process the motor execution consciously, undermining the automaticity developed through extensive rehearsal (e.g., Baumeister, 1984). The general
proposal of the distraction mechanism is that pressure causes the athlete to channel attentional resources into worry, creating a shortage of on-task attention for adequate motor execution (e.g., Nideffer, 1992). Following numerous experimental simulations of both mechanisms in contrived settings, calls for more externally valid work (e.g., Gucciardi & Dimmock, 2008; Hill et al., 2010a) prompted several qualitative investigations of attentional problems during past choking experiences. These studies found that athletes mostly attributed choking to distracting thoughts (e.g., worry) and rarely attributed choking to self-focus (Englert & Oudejans, 2014; Gucciardi et al., 2010; Hill et al., 2010b; Hill & Shaw, 2013; Oudejans et al., 2011). A general approach among these researchers was to question athletes in a holistic manner, for example, ‘What were you thinking or saying to yourself during the choke?’ (Gucciardi et al., 2010, p65). While this kind of question probably captures many distractions throughout the choking experience, self-focus only occurs, by definition, during the brief moments of motor output (see chapter 2). Given the brevity and intensity of these moments, holistic questioning may not adequately assess the frequency of self-focus. In response, the present study required golfers to consider preparation and execution thought processes separately, both in usual competitive circumstances and in past choking episodes.

**Attentional theories**

The two dominant attentional explanations of choking, self-focus and distraction, were addressed in detail in chapter 2. However, given the relevance of that content to the present research, brief descriptions of each theoretical variation are provided.

**Self-focus.** Traditional skill learning theories (e.g., Anderson, 1982; Fitts & Posner, 1967; Logan, 1988) share that expertise is achieved after transition from a cognitively inefficient and effortful phase, reliant on conscious processing, to a cognitively efficient and effortless phase that runs autonomously. Self-focus theories propose that choking occurs after a reversal of this process, in which pressure triggers a sportsperson to engage in conscious
processing of their skill, which interferes with the autonomous processing and causes poor execution. Three subtly different versions of self-focus permeate the extant literature: *Conscious Control* (Baumeister, 1984), *Explicit Monitoring* (Beilock & Carr, 2001) and *Reinvestment* (Masters, 1992; Masters & Maxwell, 2008). Under Conscious Control, explicit takeover of the execution is a maladaptive coping strategy designed to address the increased importance of performing well (i.e., pressure). Failure results because consciousness is ill-equipped to control motor execution (i.e., conscious processing is too slow and inefficient). Explicit Monitoring advocates that *monitoring* of the step-by-step motor processes is the more likely interference to automaticity. Reinvestment refers to maladaptive application of technical rules during execution, developed in earlier phases of skill acquisition (i.e., novice-like processing), which disrupts the automation. Of the three versions, reinvestment is the most specific on the contents of self-focused thought (i.e., technique). Fundamentally, self-focus accounts are concerned with interference during the motor output, since this is when conscious control or monitoring of the movement would occur.

**Distraction.** Like self-focus, several distraction models exist. The simplest version posits that pressure draws attention towards task-irrelevant concerns (e.g., worry about the outcome), leaving insufficient resources for expert execution (Nideffer, 1992). The idea has basis in cognitive test literature which suggests that anxious people divide their attention between worry and the task, logically to the detriment of their test performance (e.g., Wine, 1971). More advanced models like PET (Eysenck & Calvo, 1992) and ACT (Eysenck et al., 2007) add that people can employ compensatory effort to regain mental resources lost to worry, but failing this, performance will suffer. ACT further specifies that off-task attention is biased towards threat under anxiety. Their variations aside, distraction accounts all maintain that the final reason for choking is sub-threshold task-focused attention. Distraction theories are not specifically concerned with mental events in execution. Task irrelevant
thought could also impact, for example, the motor programming that is organised in preparation (Nieuwenhuys & Oudejans, 2012).

**Self-focus and distraction as competing or integrated accounts**

Several researchers have argued that self-focus and distraction are opposing accounts on the basis that self-focus emphasises too much attention to the skill and distraction emphasises too little attention to the skill (e.g., Beilock & Carr, 2001; Beilock, Kulp, et al., 2004; Gucciardi & Dimmock, 2008; Lewis & Linder, 1997). A softer position (Domain Specificity from chapter 2) is that distraction harms aspects of sports performance that rely on working memory, such as strategy, whereas self-focus harms aspects that run automatically, such as the execution of a short putt (Beilock & Gray, 2007). A more inclusive view is that self-focus is likely to affect some athletes and distraction is likely to affect others (Hill et al., 2010a; Mesagno et al., 2008). Some have gone further and argued that distraction and self-focus could co-exist in the same event. Hill et al. (2009) proposed that the compensatory efforts central to PET and ACT (designed to mitigate distraction) could trigger self-focus (Hill et al., 2009) – effectively, trying too hard (see also Eysenck & Wilson, 2016). Finally, the idea that self-focus is distraction has coverage (e.g., Nideffer, 1992). The most detailed elaboration is that self-focus can be considered an irrelevant focus after the early stages of skill acquisition, since this is the only time when attention to the execution process may be useful (Nieuwenhuys & Oudejans, 2012).

**Patterns of evidence in quantitative and qualitative research**

Significant dual-task experimentation suggests that task-irrelevant thought is an unlikely cause of choking in sporting experts (Beilock, Bertenthal, et al., 2004; Beilock & Carr, 2001; Beilock et al., 2002; Gray, 2004; Gray & Cañal-Bruland, 2015; Mullen & Hardy, 2000). The base evidence is that experts can successfully execute when their attention is co-opted by an extraneous secondary task (i.e., under distraction) but fail when their focus is co-
opted by a secondary task requiring movement focus (i.e., under self-focus). Similar results have been observed with and without manipulated pressure. The results imply that athletes need little on-task attention (due to automation), which weakens the argument that choking is caused by an attention shortage. Nonetheless, contrived settings, simple primary tasks, and the arbitrary application of cognitive load are reasons to be sceptical (e.g., Christensen et al., 2015; Gucciardi & Dimmock, 2008). A further concern is a persistent focus on manipulating attention during autonomous execution, rather than during the more cognitively-dependent preparation period (chapters 2 and 3).

One move towards ecological validity has been to ask athletes to explain their choking experiences. In contrast to dual-task work, the results suggest that task-irrelevant thought is an important concern. Oudejans et al. (2011) prompted athletes from various sports to recall thought processes under pressure. They found that 26% were related to worries, with another 5% related to external distractors, while only 4% were related to explicit processing. Most responses indicated adaptive thought processes. Gucciardi et al. (2010) interviewed skilled golfers about recent choking episodes and revealed a similar theme: fear of failure and reduced ability for task-focus overshadowed discussion of self-focus. Likewise, Hill et al.’s (2010b) interviews with choking-resistant and choking-susceptible golfers suggested that choking could be largely attributed to evaluation apprehension and loss of perceived control. They further observed that when self-focus occurred, it was accompanied by distractions. Considering team sport, Hill and Shaw (2013), reported that athletes frequently discussed ego-threat and losses of perceived control, but rarely mentioned self-focus. Using a mixture of experimental and qualitative methods, Englert and Oudejans (2014) found that the relationship between anxiety and performance decline in tennis serving was mediated by the self-reported level of distraction, but not the self-reported level of self-focus. This set of qualitative data has been interpreted as renewed evidence for distraction theory (Gucciardi et
al., 2010; Hill et al., 2010b; Hill & Shaw, 2013), evidence against self-focus theory (Oudejans et al., 2011) and evidence against the commonality of self-focus (Nieuwenhuys & Oudejans, 2012).

**Thinking during execution – part-process, holistic cues and external focus**

Self-focus assumes that skilled performance is normally under autonomous control, hence does not accommodate that explicit thought could be tolerable or helpful in execution (Christensen et al., 2016). However, there are alternative views. Under deliberate practice theory (Ericsson, 2003), full automaticity signals plateaued skill development and is recognised as an obstacle to further improvement. Ericsson (2003) argued that experts aspiring to mastery must continually update their representations of the skill with deliberate practice and retain some cognitive control over motor execution. Relatedly, Toner et al. (2016) noted that experts have the ability to use *part-process cues*, in which certainly bodily or technical features are processed consciously, while other automated components run in the background. Supportively, Maurer and Munzert (2013) found that 18 of 23 highly skilled basketball players preferred to think about aspects of bodily movement (e.g., snapping the wrist) in free-throw execution (much like the technical focus expected under reinvestment). Hill et al. (2010b) observed that some golfers deliberately use technical thought (knowing that it is suboptimal) as a coping strategy to moderate poor scoring. Toner and Moran (2011) showed that golfers could make technical changes to their putting stroke and remain adept. Similar results have been obtained with weightlifters (Collins, Jones, Fairweather, Doolan, & Priestley, 2001).

A similar but distinguishable concept is the *holistic cue* (Jackson & Willson, 1999), which might allow the chunking of technical knowledge into easily processed concepts that can coexist with automated action. Gucciardi and Dimmock (2008) found that golfers
adopting holistic cues during putting strokes, like ‘smooth’ or ‘easy’, showed better performance under pressure than golfers using a technical focus.

A third recognised form of thinking in execution is an external focus (Wulf, Höß, & Prinz, 1998). This refers to task-relevant attention outside the body, such as the target or the movement effect (e.g. ball flight or movement of an implement such as a bat or club). Extensive research indicates that an external focus advances learning and performance more than an internal focus – such as attention to body movement (see Wulf, 2013 for a review). To Wulf and colleagues, attending to an implement throughout execution (e.g., a bat or club) is an external focus and is thus beneficial. This contradicts dual-task work showing the opposite (e.g., that focusing on baseball bat position is detrimental to expert players – see Gray, 2004). The frequency and usefulness of explicit thought during an expert’s execution, and by extension, what an athlete should think about in the moments of action is an active debate (e.g., Winter et al., 2014).

Thinking in preparation

It is well established that experts and novices process information differently in the moments before execution (e.g., Ericsson, 2003). In externally-paced skills (e.g., baseball batting, cricket batting, and tennis receiving), performers often respond to a stimulus moving at a speed that approaches their perceptual limits (e.g., Bahill & LaRitz, 1984). Experts in these domains have a time advantage over novices, because they can process useful information, like the body position of an opponent, before ball flight (e.g., Abernethy, 1990; Abernethy & Russell, 1987). In self-paced activities (e.g., golf shots, baseball pitching, tennis serves), performers choose when to initiate action and have an abundance of time to process relevant information. Ironically, the opportunity to think may facilitate maladaptive thought processes (Boutcher & Rotella, 1987). Experts in self-paced domains use a variety of self-regulatory activities in preparation to manage distraction and facilitate a successful execution
(Singer, 2000). Often these activities are enclosed in a PPR (see chapters 2 and 3). PPRs are frequent at expert levels (e.g., Thomas & Over, 1994), are believed to improve on-task focus (Cotterill, 2010) and their implementation may reduce the risk of choking (Mesagno & Mullane-Grant, 2010). The makeup of the routine is individual, but the sports psychology literature has some general recommendations. Singer (1988) proposed a five-step strategy for managing attention in self-paced activities. The pre-performance steps are readying (e.g., establishing a suitable emotional state), imaging (e.g., visualising the results or the feelings required for execution) and focusing (e.g., holding an intense concentration on a relevant cue). The remaining steps are executing (with a quiet mind) and evaluating (see Boutcher and Rotella (1987) for a similar set of cognitive processes). Notwithstanding these suggestions, the mental tactics that self-paced performers actually use in their cognitive preparations are not widely documented. Greater knowledge of normal mental preparation informs ways that choking could occur and how it might be rationalised. For example, if a golfer seeks to attain positive images before execution, perceived inability to do so is a sensible rationalisation of failure, a plausible trigger for further interference or possibly the actual reason for failure. This and other similar scenarios are considered in the present study.

**Separating preparation and execution to assess distraction and self-focus**

One possible reason that dual-task and self-report research have revealed a different pattern of theoretical evidence is that each domain has a different scope. Dual-task studies have primarily simulated the effects of distraction and self-focus during motor output (i.e., in execution). There is a good reason for this. The self-focus mechanism only operates during motor output, hence the only way to directly compare the effect of self-focus and distraction manipulations is to manipulate interference during execution. As a key point of difference, qualitative studies of choking have not closely examined thought processes during the execution phase. Instead, they have broadly assessed thoughts throughout the experience of
choking. For example, Oudejans et al. (2011) asked ‘When the pressure you feel is at a peak, and you are failing, or you have the feeling you are about to fail, where is your attention focused and what do you think about during these decisive moments?’. Likewise, Hill and Shaw (2013) asked, ‘Exactly what happens to you as you choke?’ (Supplementary material p3). In similarly broad fashion, Gucciardi et al. (2010) enquired, ‘What were you thinking or saying to yourself during the choke?’ (p65). No qualitative choking study has attempted to isolate how pressure affects preparation and execution thought processes. As a consequence, the comparability of dual-task and qualitative results is limited. Moreover, if the athlete does not consider the execution phase, the frequency of self-focus as a rationalisation might be misrepresented. Requiring athletes to specifically consider the execution period could elicit more references to self-focus.

As mentioned, existing qualitative research is widely thought to favour distraction theory. While this work robustly demonstrates that athletes often associate distractions with choking experiences (i.e., irrelevant-thought is typically blamed), it does not show that inadequate processing resources triggers the failure. Self-focus (or other mechanisms, e.g., muscle tension) could be the final reason for execution problems. Even Baumeister (1984) suggested that pressure caused distractions (i.e., increased awareness of the need to execute correctly), yet argued that this triggered conscious control of the execution (see Gröpel & Beckmann, 2018 for a similar suggestion). Directing performers to consider interference during execution may clarify whether athletes believe that distractions simply persist throughout the execution (preventing useful on-task processing) or if they operate to trigger other problems up the line (e.g., self-focus).

The present study

Golfers of intermediate to professional standard were surveyed about normal and pressure-affected preparation and execution thoughts (from past competitions). Golf was
selected because it is a sport with clear preparation and execution phases and a qualitative research precedent in the choking domain (Gucciardi et al., 2010; Hill et al., 2010b). Normal thought processes were explored – on top of pressure-affected thoughts – because this could inform how choking occurs. This is sensible because choking is widely considered an acute departure from the normal performance state. Hence, information about the baseline state is necessary. A preparation-execution framework was applied to a) adequately assess the frequency of self-focus b) equitably compare the frequency of distraction and self-focus-based rationalisations in execution and c) examine if distraction was associated with self-focus. Various skill levels were examined because this could affect how choking is rationalised. For example, better golfers may adopt different approaches to managing distraction in general (e.g., a greater focus on visualisation or a more precisely-specified PPR), and this could impact their attributions.

**Aims and hypotheses**

The study had two major aims. The first was to map normal and pressure-affected preparation and execution thinking among golfers across skill levels. This was a largely descriptive exercise, with some expectations based on past research. Considering existing suggestions that some golfers engage in technical thought while executing (Hill et al., 2010b; Toner et al., 2016), it was expected that a deliberate technical focus would be commonplace. However, more advanced sportspeople are believed to subsume technical information with higher-level representations (Jackson & Willson, 1999; Vallacher & Wegner, 1987). Accordingly, it was predicted that less-skilled golfers would prefer a technical execution focus while more accomplished golfers would prefer an intuitive approach.

The second aim was to examine golfers’ recollections of disrupted preparation thoughts and disrupted execution thoughts in past chokes, again with consideration of skill level. The central research question was: how do golfers rationalise their past choking
experiences when explicitly considering the events of the execution period? Given the critical relevance of the execution period to self-focus theories, it was hypothesised that self-focused processing would be recognised as a common/important cause of choking when golfers were asked to consider the execution phase. Considering that expert golfers are thought to have highly-developed PPRs (Crews & Boutcher, 1986) an additional hypothesis was that better golfers would more frequently attribute choking to breaking from this process.

Method

Participants

Eighty golfers (66 males; 14 females) completed the survey. The mean age was 43 years (standard deviation = 14.4) and the mean handicap was seven (standard deviation = 4.8). Prior to data collection, ethics approval was obtained from the RMIT College Human Ethics Advisory Network (Appendix XV). Informed online consent was collected at survey commencement. To recruit golfers, local coaches, golf clubs and golf administrative bodies were approached by email and asked to distribute study information and a survey link to potential participants. Those interested were the free to participate online. To consider skill-level effects, golfers with a range of handicaps were included (+1.4 to 18.0). Handicap has recognised heuristic value as an indicator of skill level (Herrebrøden et al., 2017). Similar upper handicap limits have served in other choking studies (e.g., Mullen & Hardy, 2000; Mullen, Hardy, & Tattersall, 2005). Four professionals also completed the survey. For the skill-level analysis, each professional was assigned a handicap of +2 (i.e., playing to their handicap would necessitate a round of two shots under par). The logic was to treat the professionals as slightly better than the best amateur in the sample (who had a handicap of +1.4).
Methodological Choice and Survey design

To date, qualitative studies in the literature on choking have obtained data via survey (Oudejans et al., 2011) and semi-structured interviews (Gucciardi et al., 2010; Hill et al., 2010b; Hill & Shaw, 2013). A survey methodology was selected for the current work given the interest in gaining knowledge about a) the normality of self-focus and distraction-based rationalisations of choking and b) the normality of technical or other forms of deliberate thought processes during execution and preparation. Considering that these aims centred on the prevalence of certain kinds of thought processes, collecting data from more golfers was desirable, rather than obtaining relatively information-rich (but less generalisable) information from interviews with a small number of participants. The survey was constructed and administered using Qualtrics software (Qualtrics, Provo, UT). The full survey is in Appendix IV.

The survey mixed open-ended and forced-choice questions to converge two sources of evidence about normal and pressure-affected thinking. This kind of ‘triangulation’ of qualitative and quantitative data has significant precedent in social sciences research (e.g., Denzin, 1978; Glik, Parker, & Hategikamana, 2005; Jick, 1979; Marshall, 1981). Triangulation is grounded in the principle that any isolated method of obtaining data has weaknesses (Connidis, 1983) and that stronger inductive reasoning can be performed by converging different forms of information about the same phenomenon (Denzin, 1978; Jick, 1979). In the current study, the two data sources allowed the collection of information in the golfer’s language (open-ended questions) and information in the language of published theories and concepts (forced-choice questions). The combination of these sources then facilitated the elucidation of key thought processes and rationalisations in golf preparation and execution (normally and when choking). Using forced choices additionally protected
against the possibility that some participants would offer terse and thus uninformative responses. The order of forced-choices was randomised across participants.

Question development was both conceptually and theoretically-focused. Questions were designed to capture information about various kinds of normal and disrupted thought processes already established in the literature. Adopting this approach ensured that responses could be used to support or deny popular theoretical positions or existing conceptual understandings. These existing positions/concepts are elaborated upon below.

**Normal thought processes.** Golfers were asked to indicate normal thought processes before and during a drive off the tee and a short putt. This allowed some comparison across skills with different motor complexity. The drive (a complete golf swing) requires full body sequencing whereas a putt requires a simple shoulder rocking motion. To assess normal preparation thoughts, golfers received the following (repeated for a short putt): ‘*Many golfers undertake similar physical behaviours and mental preparations before hitting a shot. When competing, how do you mentally prepare for a drive off the tee?’* After responding openly, golfers chose up to 10 mental preparation strategies (listed as forced choices) that they might use. In addition, participants could use an ‘other’ field to provide alternative answers. The forced-choice options addressed preparatory aspects of the five-step model for self-paced skills (Singer, 1988, 2000), namely, readying (physical and mental), imaging (visualisation strategies) and focusing (cue words, targets). To assess normal execution thoughts, golfers received the following statement in relation to a short putt or a drive off the tee: ‘*When competing, describe what you normally think about (if anything) in those brief moments between taking the club away and following through (i.e., thoughts during shot execution) when taking a short putt*’. After responding openly, golfers chose up to seven normal execution foci (listed as forced choices). These options reflected part-process/technical cues (Toner et al., 2016), external focus on ball, flight or target (Wulf, 2013), holistic cues
Thoughts during choking experiences. To standardise various interpretations of choking, the experience was first defined (simply) as ‘a significant drop in performance under pressure’. To assess golfers’ general rationalisations of their past failures (i.e., with no separation of preparation or execution), the following scenario and question was then presented: ‘Consider a time when you were playing competitive golf and you had an opportunity to achieve a much-desired goal and felt great pressure to perform, but your performance faltered significantly. What do you think caused your skills to decline?’

To assess disrupted preparation thoughts, golfers were asked: ‘Thinking back to any experience of choking in competitive golf, describe any changes (from normal) you noticed to your mental preparation?’ After responding openly, golfers rated the importance of 11 preparation changes as causes of their past choking experiences as not at all important, somewhat important, quite important or very important. The rating task was introduced as follows: ‘Considering mental preparation, rate the importance of the following possible occurrences as causes of your past choking experiences’. The preparation events chosen addressed worry about the outcome (Hill et al., 2010b), perceived behaviour change (Gucciardi et al., 2010), perceived loss of control (Hill et al., 2009) and poor decision making (Beilock & Gray, 2007). This conceptual mapping of the items chosen is presented in Table 4.1.
Table 4.1. Forced choice options (preparation thoughts during choking) and associated concepts recognised in past research.

<table>
<thead>
<tr>
<th>Thought Process</th>
<th>Aligned choking-related concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worry about upcoming shot outcome and consequences</td>
<td></td>
</tr>
<tr>
<td>Worry over technique for upcoming shot</td>
<td>Worry about the outcome</td>
</tr>
<tr>
<td>Worry about ability to play upcoming shot</td>
<td></td>
</tr>
<tr>
<td>Feeling of rushing</td>
<td></td>
</tr>
<tr>
<td>Noticed a routine change</td>
<td>Perceived behaviour change</td>
</tr>
<tr>
<td>Feeling of taking too long</td>
<td></td>
</tr>
<tr>
<td>Felt mentally overloaded</td>
<td></td>
</tr>
<tr>
<td>Unable to generate positive imagery</td>
<td>Perceived loss of control</td>
</tr>
<tr>
<td>Felt helpless to stop a poor shot</td>
<td></td>
</tr>
<tr>
<td>Poor shot choice</td>
<td>Poor decision making</td>
</tr>
<tr>
<td>Poor club choice</td>
<td></td>
</tr>
</tbody>
</table>

To assess disrupted execution thoughts Golfers were asked: ‘Thinking back to any experience of choking in competitive golf, describe any changes (from normal) you noticed to your thoughts during execution?’ After responding openly, golfers rated the importance (not at all important to very important) of eight potential causes of past choking experiences. The rating task was introduced as follows: ‘Considering the very brief moments of execution, rate the importance of the following execution occurrences as causes of your past choking experiences’. The execution events chosen reflected various (potentially) maladaptive thought processes captured by distraction, self-focus or both mechanisms. This alignment is displayed in Table 4.2.
Table 4.2. Forced choice options (execution thoughts during choking) and connected theoretical mechanism.

<table>
<thead>
<tr>
<th>Thought Process</th>
<th>Aligned Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tried to ‘steer’ the ball</td>
<td>Conscious Control</td>
</tr>
<tr>
<td>Became too focused on swing mechanics</td>
<td>Reinvestment</td>
</tr>
<tr>
<td>Became very aware of swing movements during the execution</td>
<td>Explicit Monitoring (‘step by step’ attention)</td>
</tr>
<tr>
<td>Doubted technique during execution</td>
<td>Distraction (doubt) and Reinvestment (technical processing)</td>
</tr>
<tr>
<td>Worried about the shot outcome and its consequences during the execution</td>
<td>Distraction – worry</td>
</tr>
<tr>
<td>Doubted strategic choices during execution</td>
<td>Distraction - doubt</td>
</tr>
<tr>
<td>Too many thoughts during execution</td>
<td>Distraction or Self-focus (overload)</td>
</tr>
<tr>
<td>Lost focus on desired swing thoughts</td>
<td>Distraction – generic off-task thinking</td>
</tr>
</tbody>
</table>
Data analysis

Forced-choice responses. Frequencies. To analyse normal thought processes, the number of forced-choice selections was collated and presented as the percentage of golfers who chose a given focus. To analyse disturbed thought processes during choking (i.e., importance ratings), the percentage of golfers ascribing the highest two ratings (i.e., quite important or very important) was calculated as a suitable treatment of the ordinal data.

Skill level. To examine the effect of skill level on normal thought processes, a multiple linear regression model was created to predict handicap from the set of forced-choice binary response variables (focus selected=1; focus not selected=0). Multiple linear regression is a standard method to assess the unique contribution of a number of independent variables to the overall prediction of a continuous dependent variable (e.g., Tabachnick & Fidell, 2001). In the present analysis, regression coefficients were interpreted as the independent contribution of choosing a given focus (the independent variable) to the prediction of handicap (the continuous dependent variable). For example, the model was used to assess the expected change in handicap given the selection of ‘visualisation’ (while holding other selections constant). Negative coefficients indicated that better golfers preferred a given focus whereas positive coefficients indicated the opposite. Note that here ordinary linear regression was used rather than the mixed-effects regression model adopted in chapter 3 (in which observations were nested within participants). Four normal-thought process models were produced: driving in preparation (Drive_{prep}), putting in preparation (Putt_{prep}), driving in execution (Drive_{exe}) and putting in execution (Putt_{exe}).

The same method was used to examine the effect of skill level on disturbed thought processes under pressure, except that this time the predictors were item importance ratings recoded to an ordinal scale (not at all important=0 to very important=3). Regression coefficients were thus interpreted as the independent contribution of a one-step increase in
the importance rating to handicap prediction. For example, the model was used to assess the expected change in handicap given a one-step increase in the importance of ‘steering’ (while holding other importance item ratings constant). Two models were created to consider preparation changes ($\text{choke}_{\text{prep}}$) and execution changes ($\text{choke}_{\text{exec}}$). Plots of residual and fitted values for all six models revealed no unusual patterns (see Appendix V for normal process models and Appendix VII for choke models), indicating no systematic problems with the model fit (Gelman & Hill, 2007). Examination of variance inflation factors (VIF) for each model indicated that multicollinearity was not a concern (max VIF for any model was 2.17).

**Factor analysis.** To map how golfers connected the concepts represented by importance items, their responses were submitted to exploratory factor analysis (EFA) via SPSS Factor (IBM SPSS Statistics, version 25). EFA is a common method to identify underlying factors in Likert scale survey responses (e.g., Tabachnick & Fidell, 2001). One execution item was excluded (lost focus on desired swing thoughts) because it loaded weakly onto all factors and had low commonality (<0.4). The final data submitted (11 preparation items and 7 execution items) had suitable sampling adequacy (Kaiser-Meyer-Olkin =0.73), sphericity (Bartlett’s Test: $\chi^2 = 480$, df=153, p<0.01), anti-image correlation matrix diagonals (all > 0.6) and communalities (all >0.4). Five factors were extracted (eigenvalues >1). Their combination accounted for 61.9% of the variance in the importance ratings.

**Open-ended responses. Thematic analysis.** Content analysis was undertaken using a mixture of inductive procedures (recommended for developing previously unknown themes from content) and deductive procedures (recommended for developing themes in line with existing knowledge or theory) – see, for example, Patton (2002). Inductive analysis was conducted initially, while openly exploring the data for meaningful categories. Later, deductive analysis was used to reconcile the developed themes with existing theories (e.g. conscious processing expected under self-focus) or concepts (e.g., part-process execution
Flexible use of deductive and inductive procedures is well-established (e.g., Elo & Kyngäs, 2008) and consistent with grounded theory practices (Patton, 2002).

Seven open-ended response sets were analysed: general choking explanations, normal putting and driving preparation thoughts, normal putting and driving execution thoughts, preparation changes during past chokes and execution changes during past chokes. The analysis served to a) assess the content validity of the forced-choice items by assessing conceptual overlap with free-text responses b) enhance conceptual understanding with free-text examples and c) identify extra themes not addressed by forced-choice options. Extra themes were reported if mentioned by five or more golfers. Very broad explanations of normal thought processes (e.g., ‘swing thoughts’ not described further) or pressure-affected thought processes (e.g. ‘overthinking’) were disregarded (see Jackson & Baker, 2001 for a similar treatment). The remaining thought processes were grouped into meaningful themes. To assess the reliability of theme assignment, two other raters each grouped 12.5% of responses into the identified themes (i.e., 25% of total responses were considered). Concordance between original classifications and other-rater classifications was high (88.8%). As a matter of priority, forced-choice frequencies are reported instead of open-ended frequencies (given conceptual overlap). There was one exception. Open-ended descriptions of self-focus and distraction were counted and reported to test if isolating the execution phase promoted more self-focus-based rationalisations.

Skill level. Multiple linear regression models were built to predict handicap using binary response variables to predict handicap (i.e., whether or not a focus was indicated). Five open-ended (OE) content models were produced to predict handicap from normal driving preparation thought processes (OE drive\textsubscript{prep}), normal putting preparation thought processes (OE putt\textsubscript{prep}), general choking explanations (Choke\textsubscript{gen}), in-preparation choking explanations (OE choke\textsubscript{prep}) and in-execution choking explanations (OE choke\textsubscript{exe}). Normal
process execution models (for putting and driving) were not produced because the forced-
choices accounted for all major open-ended themes (i.e., the analysis was redundant). Golfers
who made full statements that were uninformative or reflected little understanding of the
question were excluded from the handicap analysis because the thought processes were
indeterminable. Exclusions ranged from one (OE drive_{prep}) to 11 (OE choke_{prep}). Considering
assumptions, plots of residual and fitted values indicated no systematic issues (see Appendix
VI) and there was no evidence of multicollinearity in any model (max VIF = 1.29).

**Results**

**Normal preparation thoughts**

**Frequencies.** Table 4.3 displays the number and percentage of the sample making
forced-choice selections and handicap regression coefficients (with associated standard
errors). These statistics are organised by associated categories of mental preparation taken
from Singer’s (1988) self-paced model. An example of each category drawn from open-
ended content is displayed to the left of the statistics. Visualisation and target focus were the
most frequently chosen preparation foci before driving and putting. A majority of golfers also
rehearsed swing feelings to prepare for driving and assessed and adjusted arousal to prepare
for putting. Content analysis indicated that the forced-choice options accounted for 66% of
distinct putting statements and 73% of distinct driving statements. Three additional
preparation strategies appeared in open-ended content. Establishing commitment or trust
(e.g., ‘building commitment in my ability to execute’) was a strategy used by 11 golfers (14%)
before driving and 18 golfers (23%) before putting. Thought reduction processes (e.g., ‘go
into a state of a mental vacuum’) were employed by 10 golfers (13%) before driving and nine
golfers (11%) before putting. Reduced outcome focus (e.g., “often I tell myself to have no
care for the result”) was employed by 10 golfers (13%) before putting.
**Skill level.** A non-significant R squared value for the Drive\textsubscript{prep} handicap model ($R^2 = 0.21$, $F(10,69)=1.82$, NS) and for the Putt\textsubscript{prep} handicap model ($R^2 = 0.18$, $F(10,69)=1.54$, NS) indicated little overall association between the nature of preparation focus and handicap. Nevertheless, *intermediate/final target focus* significantly contributed to both models. Negative weights indicated that better players preferred this focus. Open-ended handicap models were similarly non-predictive. Non-significant $R^2$ values were returned in the OE drive\textsubscript{prep} model ($R^2 = 0.02$, $F(2,76)=0.96$, NS) and the OE putt\textsubscript{prep} model ($R^2 = 0.10$, $F(3,69)=2.47$, NS). Building commitment before putting was the only significant predictor ($\beta=-3.21$, SE($\beta$)=1.28, $p<0.05$). Better golfers preferred this focus.
Table 4.3. Usual mental preparation strategies used in competition. Beta values (Β) indicate the unique contribution of each focus to handicap prediction (associated standard errors in parenthesis). Significant predictors (p<0.05) are bolded.

<table>
<thead>
<tr>
<th>Skill</th>
<th>Strategy</th>
<th>Open-ended example</th>
<th>Reason for choke</th>
<th>N(%) golfers indicating</th>
<th>B (SE Β) - handicap prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Driving</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physical Readying</td>
<td>'Take a breath, relax my shoulders, think of my swing thought and then execute the swing.'</td>
<td>Focus on breathing</td>
<td>33 (41.3%)</td>
<td>-1.88 (1.18)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Assess and adjust muscular tension</td>
<td>17 (21.3%)</td>
<td>2.45 (1.37)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Assess and adjust arousal levels</td>
<td>9 (11.3%)</td>
<td>-2.31 (1.81)</td>
</tr>
<tr>
<td></td>
<td>Mental Readying</td>
<td>'Positive reinforcement is vital. Focus on a target and do not begin the pre-shot routine if any negativity or doubt about the shot is there.'</td>
<td>Positive self-talk</td>
<td>25 (31.3%)</td>
<td>2.37 (1.26)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Block negative thoughts</td>
<td>18 (22.5%)</td>
<td>-0.43 (1.32)</td>
</tr>
<tr>
<td></td>
<td>Imaging</td>
<td>'Visualise my line, feel the shot shape in my swing, whilst muting the sounds around me.'</td>
<td>Visualisation</td>
<td>60 (75%)</td>
<td>0.65 (1.35)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rehearse swing feelings for execution</td>
<td>49 (61.3%)</td>
<td>0.97 (1.14)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rehearse swing thoughts for execution</td>
<td>34 (42.5%)</td>
<td>-1.26 (1.13)</td>
</tr>
<tr>
<td></td>
<td>Focusing</td>
<td>'I have a mantra after my practice swing and before my swing : 'focus, faith, presence'.'</td>
<td>Focus on intermediate and final target</td>
<td>53 (66.3%)</td>
<td><strong>-3.48 (1.17)</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Use cue words</td>
<td>21 (26.3%)</td>
<td>-0.38 (1.22)</td>
</tr>
<tr>
<td></td>
<td>Physical Readying</td>
<td>'Deep breath, relax hands, relax shoulders.'</td>
<td>Focus on breathing</td>
<td>26 (32.5%)</td>
<td>-0.14 (1.22)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Assess and adjust muscular tension</td>
<td>21 (26.3%)</td>
<td>1.41 (1.3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Assess and adjust arousal levels</td>
<td>6 (7.5%)</td>
<td>-1.54 (2.1)</td>
</tr>
<tr>
<td></td>
<td>Mental Readying</td>
<td>'Focus on trusting my visual setup and preparation. I try to feel like I can make any putt'</td>
<td>Positive self-talk</td>
<td>26 (32.5%)</td>
<td>-2.12 (1.26)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Block negative thoughts</td>
<td>19 (23.8%)</td>
<td>1.95 (1.34)</td>
</tr>
<tr>
<td></td>
<td>Imaging</td>
<td>'I read the break, speed and then visualise a smooth pendulum like motion, seeing the ball into the hole.'</td>
<td>Visualisation</td>
<td>59 (73.8%)</td>
<td>2.02 (1.25)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rehearse thoughts for execution</td>
<td>26 (32.5%)</td>
<td>0.68 (1.23)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rehearse feelings for execution</td>
<td>24 (30%)</td>
<td>0.08 (1.16)</td>
</tr>
<tr>
<td></td>
<td>Focusing</td>
<td>'I have a key word - i.e. believe - to encourage my commitment to and execution of the putt.'</td>
<td>Focus on intermediate and final target</td>
<td>51 (63.8%)</td>
<td><strong>-3.1 (1.16)</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Use cue words</td>
<td>21 (26.3%)</td>
<td>0.51 (1.22)</td>
</tr>
</tbody>
</table>
Normal execution thoughts

**Frequencies.** The number and percentage of forced-choice selections and handicap regression statistics are found in Table 4.4, organised by execution thought categories (i.e., holistic, external etc.). To the left of the statistics is an example of each kind of thought process drawn from the open-ended responses. A majority of golfers guided driving execution with tempo-related thoughts, body or club-related focus, or a target focus. A majority guided putting execution with attention to tempo, the target or the putter motion. A thoughtless attention style was relatively unusual for either skill (around one fifth of the sample). Forced-choice options accounted for 91% of distinct free-text putting thoughts and 88% of distinct free-text driving thoughts. The open-ended data did not reveal additional themes (i.e., themes supported by five or more golfers).

**Skill level.** The $\text{Drive}_{\text{exe}}$ model did not significantly predict handicap ($R^2 = 0.04$, $F(7,72)=0.41$, NS) and all predictors were non-significant. In contrast, the $\text{Putt}_{\text{exe}}$ model did significantly predict handicap ($R^2 = 0.18$, $F(7,72)=2.18$, $p<0.05$). A focus on tempo during putting execution was the sole significant predictor. Less-skilled golfers preferred this focus.
Table 4.4. Usual competition execution foci. Beta values (B) indicate the unique contribution of each focus to handicap prediction (associated standard errors in parenthesis). Significant predictors (p<0.05) are bolded.

<table>
<thead>
<tr>
<th>Skill</th>
<th>Strategy</th>
<th>Open-ended example</th>
<th>Reason for choke (forced-choice)</th>
<th>N(%) golfers indicating</th>
<th>B (SE B) - handicap prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Holistic</td>
<td>‘Balance and rhythm’</td>
<td>Tempo</td>
<td>50 (62.5%)</td>
<td>1.88 (1.18)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Desired force</td>
<td>17 (21.3%)</td>
<td>0.16 (1.39)</td>
</tr>
<tr>
<td>Driving</td>
<td>External</td>
<td>‘I try to stay in my visualisation of the shot I want to hit.’</td>
<td>Target</td>
<td>43 (53.8%)</td>
<td>-0.1 (1.16)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ball or ball motion</td>
<td>8 (10%)</td>
<td>-0.23 (1.89)</td>
</tr>
<tr>
<td></td>
<td>Part-process</td>
<td>‘Technique during backswing. Getting backswing and body weight set correctly.’</td>
<td>Body positioning/motion</td>
<td>42 (52.5%)</td>
<td>-0.38 (1.14)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The club or club pathway</td>
<td>40 (50%)</td>
<td>0.15 (1.14)</td>
</tr>
<tr>
<td></td>
<td>Automatic</td>
<td>‘Absolutely nothing...The thought process is done before addressing the ball, for me anyway.’</td>
<td>‘Thoughtless’</td>
<td>16 (20%)</td>
<td>-0.22 (1.41)</td>
</tr>
<tr>
<td>Putting</td>
<td>Holistic</td>
<td>‘I just think smooth and positive.’</td>
<td>Tempo</td>
<td>50 (62.5%)</td>
<td><strong>2.39 (1.15)</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Desired force</td>
<td>36 (45%)</td>
<td>1.12 (1.08)</td>
</tr>
<tr>
<td></td>
<td>External</td>
<td>‘Thinking about the ball going in the centre of the cup and focusing on visualisation of the ball going in.’</td>
<td>Target</td>
<td>53 (66.3%)</td>
<td>-1.36 (1.13)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ball or ball motion</td>
<td>19 (23.8%)</td>
<td>1.99 (1.27)</td>
</tr>
<tr>
<td></td>
<td>Part-process</td>
<td>‘Soft hands, slow action and completing follow through.’</td>
<td>Body positioning/motion</td>
<td>22 (27.5%)</td>
<td>-1.77 (1.19)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The club or club pathway</td>
<td>42 (52.5%)</td>
<td>0.7 (1.07)</td>
</tr>
<tr>
<td></td>
<td>Automatic</td>
<td>‘nothing, as I am trusting my ability to execute my pre-routine visualisation.’</td>
<td>‘Thoughtless’</td>
<td>14 (17.5%)</td>
<td>-0.79 (1.44)</td>
</tr>
</tbody>
</table>
Thoughts during choking

**General choking enquiry.** Three themes were identified. A majority of golfers (n=48; 60%) attributed choking to task-irrelevant thought. Self-focus-based attributions were unusual (n=4; 5%). Considering ‘Other’ responses, 12 golfers (15%) attributed choking to psychophysiological changes. The Choke\textsubscript{gen} model did not significantly predict handicap ($R^2 = 0.01$, $F(3,71)=0.33$, NS) and contained no significant predictors.

**Preparation thoughts during choking.** Summarised importance ratings and handicap regression statistics are displayed in Table 4.5, organised by type of interference (i.e., worry about the outcome, perception of behaviour change etc.). To the left of the statistics, an example of each type of interference taken from the open-ended content is reported. Most golfers ascribed the highest importance ratings to worry about the shot and its consequences, worry about technique, worry about ability and perceived rushing. Forced-choice items addressed 56% of issues identified in open-ended content. Four other themes were observed. Dwelling on the future or past was mentioned by 18 golfers (23%), for example, ‘Focus drifting to end result rather than task at hand’. Similarly, seven golfers (9%) made generic comments about losing focus on the task, for example, ‘not focused on the task at hand’. Eleven golfers (14%) mentioned psychophysiological changes, for example, ‘tension in the entire body’. Five golfers (6%) mentioned awareness changes, for example, ‘my swing feels very loose and my rhythm seems to disappear, and the feeling seems to grow and grow’. Modelling of handicap returned non-significant $R^2$ values for the choke\textsubscript{prep} model ($R^2 = 1.88$, $F(11,68)=0.23$, NS) and OE choke\textsubscript{prep} model ($R^2 = 0.07$, $F(4,64)=1.16$, NS). No significant predictors emerged.
Table 4.5. Importance of preparation disturbances as causes of past choking experiences. Beta values (\(\beta\)) indicate the unique contribution of importance rating to handicap prediction (associated standard errors are in parenthesis).

<table>
<thead>
<tr>
<th>Interference</th>
<th>Open-ended example</th>
<th>Reason for choke (forced-choice)</th>
<th>% rating issue as quite/very Important</th>
<th>(\beta) (SE (\beta))</th>
<th>hcap prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worry about the outcome</td>
<td>‘Fear of failure overpowers most emotions and thought processes’</td>
<td>Worry about upcoming shot outcome and consequences</td>
<td>72.5%</td>
<td>0.19 (0.58)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Worry over technique for upcoming shot</td>
<td>61.3%</td>
<td>0.82 (0.59)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Worry about ability to play upcoming shot</td>
<td>60.0%</td>
<td>0.44 (0.68)</td>
<td></td>
</tr>
<tr>
<td>Perception of behavioural change</td>
<td>‘Rushed preparation and failed to build a commitment to the shot required before pulling the trigger’</td>
<td>Feeling of rushing</td>
<td>58.8%</td>
<td>1.01 (0.58)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Noticed a routine change</td>
<td>42.5%</td>
<td>-0.79 (0.58)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Feeling of taking too long</td>
<td>22.5%</td>
<td>-1.11 (0.67)</td>
<td></td>
</tr>
<tr>
<td>Loss of perceived control</td>
<td>‘Went blank - then had lots of random thoughts - found it hard to re-focus’</td>
<td>Felt mentally overloaded</td>
<td>50.0%</td>
<td>-0.23 (0.57)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unable to generate positive imagery</td>
<td>47.5%</td>
<td>-0.09 (0.66)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Felt helpless to stop a poor shot</td>
<td>41.3%</td>
<td>1.12 (0.64)</td>
<td></td>
</tr>
<tr>
<td>Poor decision-making</td>
<td>‘Got caught up in the moment and thought I needed to recover everything on that one shot’</td>
<td>Poor shot choice</td>
<td>50.0%</td>
<td>0.77 (0.66)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Poor club choice</td>
<td>32.5%</td>
<td>-1.11 (0.72)</td>
<td></td>
</tr>
</tbody>
</table>
Execution thoughts during choking. Summarised importance ratings and handicap regression statistics are displayed in Table 4.6, organised by their broad alignment to self-focus or distraction accounts. Examples of distraction-based and self-focus-based open-ended responses are also provided. A large proportion (>65%) ascribed the highest importance ratings to worry about the outcome (distraction), too many thoughts (distraction or self-focus) and attempts to steer the ball (self-focus). Over-attention to swing mechanics was less common. Content analysis revealed four themes. A majority of golfers (n=48; 60%) connected task-irrelevant thought to choking. Most of these descriptions referred to worry about outcome, for example, ‘I’m more worried about the potential consequences of a bad shot, and ruining my good round’. Fewer golfers (n=12; 15%) attributed performance decline to self-focus, for example, ‘really nervous hands, i.e., locking tight or premature release in an uncontrollable manner’. Nevertheless, this number exceeded the count obtained in the general choking enquiry (n=4). Ten golfers (12.5%) described a loss of trust or commitment to the shot. Some responses reflected a lack of trust in the choices made, for example, ‘a lack of commitment to the shot either due to a wrong club selection, shot choice, technical struggles’. Other responses reflected a lack of trust in freely executing, for example, ‘Mainly a feeling of lack of commitment, lack of confidence through the shot’. Eight golfers (10%) perceived that they were rushing, for example, “feel like I am rushing during my swing”. Modelling of handicap returned non-significant R squared values in the choke_{exe} model (R^2 = 0.11, F(8,71)=1.11, NS) and the OE choke_{exe} model (R^2 =0.07 , F(4,70)=1.29, NS). No significant predictors emerged from either model.
Table 4.6. Importance of mental execution problems as causes of past choking experiences. Beta values (B) indicate the unique contribution of importance rating to handicap prediction (associated standard errors are in parenthesis).

<table>
<thead>
<tr>
<th>Interference</th>
<th>Open-ended example</th>
<th>Reason for choke (forced-choice)</th>
<th>% rating issue as quite/very Important</th>
<th>B (SE B) - hcap prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distraction (off-task thought)</td>
<td>‘Thinking about a negative outcome rather than on just simply executing’</td>
<td>Worried about the shot outcome &amp; consequences during execution</td>
<td>73.8%</td>
<td>0.81 (0.58)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Too many thoughts during execution</td>
<td>72.5%</td>
<td>0.93 (0.62)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lost focus on desired swing thoughts</td>
<td>62.5%</td>
<td>0.89 (0.62)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Doubted strategic choices during execution</td>
<td>45.0%</td>
<td>-0.83 (0.65)</td>
</tr>
<tr>
<td>Self-focus (conscious processing)</td>
<td>‘Just lots and lots of thoughts about what my hands are doing’</td>
<td>Tried to steer the ball (Conscious Control)</td>
<td>66.3%</td>
<td>-0.08 (0.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Became very aware of swing movements during execution (Explicit Monitoring)</td>
<td>60.0%</td>
<td>-0.49 (0.6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Doubted technique during execution (Explicit Monitoring/Reinvestment)</td>
<td>57.5%</td>
<td>-0.24 (0.65)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Became too focused on swing mechanics (Reinvestment)</td>
<td>36.3%</td>
<td>0.59 (0.63)</td>
</tr>
</tbody>
</table>
Factor Analysis

Item loadings onto the five extracted factors are displayed in Table 4.7. The first factor (15.4% of variance) was labelled worry → self-focus to reflect that worry outcome (in preparation and execution), worry ability (preparation) and steering (execution) loaded heavily onto the same factor. This factor was interpreted as a representation of choking in which worry about the result (or the ability to attain the result) was paired with thoughtful execution (i.e., self-focus). The second factor (13.5% of variance) was labelled as worry → reinvest because worry technique (preparation), doubt technique (execution) and focused swing mechanics (execution) loaded strongly onto the same factor. This factor was interpreted as a representation of choking in which concern over technical skill was a paired with an excessive focus on mechanics (i.e., reinvestment). The third factor (12.1% of variance) was labelled poor strategy → distraction because two strategic issues in preparation (poor shot choice and poor club choice) and distraction in execution (doubt about strategy) loaded strongly onto the same factor. This factor was interpreted as a representation of choking in which compromised decision-making in preparation and task-irrelevant thought in execution were paired. The fourth factor (10.5% variance) was labelled broken routine to reflect that taking too long, rushing and routine change (all connected to preparation consistency) loaded strongly onto the same factor. This factor was interpreted as a representation of choking in which abnormal preparations were grouped as triggers. The final factor (10.5% of variance) was labelled cognitive overload, principally because mental overload (preparation) and too many thoughts (execution) loaded strongly onto the same factor. This factor was interpreted as a representation of choking in which losses of cognitive control in preparation and execution were grouped.
Table 4.7. Loadings from exploratory factor analysis on importance ratings. Loadings > 0.5 are bolded. Loadings <0.3 are not reported.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Item</th>
<th>Worry → self-focus</th>
<th>Worry → reinvest</th>
<th>Poor strategy → distraction</th>
<th>Broken routine</th>
<th>Cognitive overload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exe</td>
<td>Worry outcome</td>
<td>0.84</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prep</td>
<td>Worry outcome</td>
<td>0.79</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prep</td>
<td>Worry ability</td>
<td>0.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exe</td>
<td>Tried to ‘steer’</td>
<td>0.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exe</td>
<td>Too focused on mechanics</td>
<td></td>
<td>0.77</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prep</td>
<td>Worry technique</td>
<td>0.38</td>
<td>0.62</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prep</td>
<td>Helpless to stop poor shot</td>
<td>0.32</td>
<td>0.58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exe</td>
<td>Doubt technique</td>
<td>0.34</td>
<td>0.56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exe</td>
<td>Very aware swing movements</td>
<td></td>
<td></td>
<td></td>
<td>0.42</td>
<td></td>
</tr>
<tr>
<td>Prep</td>
<td>Poor shot choice</td>
<td></td>
<td></td>
<td></td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td>Exe</td>
<td>Doubt strategy</td>
<td></td>
<td></td>
<td></td>
<td>0.76</td>
<td></td>
</tr>
<tr>
<td>Prep</td>
<td>Poor club choice</td>
<td>0.74</td>
<td></td>
<td></td>
<td>0.41</td>
<td></td>
</tr>
<tr>
<td>Prep</td>
<td>Taking too long</td>
<td>0.33</td>
<td></td>
<td>0.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prep</td>
<td>Rushing</td>
<td></td>
<td></td>
<td></td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>Prep</td>
<td>Routine change</td>
<td></td>
<td></td>
<td></td>
<td>0.67</td>
<td>0.42</td>
</tr>
<tr>
<td>Prep</td>
<td>Mental overload</td>
<td></td>
<td></td>
<td></td>
<td>0.76</td>
<td></td>
</tr>
<tr>
<td>Exe</td>
<td>Too many thoughts</td>
<td></td>
<td></td>
<td></td>
<td>0.59</td>
<td></td>
</tr>
<tr>
<td>Prep</td>
<td>Imagery impaired</td>
<td>0.40</td>
<td></td>
<td></td>
<td>0.54</td>
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</tr>
</tbody>
</table>
Discussion

Analysis of normal and disrupted thought processes in preparation and execution produced several novel findings. First, self-focus during execution was recognised as an important explanation of past choking events. Second, evidence was obtained that some golfers represent distraction and self-focus as intertwined notions. Third, losses of trust in ability or commitment emerged as interesting rationalisations of choking. Relatedly, preparation was used by some golfers to build this trust/commitment. While a loss of trust in physical ability has been observed in past choking research (Gucciardi et al., 2010), a new finding was that lost trust/commitment sometimes referred to inability to settle on preparation choices before action. Fourth, many golfers, regardless of skill level, indicated some form of technical focus during execution (e.g., ‘getting backswing and bodyweight set correctly’). Like several past qualitative studies of choking, various distractions were observed as key rationalisations of failure, along with psychophysiological changes (e.g., muscle tension) and behavioural changes (e.g., rushing) under pressure.

Normal thought processes

Visualisation was commonly used in driving preparation (75% of golfers) and putting preparation (74% of golfers). Generating images of the desired result and a representation of how to achieve that result (e.g., the rehearsal of swing feelings) appear to be two important ways that golfers prepare across skill levels. Visualisation in sport is well established and has permeated coaching and applied sport psychology (Martin, Moritz, & Hall, 1999; Orlick & Partington, 1988). Visualisation effectiveness (not assessed in this study) might vary with skill level. Previous research suggests that better performers might attain clearer images (Vealey & Greenleaf, 2001) or entertain more motivational content (Callow & Hardy, 2001). A target or intermediate target focus (in driving and putting) was common and favoured by better golfers. This might reflect a tendency among more skilful golfers to bias their
processing towards their goal, while letting their skills do the rest. This is consistent with a long-held view that attention is deployed to higher-level mental representations with practice (e.g., Vallacher & Wegner, 1987) and evidence that expert golfers bias their preparatory attention towards features that allow programming the force and direction of putts, such as the target (Cooke et al., 2014).

Technical thought was widespread in normal execution thought processes. Approximately half the sample indicated a club focus during driving (50%) and putting (53%). A bodily focus was equally popular for driving (53%), but less prevalent for putting (28%). This difference could reflect the more complex body sequencing required for driving (i.e., coordination of lower and upper body). Skill level was unrelated to club or bodily attention although there could be unmeasured differences in how more accomplished golfers organise the technical information (e.g., via chunking). The results fit with broader evidence that skilled athletes effectively use part-process cues (e.g., Maurer & Munzert, 2013). This does not mean that focusing on technique is optimal or necessarily helpful; its acceptance may simply reflect popular teaching methods (Rotella, 2007). Notwithstanding, functional use of part-process cues sits uncomfortably with self-focus theories. This is especially true for Reinvestment, which directly blames choking on a technical focus. As such, the current study reinforces that self-focus theories lack detail on which explicit thoughts are damaging and which are manageable (see also Christensen et al., 2016; Toner et al., 2016; Winter et al., 2014). Several factors are presumably at play. One is how much explicit thought is actually used (conversely, how much of the action can run autonomously). A basic but easily assessed proxy for this dimension is how many cues a golfer seeks to focus on throughout the swing. Elite golfers typically seek to minimise this number (Jenkins, 2007). Another variable is whether or not the explicit thought is wanted or perceived as useful. An unsolicited thought may trigger negative evaluation, and this could trigger some influence over the movement
(e.g., due to hesitation or correction). If the thought is sanctioned (e.g., approved by a coach), the performer may avoid interference. Relatedly, the extent that the athlete applies some judgment on the correctness of the action is also a potential factor. One golfer illustrated this issue with, ‘If I take the club away some other way than what's ‘normal’ it breaks my zone and I become conscious’. A negative judgment of the initial action could motivate conscious correction. This issue is revisited in chapter 6.

**Disrupted thought processes**

**The frequency of self-focus.** Like previous work (e.g., Oudejans et al., 2011), the current data supports that distractions and choking are popularly associated. A novel finding was that references to self-focus increased (in open-ended responses) when golfers specifically considered pressure-related failures in execution. Furthermore, when offered theoretically relevant forced-choices, two indications of conscious intervention (*steering the ball* and *very aware of swing movements*) were popularly associated with choking. That is, more than 60% of the sample rated these issues as quite or very important reasons for past chokes. The fact that general probing of past choking events did not reveal (and has not previously revealed) self-focus-based attributions suggests that conscious processing of the execution is less salient than certain distractions throughout the experience. This might be because the timeframe of the execution phase is narrow or because execution thought is represented differently, for example as an ‘action gist’ (Christensen et al., 2016). It may also be because execution thought is challenging to describe or recall, given its relatively implicit nature. However, failure via self-focus is definitively conscious, so it should be verbalisable. Another reason why skilled sportspeople perhaps disregard self-focus (or at least Reinvestment) as an explanation for choking is that a technical focus is relatively normal (see the previous section). These possibilities aside, the present data indicates that if athletes
consider mental changes during execution, self-focus is likely to be a more common attribution.

**Rushing and loss of routine.** A majority of surveyed golfers (~59%) believed that rushing their preparation was a quite or very important reason for their past choke. The problem of rushing has precedence in published work. Gucciardi et al. (2010) and Hill et al. (2010b) both reported that some golfers associated rushing with past chokes. Additionally, observational research on soccer has shown that players with shorter preparation times are less successful (Jordet, 2009). Relatedly, there is evidence that elite rugby goal kickers concentrate for longer under pressure (Jackson, 2003). Jordet (2009) suggested that a rushed preparation might reflect a desire to escape an uncomfortable situation. Rushing the execution to escape discomfort is similarly plausible. For example, one of Hill et al.’s (2010b) choking-susceptible golfers described rushing the execution as a way to escape from distress (p.226).

**Psychophysiological changes.** Some golfers associated choking with physiological changes, such as elevated heart rate or increased muscle tension (n=11 in preparation; n=12 generally). This affirms similar findings in other qualitative choking studies (Gucciardi et al., 2010; Hill et al., 2010b; Oudejans et al., 2011). However, there is significant doubt that elevated physiological arousal (even to high levels) can actually explain choking, since performance in aiming tasks can be maintained in this state if cognitive effort is increased (Vickers & Williams, 2007). Relatedly, there is also doubt that decreased arousal can explain good performance. For instance, expert putters generally exhibit a large heart-rate deceleration, relative to novices, in the seconds before initiating the action (Neumann & Thomas, 2009) – however, the extent of the deceleration does not necessarily signal better putting outcomes (Cooke et al., 2014). A negative interpretation of arousal (and thus secondary arousal) might be necessary for the athlete to become overwhelmed (Hill et al.,
Changes in muscle tension may be a more informative variable. A sensible (yet often overlooked) model of choking is that pressure triggers muscle tension which inhibits the smooth execution of the motor action. Supporting this idea, Cooke, Kavussanu, McIntyre, and Ring (2010) observed that increased muscle activity in extensor carpi radialis muscle (leading to a tighter grip) contributed to inferior putting performance. Similar effects could occur in the full swing. There is also some evidence that covert changes to psychophysiology can explain choking. For example, alpha power fluctuations before execution are known to signal putting performance (Babiloni et al., 2008). Examinations of gaze-behaviour also suggest that pressure (and anxiety) can trigger more scattered fixation patterns and less target focus (e.g., Wilson, Wood, et al., 2009).

**The relatedness of self-focus and distraction**

Choking was robustly attributed to distractions throughout the study. Distraction-based rationalisations were similar in the general choking enquiry and the in-execution choking enquiry (approximately 60%). Forced-choice data targeting the preparation indicated that worry about the upcoming shot (and consequences), worry about ability to play the shot and worry about technique to play the shot were widely considered problematic. Additionally, a switch in attention from the current shot to the outcome during preparation was the most frequent concern obtained from the free-text data. Similar problems with outcome-focused thinking have been noted in previous work (Gucciardi et al., 2010).

Notwithstanding the popularity of distraction-based attributions, the relevant point for choking theorists is if the outcome focus is itself fatal, or if it triggers conscious involvement or other issues. Some of the present findings offer additional detail.

Distraction theorists could argue that a golfer who is worried about the outcome (or an ability to achieve the outcome) is distracted and has probably missed crucial task-relevant information. However, self-focus theorists could argue that a natural response to worrying...
about the outcome would be conscious attention or split-second mechanical adjustment (e.g.,
rushing or calibrating the action). Regarding the latter, factor analysis suggests that the
sample connected worry and self-focus. The worry → self-focus and the worry →
reinvestment factor absorbed the most variance in importance scores. Both factors imply
some blending of the theoretical mechanisms, where concern about an outcome or ability to
achieve an outcome is connected to exercising control over the action. Baumeister’s (1984)
original self-focus proposal alludes to this idea. He proposed that increased awareness of the
importance of correct execution encourages attempts to carefully process the execution.

Content analysis revealed that some golfers attributed choking to a loss of trust or
commitment to their swing (n=10). A number of golfers further indicated that a goal of their
preparation was to build commitment or trust (n=11 for driving; n=18 for putting),
presumably to ensure appropriate application to the execution. In putting, this strategy was
usually adopted by better players. Two related preparation strategies were thought reduction
methods (n=10 for driving; n=9 for putting) and outcome focus reduction (n=10 for putting);
also presumably designed to allow uninterrupted execution. Losses of trust or commitment
could support either distraction or self-focus. On one hand, a lack of trust/commitment could
imply negative off-task thinking (e.g., worry about a choice made or the likely results) and
loss of devotion to the task, for example, ‘harder/takes longer to commit to deciding on
shots’. On the other hand, a lack of trust/commitment could imply conscious impedance
throughout the swing, for example, ‘the inability to trust my swing and then try to correct
based on overthinking’. The results of the survey suggest that self-focus and distraction may
be represented in an integrated way rather than as competing concepts.

A second potential implication of worrying about the outcome is premature attention
to the result before the action is completed (e.g., lifting the head to see the result of a putt
before completing the stroke). In the published literature on choking, exactly how task-
irrelevant thought leads to motor-skill failure is often ill-defined (see chapter 2). At a perceptual level, a clear hypothesis exists. Examiners of covert visual processes have argued that reduced visual focus on task-relevant elements leads to inadequate motor planning (e.g., Nieuwenhuys & Oudejans, 2012). At the psychological level, the specifics are not obvious given that task-irrelevant thought and good performance can co-exist (e.g., Gray, 2004). Prematurely attending to the result is one way that failure could occur via distraction. Several golfers described keeping their heads down or staying down in order to complete the action before viewing the result, for example, 'watch the ball with head down until after execution of the shot'. Furthermore, some golfers specified the consequences of premature attention to the results, for example, 'don't maintain posture due to eagerness to see the result' or 'didn’t...hit through the ball (thought of pulling the shot) which means I come out of the shot which leaks right'. The latter examples highlight how preoccupation with the outcome (i.e., distraction) could convert to motor-skill failure via a mechanical change. This possibility is revisited in chapter 6.

**Limitations, future research and intervention possibilities**

The current survey methodology was advantageous because it enabled triangulation of open and closed data obtained from numerous golfers. However, even richer data could be obtained by interviewing athletes. For example, future work could use a grounded theory interview approach (Corbin & Strauss, 1990; Gucciardi et al., 2010; Hill et al., 2009) to gather more detail about pressure-affected thinking in preparation and execution. A further limitation of the current work is the potential inaccuracy of reports, given that recalled events were from an unspecified time in the past and that memories can distort over time (Ericsson & Simon, 1980). A specific concern is that emotional content, such as past choking episodes (Hill et al., 2009) can be shaped to preserve current beliefs (Ochsner & Schacter, 2000). Accurate recall of rapid execution moments might be especially challenging. To address this
in future, researchers might ask golfers to announce their thoughts immediately after shots have been taken under low and high pressure (i.e., think aloud protocols), and assess any differences. Nicholls and Polman (2008) found this to be a useful approach to capture golfers’ in-game coping strategies.

One problem with using self-report data as evidence for self-focus and distraction theories is that it assumes that athletes can judge how they distribute their attention. To date, there is no demonstration (to the author’s knowledge) that this is a safe assumption. Some aspects are more observable than others. For example, verifying that an athlete has rushed, slowed or lost consistency is verifiable, yet only one study has considered this issue. Jackson and Baker (2001) found that an elite rugby goal kicker’s perception of temporal consistency was not supported by observational data. If athletes do lack insight into their preparation speed and consistency, this may be worth raising in cognitive interventions. For example, this finding could allow to the practitioner to challenge secondary worry created by a faulty perception of rushing, or generally challenge that an athlete’s negative self-perceptions are always credible. Alternatively, demonstrating that athletes accurately perceive their preparation behaviours would be a step towards validating existing self-report data.

Understanding golfers’ belief systems is informative for practitioners, independent of their accuracy. In part this is because the golfers’ self-perception probably contributes to their failures (e.g., Bandura, 1977; McAuley, 1985). For example, a golfer who feels overloaded, rushed or too focused on the outcome has a problem, regardless of actual cognitive capacity, speed of play, and direction of focus. In theoretical terms, this is because they have lost contact with a relevant focus (i.e., distraction), because conscious intervention is becoming more likely (i.e., self-focus) or both. Moreover, a golfer’s current rationalisation of past events is relevant because future interpretations and actions could be affected (Gucciardi et al., 2010). In this regard, the current data provides some useful information for the
Evidence that worry about the outcome and steering are sometimes paired (the worry → self-focus factor) is instructive. Practitioners may consider challenging the assumption that steering, hesitation or loss of commitment (or other similar concepts) is a necessary consequence of worry, and simultaneously develop the attitude that worry can coexist with determined action. This idea is embodied in Acceptance and Commitment therapy approaches to sport (e.g., Bernier, Thienot, Codron, & Fournier, 2009; Gardner & Moore, 2012) which involve modifying the performer’s relationship with negative thoughts (i.e. acceptance) while encouraging devotion to a relevant focus (i.e., commitment). A second factor identified in the study – the poor decision → distraction factor – is also potentially instructive. The factor reflects an inability to trust or commit to decisions made (also often raised in open-ended content). To address the issue, the practitioner could develop strategies to assist the performer fully invest in choices made before the shot. One existing approach for golfers is called think box, play box (Marriott & Nilsson, 2011). Under this method, the golfer is instructed to complete all cognitive activity before a cue (e.g., crossing an imaginary line) that marks a switch to a more instinctive approach until shot completion. That is, the cue signals the switch from the think box to the play box.

**Concluding remarks**

The study sought to gather information from golfers of varied skill levels to map normal and disrupted processes in preparation and execution. The results provide the first evidence that golfers (in general) believe that self-focus is an important concern. The data also indicates that some golfers subtly blend self-focus and distraction, suggesting that both mechanisms could operate leading up to and during a single skill execution. This finding contrasts the traditional views that a) only self-focus or distraction could operate, b) self-focus and distraction harm different kinds of skills (e.g., cognitive vs. automated) or c) self-
focus and distraction affect different people. Future research could isolate preparation and execution in a deeper manner, using interviews, to obtain richer detail about these matters.

In this chapter, a gap in the qualitative choking literature was addressed. In the next chapter, the focus shifts again to the observational study of choking in self-paced sport and the goal of identifying the behavioural correlates of pressure and choking. It is proposed that observational studies of pressure and choking, to date, have not been comprehensive. Primarily this is because the steps of a) observing baseline behaviour, b) observing changes under pressure and c) directly connecting those changes to performance have not all been undertaken in the same study. Accordingly, a study is introduced in the next chapter that addresses all these aspects.
Chapter 5 – Study 3. Observations of preparation timing and physical behaviour under pressure

‘Collect the info. Create a plan. Connect to a feeling. Go.’

A golfer from this thesis, on preparing for a shot.

In chapters 3 and 4, discussion centred on how compromised attention during preparation and execution could independently or collaboratively explain choking. In this chapter, the investigation of pressure-related impacts in preparation is expanded to consider a) how pressure (or associated anxiety) influences preparation behaviour (e.g., preparation timing or characteristic movements) and b) whether or not a change in behaviour under pressure reliably signals a change in performance (e.g., choking). In situating this work, past studies are described that have addressed the association between preparation timing/behaviour and performance, but without considering pressure. Other similar work is described that has considered timing under pressure, but without a baseline, or without directly examining performance impacts.

Pressure, behaviour and choking

An attractive idea in sport psychology is that an athlete’s non-verbal behaviour before an action might be used to predict the outcome. The notion seems especially feasible if the performer is anxious, because observers can identify the presence and intensity of anxiety via hand, facial, and torso positions (Waxer, 1977). Moreover, non-verbal behaviour can reveal how well a sportsperson is performing. For example, body language alone is enough for naïve observers to identify a leading or trailing player (Furley & Schweizer, 2014). Thus, it seems reasonable that athletes under pressure might exhibit behaviours before execution that exposes their mental state and signals upcoming performance. In turn, precursors of success under pressure and failure under pressure (i.e. choking behaviour) could be identified. Such a
development would allow practitioners and coaches to raise awareness and usefully intervene in maladaptive processing. The solution, if identifiable, is unlikely to be simple. Anxiety can positively or negatively affect performance and is multidimensional (e.g., Hardy, 1996). Although some researchers have examined if pre-performance behaviours can signal upcoming performance and others have examined if pressure influences behaviour, an observational study is yet to examine comprehensively if behavioural changes under pressure can predict performance.

In the study of the behaviour-performance link, self-paced sports have been a natural focal point. One reason is that preparations in these fields are slow and easily observed. Another is that skilled performers often prepare in a regimented form (i.e., they employ a PPR) such that abnormalities might stand out. A PPR tends to be idiosyncratic (Cotterill, 2011), but there are a few classic elements. For example, relaxing (e.g., deep breathing), visualisation (e.g., visual or kinaesthetic imagery), and cuing (e.g., a keyword to trigger action) are frequently recommended in the sports psychology literature (Boutcher & Rotella, 1987; Cohn, 1990; Cotterill, 2011; Hazell, Cotterill, & Hill, 2014; Mesagno & Mullane-Grant, 2010; Singer, 1988)

**Consistency or flexibility**

A widespread view among sport psychologists and researchers is that preparation for self-paced sport should be consistent (Cotterill, 2010). The word ‘routine’ alone instructs this. The classical position is that the PPR, although individual, should be completed invariantly once developed (e.g., Boutcher & Rotella, 1987). This is logical since the performer can apply the same task-relevant process regardless of arbitrary context (e.g., the importance of the occasion). Perhaps reflecting the view of coaches, psychologists and mentors, self-paced athletes also appear invested in the importance of consistency. For example, both Gucciardi et al. (2010) and Hill et al. (2010b) reported that golfers attributed choking under pressure to
rushing their routine. Similarly, in chapter 4, rushing was also generally assessed as problematic.

Empirical evidence demonstrating the value of consistency is equivocal. Early observational work with golfers showed that skilled performers prepared with greater behavioural consistency than novices (Boutcher & Zinsser, 1990). Other work has demonstrated that among elite golfers, better performers are more consistent (Crews & Boutcher, 1986). Considering basketball free-throws, Wrisberg and Pein (1992) found that athletes exhibiting greater temporal consistency (i.e., lower variability in their preparation times) were more likely to make shots. However, Lonsdale and Tam (2008) determined that behavioural consistency, rather than temporal consistency, predicted free-throw success. They showed that those players following a dominant behavioural sequence (e.g., the same number of breaths taken, ball bounces, ball spins and so on) tended to do better. Contrasting the consistency hypothesis, other research suggests that preparation flexibility is sensible for skilled performance. In a case study of an elite rugby goal kicker, Jackson and Baker (2001) split the PPR duration into two intervals: physical preparation time (walking back into kicking position) and concentration time (the action-free period between completion of physical preparation and the initiation of action). Both physical and concentration intervals increased with shot difficulty (i.e., a global increase in preparation time). Jackson (2003) replicated this finding with more players. The results suggest that a PPR timing adjustment commensurate with task demands, rather than rigid consistency, might be appropriate.

**Considering pressure**

A small group of observational studies have considered the behaviour-performance link under pressure. Jordet and Hartman (2008) and Jordet (2009) both observed an association between faster preparation times and inferior penalty kick performance in the soccer World Cup finals (clearly a high pressure situation). To explain the effect, Jordet and
Hartman (2008) argued that an anxious player’s desire to escape a mentally uncomfortable situation might trigger a faster preparation – and that this avoidance caused the performance decline. However, in both studies, baseline times were not reported so it is not clear that players actually sped up. In another relevant example, Jackson (2003) compared concentration and physical preparation times of rugby goal kickers at different moments during international games. Shots taken when the game score was close (0-3 points) and after half time (i.e., relatively high pressure kicks) had longer concentration times than shots taken in more one-sided situations after half time (≥4 points). This suggests that some flexibility under pressure is normal for elite performers. Jackson did not report the relationship between longer concentration intervals under pressure and shot performance, so it is unknown if there was any association between this temporal flexibility and the outcome. In the laboratory, Wilson, Smith, et al. (2007) observed the preparations of mid-handicap golfers as they prepared under low and high pressure conditions. They found that golfers had longer preparation times and more target glances under pressure but did not directly relate these changes to performance. That is, separate analyses were conducted on performance and behaviour change.

In summary, some observational studies have considered the statistical relationship between a) preparation behaviour and performance and b) pressure and preparation behaviour; however, complete examinations of the pressure-behaviour-performance link are absent. A complete examination would measure individual timing and physical behaviours, compare these measurements between moments of relative pressure, then correlate any changes with performance. These steps were taken in the current work.

**Applying theory**

Observational work on the behaviour-performance link has often been atheoretical. However, evidence of flexible preparation under pressure without performance decline is
consistent with two theories of performance under anxiety: PET (Eysenck & Calvo, 1992) and its later redevelopment, ACT (Eysenck et al., 2007). Under both theories, anxiety has a deleterious effect on the available task-focused resources, however, this compels the performer to expend effort towards recruiting more resources. This process is referred to as compensation. If the performer can recruit sufficient resources, performance will be preserved (i.e., successful compensation), otherwise it will deteriorate (e.g., choking). Compensation is thought to manifest in various ways. In reading comprehension, longer processing times and repeated glances at previous text are two identified forms (Calvo et al., 1994). Similarly in golf, longer preparation times and extra target glances are two potential manifestations (Wilson, Smith, et al., 2007).

The present research

This work was co-conducted with research reported in chapter 3 and involved the same 24 golfers of advanced standard (handicap <=6). Prior to data collection, ethics approval was obtained from the RMIT College Human Ethics Advisory Network (Appendix XV). The participants completed all conditions described in chapter 3 (i.e., a control condition and four interference conditions). In addition, the study was concluded with a pressure condition (explained under procedure). Temporal/physical behaviours and corresponding golf shot accuracy were compared across the control condition and the pressure condition.

Research questions and hypotheses

The study had two principal research questions. The first was: How does pressure influence golfers’ preparation timing and behaviour? Based on the predictions of PET and ACT, it was hypothesised that a) compensatory behaviour would be observed under pressure (e.g., longer preparations and more glances toward the target) and that b) golfers most affected by pressure (i.e., those with more state anxiety) would compensate the most.
Simultaneously, the research also considered the extent and manner that behavioural change would occur across less and more difficult shots. Given Jackson’s (2003) observation of temporal flexibility in rugby goal kicking preparation, the corresponding hypothesis was that golfers would lengthen their preparation when faced with more difficult shots. The second principal research question was: does pressure-induced behavioural change predictably signal performance change? Based on PET and ACT, the hypothesis was that performance would decline predictably under pressure only when compensatory behaviours were not undertaken.

Method

Apparatus

Footage was captured with a go-pro Silver 4 (frame rate: 50fps), placed directly behind the golfer. The golf simulator is described in chapter 3.

Procedure

The control condition always preceded the pressure condition. Due to counterbalancing (see chapter 3), the gap between control and pressure conditions varied between golfers. For example, control and pressure could have occurred sequentially (i.e., position five and six in the sequence), or up to five conditions later (i.e., position one and six in the sequence). The influence of this gap was accounted for in the analysis by considering the number of interleaving conditions as a fixed factor in the modelling (described under data analysis). The same general procedure was adopted from chapter 3 in both conditions (i.e., 10 shots were executed from 60-150m in a random order). To mark the beginning of each trial, golfers were prompted by the experimenter to turn around and face the screen. This demarcation allowed the measurement of the preparation duration. At the beginning of the study, golfers were asked to carry out their normal routine before each shot. To assess state anxiety, the CSAI-2R (Cox et al., 2003 - described in chapter 3) was administered at the
beginning of the experiment, then again immediately after the introduction of the pressure condition.

**Control.** Golfers prepared and executed the 10 shots with no interference or application of pressure.

**Pressure.** To create a pressure effect, participants were entered into a competition with other participating golfers in which the winner would have the lowest average error from the target (i.e., radial error) after the 10 shots. Monetary prizes (vouchers of the players’ choice) were offered for the top four places in the following denomination: $175 for first, $125 for second, $80 for third and $50 for fourth. Several studies have created competition between participants to increase pressure (e.g., Gray & Cañal-Bruland, 2015; Gucciardi & Dimmock, 2008). To enhance the feeling of competition, a leader-board was displayed on a 50 inch television monitor adjacent to the golfer. Leader-boards have been used elsewhere to create pressure in experimental settings (e.g., Wilson, Smith, et al., 2007). Participants were informed that the final winning scores of the competition were unknown (i.e., because the experiment was ongoing) but that simulations of the likely winning scores had been produced. To generate the simulations (not explained to golfers), scores from pilot testing with a golfer of equivalent skill were bootstrapped (random sampling with replacement) and the best four scores were taken. Figure 5.1 shows the display presented on the monitor. On each trial, the shot error was entered such that golfers could track their progress relative to the prize-winning scores. For clarity, golfers were reminded that keeping their error line below the top four lines was ideal. Ultimately, the simulations appeared suitable and were narrowly out of reach for most golfers (only one golfer had a lower score than the simulated first place). Using projected scores allowed an equal application of pressure across participants. If actual scores had been used, the first and last golfers, for example, would probably experience a different amount of pressure. Projection of a threshold score is also realistic to
golf competition. Golfers are often highly aware of the likely ‘cut’, qualification score or competitive total, and are known to adjust their behaviour accordingly (Hood, 2008). To boost evaluative pressure, golfers were explicitly told that the goal of the condition was to assess their ability to hit the ten shots in competitive circumstances. This direct approach also has precedent in research on choking (Otten, 2009).

![Projected leader-board displayed adjacent to golfers during the pressure condition. Participant’s running average was updated each shot.](image)

**Figure 5.1.** Projected leader-board displayed adjacent to golfers during the pressure condition. Participant’s running average was updated each shot.

**Measures**

**Timing.** Preparation time was split into an *Information Collection Interval* (ICI) and a *Representation Interval* (RI). The beginning of the ICI was the moment that the golfer turned to face the screen (i.e., when they identified the distance of their next shot). The end of the ICI was the moment that the golfer completed their final screen look before execution. The interval captured the period within which visual information about the distance and target was collected. The beginning of the RI was the end of the ICI. The end of the RI was the
initiation of the motor action. The RI signified the time that the golfer spent looking at the ball, while presumably mentally representing the information collected earlier. This split-timing approach followed Jackson and Baker (2001), who divided preparation time for a rugby goal kick into a physical preparation interval (the time spent stepping away from the ball) and a concentration interval (the time spent motionless, looking at the ball and target). Physical and concentration intervals were unsuitable for this study because golfers often used settling-type movements up until execution. That is, physical preparation in some form continued throughout the whole preparation. Splitting the preparation timing is a sensibly detailed step to discover subtle (yet observable) changes in behaviour yet to clearly surface from less granular measures (e.g., overall preparation time). Timings were calculated directly from the video record.

**Dominant Routines.** The early analysis approach was to identify the dominant pre-shot routine for each player, then assess the consequences of deviation from that routine. Following Lonsdale and Tam’s (2008) analysis of basketball free throws, a dominant routine was defined as a set of behaviours that were repeated in the majority of control condition trials (i.e., more the 50% of trials). However, this approach was ultimately discarded because most golfers exhibited built-in preparation flexibility. Thorough observation of all golfers’ preparations in the control condition found only seven with a classifiably dominant routine (i.e., an approximately ordered set of behaviours repeated on more than half the control trials). For most golfers, some variability existed in the number of behaviours (e.g., one or two distinct club lift movements or one or two practice swings) or in the order of behaviours. Accordingly, a more detailed approach was adopted (described below) to include more golfers in the analysis. To address the value of consistency versus flexibility, the performance of the seven dominant-routine golfers and remainder of the sample was briefly assessed.
**Behaviour Counts.** Individual behaviours were observed (on video) then classified by a golfer of equivalent standard to the participants. In the first step of the classification, all videos were viewed, then notes were taken about each golfer’s typical behaviours. These typical behaviours were then defined. For example, a ‘club lift’ was defined as a ‘distinct vertical elevation of the club at address and re-placement on the ground’. To accommodate the behavioural idiosyncrasy of the golfers into a meaningful analysis, behaviours were then grouped in higher-order categories. For example, waggling the club laterally and raising and lowering the club vertically were grouped as ‘settling behaviours’. This captured the comfort-seeking nature of these behaviours – and because almost every golfer exhibited some form of settling – allowed a more complete analysis of the data.

The grouping process converged on the following four categories. **Screen looks** captured discrete looks at shot information in the upper left of the screen or at the virtual target (roughly the middle of the screen). **Settling behaviours** captured re-taking of the stance, the distinct lifting of the club or waggling of the club. **Rehearsal behaviours** captured practice swings or practice takeaways (shorter versions of the practice swing). **Loosening behaviours** captured stretching of the arms, rolling the shoulders, or loosening the shirt. Category counts were compared across the control and pressure conditions. Analysis of each behaviour group only included golfers who regularly exhibited that tendency. ‘Regularly’ was defined as performing the behaviour in at least half of the control conditions trials. All golfers regularly undertook screen looks (n=24), whereas a subset regularly exhibited settling behaviours (n=23), rehearsal behaviours (N=10) and loosening behaviours (N=8). To assess count reliability, an experienced academic in the sports analytics field also tallied the four behaviour group counts on a semi-random subset of trials (12.5% of the full dataset), arranged such that an equal number of control and pressure trials were rated. The inter-rater reliability correlation between counts was high (r=0.91).
Data Analysis

**Missing data.** On occasions, an interruption prevented a normal preparation (e.g., a ringing phone or a participant speaking to the experimenter). For these reasons, 22 trials were discarded (5%), leaving 458 trials for timing/behavioural analysis (95%). Additionally, the simulator occasionally produced implausible measurements (misreads); for example, an impossible shot distance or unlikely ball flight (discussed in chapter 3). For these reasons, a further 12 trials were discarded, leaving 446 trials for behavioural-performance analysis (93%).

**State anxiety.** Changes in CSAI-2R Cognitive and Somatic anxiety subscale scores from baseline to pressure introduction were assessed using separate paired-samples t-tests.

**Modelling preparation timing and performance.** Mixed-effects linear regression was employed to separately model a) preparation timing and b) the link between timing changes and radial error. Justification for using mixed-effects modelling is detailed in chapter 3. The principal advantages were the ability to analyse every available trial, appreciate individual differences with individual regression intercepts and/or slopes, conveniently negotiate missing data and expediently account for relevant covariates.

Two timing models separately evaluated predictors of the ICI and the RI. A further two performance models quantified the association between ICI/RI and radial error. The first performance model assessed the general influence of timing upon radial error. The second specifically assessed if a change in timing attributable to the pressure manipulation affected radial error. In all timing/performance models, the participant was treated as a random variable (i.e., each golfer had an intercept and/or slope). Timing and performance modelling was conducted with R’s *lme4* package (Bates et al., 2015). In arriving at the reported models, several models were trialled by piloting theoretically relevant fixed factors (e.g., distance,
condition gap and cumulative error). Models with the best fit under the Bayesian Information Criteria (BIC) were reported. Condition and cognitive anxiety (CA) were always included to examine the importance of the manipulation. Somatic anxiety was not modelled because this component was unaffected by the pressure manipulation (see results). All continuous variables included in the models (e.g., shot distance) were mean-centred (at the overall level) to improve intercept interpretability (e.g., shot distance for a given trial less the study’s mean shot distance).

For timing models and the first performance model, CA was first mean-centred at the person level. This allowed assessment of whether or not an individual change in CA due to pressure was associated with timing or performance changes. As an example, take a golfer with a baseline-CA score of 14 and a pressure-CA score of 18 (mean=16). This golfer would have a person-centred CA value of -2 entered against all control condition trials (i.e., 14-16) and a person-centred CA value of +2 entered against all pressure condition trials (i.e., 18-16). Thus, the model examined the effect of within-subjects CA variability attributable to the pressure manipulation, without influence from between-subjects variability (e.g., especially high or low CA scores) – improving its interpretability. The use of within-level centering (e.g., observations within participants) in mixed-effects models to obtain meaningful zero points is a recommended approach (e.g., Enders & Tofighi, 2007). In the second set of performance models, the CA change score from control to pressure was used, which is person-centred by definition.

Plots of fitted vs. residual values (see Appendices VIII to IX) were produced to assess systemic problems with the model fit (Gelman & Hill, 2007). The plots were largely unproblematic. Minor violations were improved by transforming the dependent variable (using square root, log+1, or reciprocal scaling). Doing so did not influence the interpretation of results, hence, untransformed figures are reported. Due to the uncertainty in estimating the
number of degrees of freedom in mixed-effects models (Baayen et al., 2008, also see chapter 3), the significance of predictors is not reported. Coefficients more than twice the size of the standard error were treated as credible predictors in the model and interpreted accordingly. Regression coefficients meeting this standard are bolded in the reported tables (with their standard errors reported in parenthesis).

**Current performance.** The cumulative average (radial) error at any given trial in a given condition was incorporated into both timing models. This served to indicate the current level of performance in the condition and, heuristically, engagement with the task. The proposed logic of this measure is that a golfer performing well is unlikely to lose interest. On the first trial of a condition, the cumulative error value was set to zero. Thereafter it was calculated as the average error of the preceding trials. For example, to predict timing on the fifth trial, the value modelled was the average cumulative error after four trials. Cumulative average error was also mean-centred at the person level to offset undue influence from any particular golfer’s performance (i.e., the cumulative error on a given trial less the golfer’s mean cumulative error).

**Compensation.** Golfers were split into those who increased their mean ICI in response to CA (compensators) and those who did not (non-compensators). Specifically, golfers were classified as compensators if they had elevated CA under pressure and had a higher average ICI under pressure (N=11). Golfers were classified as non-compensators if they had elevated CA under pressure, yet had lower or equivalent average ICI under pressure (N=3). The remaining golfers (N=10) reported the same level of CA at control and pressure (i.e., were unaffected by the manipulation). Mean radial error was then compared between the two groups with an independent samples t-test. RI was not examined in the compensation analysis due to a lack of association with CA (see Results).
Behaviour Change

**Global judgement.** To make a qualitative assessment of behaviour change from control to pressure, a rater judged the sameness of preparation (i.e., as ‘same’ or ‘different’) across same-distance trials in the control and pressure condition. Shots from 110 metres were compared because this was approximately the median distance and the behavioural dataset was complete. A second comparison was made within the control condition to obtain baseline variability. Since distances were not repeated within a condition, baseline comparisons were made between the 110m shot and either the 100m shot or 120m shot (selected at random). For each comparison, the rater viewed a video the first preparation on one screen, then a video of the second preparation on a second screen immediately after. Their task was to make a binary judgement about the sameness or difference of the preparation. They were allowed two viewings to make their choice. A preparation was judged as the *same* given no significant visible change from one trial to the next (or on the repeat viewing). A significant visible change was determined when, for example, there was an extra practice swing, an extra look at the target or an obviously longer deliberation. The proportion of shots judged as different in the baseline comparison and the control-pressure comparison was contrasted to assess behaviour change. A second rater judged the sameness of 25% of the comparisons. The sameness criteria was shared between raters. Inter-rater concordance was high (83%).

**Physical behaviour counts and performance.** Mixed-effects Poisson regression was used to model physical behaviour counts. Separate models were computed for each behaviour. Mixed-effects linear regression quantified the relationship between behaviour counts and radial error. Two sets of performance models were produced to predict radial error. The first set assessed the general relationship between behaviour counts and radial error. Separate models were needed to assess each behaviour’s influence on radial error because different subsets of participants regularly undertook each behaviour. Person-centred
behaviour counts were used to predict radial error (e.g., screen look count in a given trial minus the golfer’s mean screen looks). This process prevented high or low individual counts from biasing the model’s predictions. The second set of performance models specifically examined if a change in the behaviour count under pressure influenced radial error. For all behaviour count and performance models, piloting of relevant fixed effects (judged using the BIC) was again undertaken. As with the timing/performance models described above, continuous variables were mean centred (with the grand mean) to improve intercept interpretability. Likewise, condition and CA and were always included to examine the importance of the manipulation. In the behaviour count models and the first set of performance models, CA was first person-centred to examine the effect of within-subjects changes. In the second set of performance models, the CA change score was used.

For Poisson models, standard fitted/residual plots are not diagnostic (i.e., quadratic structures are normally present). Poisson models assume that the mean and variance of the dependent variable (i.e., the count) are approximately equal (Mohebbi, Wolfe, & Forbes, 2014). To examine this property, dispersion tests were undertaken to test model suitability using R’s DHARMa package (Hartig, 2018, v2.0). The results indicated that the models built to predict screen looks and rehearsals were under-dispersed (see Appendix X) – that is, the variance of the dependent variable fell below the mean (e.g., Zhu, 2012). Under-dispersion is often a consequence of autocorrelation between counts (Kokonendji, 2014). In this case, autocorrelation could be due to, for example, each golfer taking a similar number of looks each trial. There are complicated methods to deal with under-dispersed repeated measure count data (e.g., Grunwald, Bruce, Jiang, Strand, & Rabinovitch, 2011) but these are not pursued here. With this caveat in mind, the Poisson models are reported. Regarding the performance models, plots of fitted vs. residual values (Appendix XI and XII) were again
largely unproblematic. Once more, minor violations were correctable with standard dependent variable transformation and did not impact the interpretation of results.

**Results**

**State anxiety**

Introduction of the pressure condition lead to a significant increase in cognitive anxiety, $t(23)=3.05, p<0.05$ and a non-significant change in somatic anxiety, $t(23)=-0.54, \text{NS.}$

**General performance**

Mean radial error was marginally lower in the pressure condition ($M=8.51, \text{SD}=6.58$) than the control condition ($M=9.25, \text{SD}=5.85$). A paired samples t-test confirmed that the difference was not significant, $t(23)=1.39, \text{NS.}$ The performance models described shortly corroborated this result. Across all trials, dominant-routine golfers ($n=7$) had slightly lower mean radial error ($M=8.26, \text{SD}=2.20$) than non-dominant-routine golfers ($M=8.95, \text{SD}=2.27$). An independent samples Welch’s t-test confirmed the difference was not significant, $t(9.20)=-0.65, \text{NS.}$

**Timing**

Both timing models are reported in Table 5.1. The ICI model was improved by varying each golfer’s slope and intercept. Shot distance improved the ICI and RI models and was retained in each case. Cumulative error improved the ICI model and was accordingly retained but harmed the fit of the RI model and was omitted. The gap between the two conditions was also trialled, but harmed both model fits and was omitted. The results indicated three subtle changes in timing due to situational factors. First, longer distance shots were typically met with longer ICIs and RIs. Comparing the shortest and longest shots (i.e., 60m and 150m), the model estimated that a golfer would lengthen the ICI by around 2 seconds and the RI by around 1 second (assuming the constancy of other factors). Second,
elevated CA signalled longer ICIs but not RIs. Other factors held equal, the ICI model estimated an extra 1.4 seconds of information collection time given a typical increase in CA from control to pressure (mean change for those reporting an increase was 7.6 points). Third, elevated cumulative error signalled lower ICI. Holding other factors constant, the model estimated that five additional metres of cumulative error would result in, approximately, a one second reduction in the ICI.

Table 5.1. Modelling of the ICI and RI.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ICI</th>
<th>RI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>16.0 (1.03)</td>
<td>4.15 (0.59)</td>
</tr>
<tr>
<td>Condition (pressure)</td>
<td>0.37 (0.66)</td>
<td>-0.13 (0.20)</td>
</tr>
<tr>
<td>Distance</td>
<td>0.02 (0.006)</td>
<td>0.01 (0.003)</td>
</tr>
<tr>
<td>CA (person-centred)</td>
<td>0.18 (0.09)</td>
<td>0.05 (0.03)</td>
</tr>
<tr>
<td>Cumulative error (person-centred)</td>
<td>-0.19 (0.04)</td>
<td></td>
</tr>
<tr>
<td>Random Effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept variance (standard deviation)</td>
<td>23.3 (4.82)</td>
<td>7.98 (2.83)</td>
</tr>
<tr>
<td>Slope variance (standard deviation)</td>
<td>5.03 (2.24)</td>
<td></td>
</tr>
<tr>
<td>Diagnostics (BIC)</td>
<td>2519.3</td>
<td>1898.3</td>
</tr>
</tbody>
</table>

Timing and performance

Timing-performance models are displayed in Table 5.2 and Table 5.3. In the first model (Table 5.2), ICI and RI was used to predict radial error. Both measures were mean-centred at the person level (e.g., the ICI on a given trial less the golfer's mean ICI) to prevent long or short individual times from biasing the model. The condition by centred ICI interaction and the condition by centred RI interaction were modelled to examine if a change in pressure affected how timing influenced performance. Condition gap harmed the model fit and was omitted. Shot distance was the only credible predictor and indicated that long shots
were more difficult (i.e., had lower accuracy). Centred ICI or RI did not credibly signal a change in accuracy. No interaction effects were found.

Table 5.2. Modelling of timing and performance.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Radial Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Effects</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>9.17 (0.58)</td>
</tr>
<tr>
<td>Condition (pressure)</td>
<td>-0.82 (0.63)</td>
</tr>
<tr>
<td>CA (person-centred)</td>
<td>0.08 (0.09)</td>
</tr>
<tr>
<td>ICI (person-centred)</td>
<td>-0.16 (0.14)</td>
</tr>
<tr>
<td>RI (person-centred)</td>
<td>-0.19 (0.25)</td>
</tr>
<tr>
<td>Distance</td>
<td>0.05 (0.01)</td>
</tr>
<tr>
<td>Condition: ICI (person-centred)</td>
<td>0.08 (0.18)</td>
</tr>
<tr>
<td>Condition: RI (person-centred)</td>
<td>-0.02 (0.35)</td>
</tr>
<tr>
<td>Random Effects</td>
<td></td>
</tr>
<tr>
<td>Intercept variance</td>
<td>3.70 (1.92)</td>
</tr>
<tr>
<td>Diagnostics (BIC)</td>
<td>2890.0</td>
</tr>
</tbody>
</table>

In the second model (Table 5.3), ICI change and RI change on same-distance trials in the control and pressure condition (i.e., timing differences between the most comparable trials) was used to predict radial error in the pressure condition. Distance improved the model fit and was retained. Condition gap harmed the model fit and was omitted. The results did not show a reliable association between ICI or RI change and radial error.
Compensation. Change in performance (mean radial error difference) from control to pressure was examined between compensators and non-compensators. Compensators (mean error change=−0.74m) performed relatively well in pressure condition compared to non-compensators (mean error change=2.35m). A Welch’s independent samples t-test on the change scores (equal variances not assumed) revealed a significant difference between the groups, t(7.46)=−2.52, p<0.05.

Behaviour change

Qualitative Change. Global judgment of baseline shots (110m vs 100/120m shots in the control condition) indicated that 15 of 24 shots had observably different preparations (63%). Global judgment of control-pressure shots (110m in the control condition vs. 110m in the pressure condition) indicated that 14 of the 24 assessed shots (59%) had observably different preparations. A McNemar’s Chi-square test (for repeated measures data) confirmed
that there were no significant differences in variability across condition, \( \chi^2 (1, N=24) = 0.11, \) NS.

**Behaviour count modelling (screen looks etc.).** The results of Poisson modelling are displayed in Table 5.4. Like the timing models, distance, cumulative error and the gap between conditions were trialled as fixed factors. Their inclusion harmed all fits; hence, they were excluded. No effects of condition or CA were found.

Table 5.4. Mixed-effects Poisson modelling of behaviour counts

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Screen</th>
<th>Settle</th>
<th>Rehearse</th>
<th>Loosen</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed Effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>1.00 (0.08)</td>
<td>0.78 (0.14)</td>
<td>0.26 (0.12)</td>
<td>0.43 (0.20)</td>
</tr>
<tr>
<td>Condition (pressure)</td>
<td>0.10 (0.06)</td>
<td>0.08 (0.07)</td>
<td>0.16 (0.14)</td>
<td>-0.23 (0.15)</td>
</tr>
<tr>
<td>CA (person-centred)</td>
<td>0.004 (0.01)</td>
<td>0.002 (0.01)</td>
<td>-0.01 (0.02)</td>
<td>0.005 (0.02)</td>
</tr>
<tr>
<td><strong>Random Effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept variance</td>
<td>0.09 (0.30)</td>
<td>0.40 (0.63)</td>
<td>0.04 (0.21)</td>
<td>0.23 (0.47)</td>
</tr>
<tr>
<td>Diagnostics (BIC)</td>
<td>1490.5</td>
<td>1376.5</td>
<td>492.8</td>
<td>456.2</td>
</tr>
</tbody>
</table>

**Physical behaviour change and performance**

Physical behaviour-performance modelling is reported in Table 5.5 and Table 5.6. In the first set of models (Table 5.5), interactions between condition and person-centred behaviour counts were modelled to test for differences in the behaviour-performance association across conditions. Condition gap harmed all fits and was omitted. Shot distance benefitted all models and was retained throughout. The results did not reveal effects of behaviour counts or associated interactions.
Table 5.5. Modelled association between physical behaviour counts and radial error (RE).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>RE (Screen)</th>
<th>RE (Settle)</th>
<th>RE (Rehearse)</th>
<th>RE (Loosen)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed Effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intercept</strong></td>
<td>9.22 (0.58)</td>
<td>9.09 (0.59)</td>
<td>9.16 (0.66)</td>
<td>9.92 (1.24)</td>
</tr>
<tr>
<td>Condition (pressure)</td>
<td>-0.84 (0.63)</td>
<td>-0.80 (0.62)</td>
<td>-0.73 (0.88)</td>
<td>-0.36 (1.22)</td>
</tr>
<tr>
<td>CA (person-centred)</td>
<td>0.05 (0.84)</td>
<td>0.06 (0.08)</td>
<td>0.09 (0.13)</td>
<td>0.05 (0.12)</td>
</tr>
<tr>
<td>Behaviour (person-centred)</td>
<td>0.11 (0.50)</td>
<td>-0.84 (0.51)</td>
<td>1.46 (1.24)</td>
<td>0.07 (0.74)</td>
</tr>
<tr>
<td><strong>Distance</strong></td>
<td>0.05 (0.01)</td>
<td>0.04 (0.01)</td>
<td>0.05 (0.01)</td>
<td>0.07 (0.02)</td>
</tr>
<tr>
<td>Condition: Behaviour</td>
<td>-0.23 (0.67)</td>
<td>0.41 (0.65)</td>
<td>-0.86 (1.62)</td>
<td>-0.19 (1.22)</td>
</tr>
<tr>
<td><strong>Random Effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept variance</td>
<td>3.68 (1.92)</td>
<td>3.88 (1.97)</td>
<td>0.98 (0.98)</td>
<td>6.82 (2.61)</td>
</tr>
<tr>
<td>Diagnostics (BIC)</td>
<td>2880.0</td>
<td>2749.8</td>
<td>1176.6</td>
<td>1064.0</td>
</tr>
</tbody>
</table>

In the second set of models (Table 5.6), the difference in physical behaviour counts on same-distance trials in the control and pressure condition was used to predict radial error under pressure. Condition gap harmed all fits and was excluded. Distance was added as additional fixed factor and improved the fit of each model. No effect of physical behaviour change was found.
Table 5.6. Modelled association between physical behaviour change and radial error (RE).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>RE (Screen)</th>
<th>RE (Settle)</th>
<th>RE (Rehearse)</th>
<th>RE (Loosen)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Effects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>8.32 (0.56)</td>
<td>8.16 (0.57)</td>
<td>8.54 (0.74)</td>
<td>9.91 (1.06)</td>
</tr>
<tr>
<td>Behaviour Count difference</td>
<td>-0.23 (0.36)</td>
<td>-0.26 (0.34)</td>
<td>0.37 (0.96)</td>
<td>-0.86 (0.60)</td>
</tr>
<tr>
<td>Distance</td>
<td>0.06 (0.01)</td>
<td>0.05 (0.01)</td>
<td>0.07 (0.02)</td>
<td>0.11 (0.03)</td>
</tr>
<tr>
<td>Cognitive anxiety change</td>
<td>-0.02 (0.09)</td>
<td>-0.02 (0.09)</td>
<td>0.05 (0.14)</td>
<td>-0.09 (0.12)</td>
</tr>
<tr>
<td>Random Effects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept variance</td>
<td>3.49 (1.87)</td>
<td>3.67 (1.92)</td>
<td>1.83 (1.35)</td>
<td>2.34 (1.53)</td>
</tr>
<tr>
<td>Diagnostics (BIC)</td>
<td>1389.8</td>
<td>1322.7</td>
<td>596.4</td>
<td>538.9</td>
</tr>
</tbody>
</table>
Discussion

Summary of results

Observation of behaviours under control and pressure conditions indicated several flexibilities in preparation timing. First, golfers collected information over longer periods (ICI) and dwelled on that information for longer periods (RI) when facing longer shots. Next, golfers exhibited longer ICIs when experiencing elevated cognitive anxiety attributable to pressure. Finally, golfers had longer ICIs when their cumulative error was lower. Global judgement of behaviours indicated that golfers varied their preparation similarly during the control condition and between control and pressure conditions. This implies that the manipulation had no stable impact on physical preparation behaviours. Supporting the same conclusion, modelling of individual behaviour counts revealed that pressure or CA did not reliably influence the frequency of characteristic behaviours. Analysis of radial error offered no evidence that variability in the frequency of physical actions reliably precipitated better or worse performance, in general or under pressure. Finally, while the ICI appeared as a flexible parameter, there was no evidence that ICI variability predictably influenced radial error, in general or under pressure.

Temporal flexibility under cognitive anxiety

Golfers with elevated CA typically spent more time collecting shot information without harming their performance. This finding is consistent with several other observations of temporal preparation flexibility as a functional response to situational demands (Jackson, 2003; Jackson et al., 2006; Jackson & Baker, 2001; Wilson, Smith, et al., 2007). Consequently, the findings also challenge the popular idea that consistency is necessary to perform well under pressure (e.g., Hill et al., 2010b; Mesagno & Mullane-Grant, 2010). Longer ICIs under pressure did not predict better performance, implying that taking longer as blanket approach will not necessarily boost performance. However, a longer ICI might help
to save performance under pressure. The compensation analysis indicated that when the performer becomes worried (i.e., has higher CA), a longer ICI can help to maintain performance under pressure, and that the avoidance of taking extra time may be problematic. The key caveat is that only three non-compensators were identified (i.e., avoiders of additional effort). While this low number restricts the applicability of the result, the analysis does offer a novel and theoretically-relevant manner to examine the importance of compensation in future. Accordingly, a similar compensation analysis on larger sample would be a helpful next step. The results conform to the general principles of ACT and PET since increased cognitive anxiety was associated with lost efficiency and additional effort (i.e., longer ICIs). As predicted by both theories, compensation was a normal response to anxiety and may have played a role in maintaining performance. The ICI does not indicate how anxiety was self-regulated; it simply captures the length of time over which information was collected. A variety of self-regulatory functions were probably carried out in this time, such as longer or repeated visualisations and/or recurrent rehearsal of execution thoughts.

Other adaptations

Analysis of preparation timing identified two other flexibilities. First, longer shots typically received longer ICIs and RIs (i.e., a longer overall preparation). Longer shots were also more difficult, according to analysis of radial error\(^2\). Jackson (2003) noted a related effect. Rugby goal kicks taken from more acute angles were met with longer physical preparation and concentration intervals. Second, better current performance (i.e., low cumulative error) was associated with longer ICIs under lower and higher pressure. Longer ICIs when performing well could reflect enhanced engagement with the task, for example, a

\(^2\) Note that in chapter 3, 60-70m shots were judged as the most challenging, but this was on the basis of vertical error (i.e., the distance variable was hard to control) and not the radial error.
willingness to study the shot parameters carefully. Likewise, underperformance could
eventually lead to a loss of task interest as meeting the desired standard becomes increasingly
unlikely. This could manifest in less effort to collect information.

**Behaviour change**

Analysis of physical behaviours produced three interesting outcomes. First, widespread flexibility in golfers’ physical preparations was evident. For example, a minority of golfers exhibited a dominant routine under lower pressure. Second, qualitative and quantitative analysis provided no evidence that the pressure condition elicited a reliable change in golfers’ distinct physical behaviours. Third, behaviour count or a change in behaviour count had no clear relationship with shot accuracy. These null findings deviate from several related studies. More target looks under pressure (or with anxiety) were anticipated, given that Wilson, Smith, et al. (2007) observed that mid-handicap golfers (10-18) glanced at the hole more often under pressure (also in indoor conditions). Diagnosing the issue is muddled by several design and analysis variations between the studies. The current study recruited more skilful golfers and manipulated pressure differently. While pressure in this study did not reliably elicit more target looks, cognitive anxiety (from pressure) may have affected *when* looking occurred. The nature of ICI tells us this. A late final look at the target will, by definition, increase the ICI. Golfers affected by pressure may have been prone to take a late look at the target; even though the total looks was relatively consistent across conditions.

The current results also differ from Lonsdale and Tam (2008), who observed that a departure from the normal behavioural routine harmed the chance of making a free-throw. One explanation is that the free-throw and the golf approach shot have different requirements. A free-throw is undertaken (and practiced) under constant conditions (i.e., indoors and from the same distance). The approach shot is taken from different distances, with different clubs.
that feel different, may be swung slightly differently, and that make the ball behave differently. Additionally, in normal circumstances, the golfer faces a variety of environmental differences that require consideration and could impact the similarity of behaviours. So it may be normal that most golfers in this study exhibited built-in variation in their preparation (i.e., ‘normal’ was difficult to classify). The fact that golfers played from different distances each trial could explain the lack of preparation consistency throughout, since some may tweak their routines for short and long shots. That said, global judgments indicated preparation differences across shots of similar distance in the same condition. While golfers all showed characteristic preparation behaviours, they did not often adhere to certain number or order. Behavioural flexibility was evident generally and did not present as a response to situational features.

**Limitations and future research**

The pressure manipulation lead to a significant increase in CA across the sample; however, the anxiety experienced most likely fell short of the pressure experienced in tournaments. Additionally, the manipulation failed to significantly harm the groups’ golf performance (on average). This null result is an important limitation of the study and limits the conclusions about choking that can be drawn. Raising the stakes would be useful to strengthen inferences about the behavioural and performance consequences of pressure. For example, inducing more pressure would presumably increase the proportion of non-compensators in the sample. This would have allowed a stronger inference about the relevance of ICIs under stress. Future studies may consider a similar evaluation of temporal/behaviour change under pressure, but with the additional presence of an audience (e.g., Mesagno, Harvey, & Janelle, 2011). Recruiting a team of performers (e.g., a university, club or state golf team) would also scale-up the possibilities for adding pressure. For example, informing the members that performance would influence later team selection (e.g.,
Vickers & Williams, 2007) would probably have a more powerful effect on players. Observation of actual competition (via pre-existing or new footage) is a further useful approach. While some choking-related studies have attempted this (Jackson, 2003; Jordet, 2009; Jordet & Hartman, 2008), elements that allow a complete understanding of the influence of pressure have not been obtained or reported (e.g., collection of individual baselines or direct examination of behavioural-performance links). Future research could seek to identify moments of organic pressure change, assessment of individual temporal and behavioural change and then the connection to performance.

The data for this study was collected conveniently during the experiment described in chapter 3. This may have introduced some undesirable effects. In particular, the number of conditions (and thus the number of golf shots hit and effort exerted) between the control condition and pressure condition varied across participants. Given that the interleaving conditions involved secondary cognitive tasks, some participants may have experienced more cognitive depletion than others, which could harm mental control under pressure (e.g., Englert, Zwemmer, et al., 2015). Statistical control was attempted by incorporating the number of interleaving conditions as a fixed factor. Doing so did not improve the modelling of timing or radial error, implying that the amount of exposure to secondary tasks had little effect. Nevertheless, the general effect of having multiple other conditions within the same hour of experimentation is unknown. It is possible that the pressure manipulation (as conducted) was diminished by the other novel activities performed throughout (e.g., counting backwards). A separate study with control and pressure conditions only would resolve this issue.

Running the pressure condition at the end of the study may have introduced issues of fatigue and diminished interest in the task, although these are also problems in real tournament play. Moreover, performance under pressure in this task was often good,
suggesting that the level of fatigue was not detrimental. Task interest was approximated in the modelling using the current cumulative error, hence some statistical control over this variable was attempted. A practice effect is unaccounted for, and this could explain the null effect of pressure upon performance. Future research could design-out these issues (uneven cognitive depletion, fatigue, loss of interest and practice) with a control condition that immediately precedes the pressure condition and a second control condition immediately following.

**Practical Implications**

The results suggest qualification to the notion that routine consistency is necessary for skilled performance under pressure. Given that situational variables (length of shot, elevated worry and current performance) signalled timing changes, practitioners, coaches and players may wish to consider how fastidious they are about the consistency of routines. The data indicates, at least, that it is functional to spend extra time collecting information when worried, facing a harder shot or generally performing poorly (or well). This result is echoed elsewhere (Jackson, 2003; Wilson, Smith, et al., 2007). Furthermore, the results provide no indication that a change in physical behaviour reliably signals a performance decline. While a clear routine may afford a performer a suitable point of focus before execution, variation of physical behaviours may only be detrimental if the performer becomes concerned over the loss of routine. If much thought is devoted to the correct execution of the routine, the PPR could become its own distraction.

While taking additional time under pressure appears functional, rushing may be dysfunctional (Gucciardi et al., 2010; Hill et al., 2010b; Jordet, 2009; Jordet & Hartman, 2008). However, this matter is not settled either. Beilock, Bertenthal, et al. (2004) found that skilled golfers performed better when instructed to execute as quickly as possible (<3 seconds). The researchers explained that the reduced processing time limited explicit
attention towards the motor execution (i.e., prevented self-focus), which is believed to cause erratic timing (e.g., Gray, 2004; Marquardt, 2009). A number of issues make converging the evidence difficult. For one, Jordet (2009) and Jordet and Hartman (2008) provided no evidence of rushing, just evidence that faster players had less success than slower players. Similarly, qualitative work provides no evidence that rushing occurred, just the perception of rushing. Beilock, Bertenthal, et al.’s (2004) work reflects a common view present in the choking literature (and colloquially) about the dangers of overthinking. However, their golfers undertook short putts (on carpet) that probably required little preparatory consideration, and under no pressure. Moreover, golfers were not timed until they had addressed the ball. The pre-address period may be highly relevant for information collection and shot calibration considerations. More work is needed to establish if rushing can be linked to poor performance, if athletes’ perception of rushing is accurate and the mechanisms that drive any problem. This issue is taken up further in the next chapter.

**Concluding remarks**

This study considered the pressure-behaviour-performance link by a) examining individual behaviours, b) observing changes across a pressure change and c) connecting the changes to performance. The results provide evidence that temporal changes under pressure are normal and potentially adaptive. While temporal and behavioural change did not reliably predict performance under pressure; longer ICIs may facilitate maintenance of performance for those experiencing worry. There was no evidence that physical behaviours changed systematically under pressure, or that the changes that did occur affected performance. Similarly detailed work is needed with enhanced manipulated pressure situations or with observations of actual tournament play.

This chapter has served to close a gap in the observational study of pressure and choking, with comprehensive analysis of links between pressure, behaviour and performance.
In the next chapter, the present findings are pooled with those from chapters 3 and 4 to illustrate how choking could occur across the preparation-execution timeline, using the principles of distraction theory, self-focus theory and their combination. Then, future research to study these mechanisms is considered. Finally, ways to arrest choking are explored.
Chapter 6 – General Discussion

‘No idea. Wish I knew.’

A golfer from this thesis, on what causes choking

In chapter 1, the three key objectives for the thesis were described. The first was to reconsider dual-task and self-report studies of choking by paying closer attention to the preparation-execution timeline (addressed by chapters 3 and 4). The second was to examine how pressure observably impacted preparation and if these changes correlated with performance (addressed by chapter 5). The aim of the present chapter is to summarise and integrate the findings of the three studies conducted, in the context of existing research. Concurrently, focus is given to the final objective of the thesis; to map how attentional disturbances in preparation might set a course for eventual performance decline. The chapter concludes with a review of treatment options found in the literature on choking and suggestions for further possibilities.

Summary of research findings

The dual-task experiment (chapter 3) uncovered evidence that a distracted preparation can affect expert motor-skill performance in attentionally demanding situations. Specifically, these results suggest that restricted cognitive resources during preparation can affect skilled golfers’ ability to calibrate shot distances when the shot requires explicit adjustment (e.g., shortening the backswing). Insomuch as the arbitrary removal of cognitive resources simulates a shortage of cognitive resources under pressure, the data offer one way that skilled motor performance might be impaired by a distracting pressure situation. Nevertheless, a similar study that combines a pressure manipulation with attentional interference during preparation is needed to conclude this safely. There was no clear evidence to support Beilock & Gray’s (2007) assumption that cognitive skill impairment and autonomous motor skill
impairment can be neatly separated (i.e., the Independence Assumption). Chapter 3 tested this via the co-examination of vertical error and shot quality. The preferred interpretation of the data is that cognitive interference in expert preparation can set up multiple avenues to failure. On some occasions, a preparation spent off-task might induce a cognitive mistake (e.g., a poor decision), while the execution quality remains high. At other times, a preparation spent off-task might induce a timing error (perhaps due to fractured self-regulation). Hence, while the results of chapter 3 indicate that distraction can lead to poor distance control, lost attentional resources in preparation could also manifest in too much conscious involvement during execution (e.g., due to a lack of a committed plan before motor initiation)

The results of the questionnaire (chapter 4) indicate that both self-focus and distraction have an important place in the reconciliation of choking experiences. To a lesser extent, this conclusion has been reached elsewhere (Hill et al., 2009; Hill et al., 2010b). However, by asking golfers to consider the moment most salient to self-focus (the execution), more detail emerged. Not only did considering the execution phase elicit more self-focus-based explanations of choking and indicate that several self-focus variants are considered to be important problems, the results also suggest that golfers co-mingle self-focus and distraction-based explanations in a single shot. Specifically, factor analysis indicated that golfers connected a) worry about negative consequences or technique followed by b) conscious control or monitoring of the action. Given that self-focus theories are centred on a conscious verbaisable experience, self-reported validation is important evidence. That is, if conscious processing is a reason for choking, it seems reasonable that athletes would be able to remember and articulate this problem to some degree. Considering that distractions can be covert (e.g., aspects of visual attention), verbal recall is less necessary as a form of evidence. There is no covert conscious processing.
Several other themes emerged from the questionnaire. Regardless of skill level, golfers commonly engaged in explicit processing throughout execution. This leaves a pressing question for self-focus theorists. Which forms of conscious processing are safe and which are harmful? Ways to answer this question are considered shortly under Future Studies. Finally, a loss of trust/commitment emerged as an interesting rationalisation for choking. Relatedly, some golfers used their preparation to build trust/commitment before the shot. Issues of trust/commitment are relatable to both distraction theory and self-focus theory. On some occasions, trust/commitment responses seemed to reflect golfers’ inability to develop a mindset for execution clear of distraction. On other occasions, trust/commitment responses seemed to reflect golfers’ inability to execute free of conscious interjection.

The results of the observational work (chapter 5) challenge the popular notion that self-paced preparation needs to be highly consistent. In this study, observable adaptation to the experience of worry, task difficulty and current performance was found to be commonplace and not obviously detrimental. Golfers experiencing elevated worry tended to slow their preparations, in particular while collecting information about the shot parameters. This slowing resembled compensatory effort, as described by ACT and PET. Furthermore, the analysis hinted that failing to compensate with extra information collection time under pressure was detrimental. A study with more participants or a stronger pressure manipulation is needed to confirm this. Verification would supply useful evidence for ACT and PET since it could show that a) compensation can salvage performance and b) that an absence of compensation can compromise performance. The data did not support the idea that performance under pressure is predictable from variability in physical behaviours or preparation timings. The more important factor is probably the clarity of the mindset developed throughout the preparation.
Mapping the causes of choking in self-paced skills

Closer consideration of events in motor skill preparation and execution allows a more comprehensive mapping of the causes of choking. Figure 6.1 displays a psychological model of choking in self-paced sports that draws on the present results and other contemporary understandings of how misdirected attention causes choking. The model is speculative and is presented to provide insight into the status of the current research and to give direction to future research in the area. The emphasis of the model is on choking in a single self-paced execution. This is not to suggest that choking is always so well confined (Gucciardi et al., 2010). With each failure, a performer’s attention may become increasingly overwhelmed and thus, performance may become progressively worse. Figure 6.1 assumes that the same basic pathway to choking would occur with each failure, even if with less resistance from the performer. The model captures pathways to choking based on the principles of distraction, self-focus or their combination. Task complexity is not featured. This departs from Mesh (Christensen et al., 2016), introduced in chapter 2. Mesh predicts that choking via self-focus is increasingly likely as the task simplifies, whereas distractions to situation awareness and action representation (the action gist) become more relevant as task complexity increases. In Figure 6.1, choking via self-focus, distraction or both can occur in tasks of varying complexity. On the surface, bypassing complexity might seem to conflict with results described in chapter 3, in which distraction uniquely impacted the relatively complex 60-70m shot. However, cluster analysis suggested that a distracted preparation ultimately impacted performance in multiple ways (e.g., via interrupted strategy or timing issues potentially attributable to explicit thought).
Figure 6.1. A multi-pathway model of choking in self-paced sporting tasks
The model has two resting assumptions that draw from ACT and PET and the results of chapter 5. The first is that pressure interferes with the efficient processing of task-relevant information. Substantial evidence for this assumption is found in literature on perceptual-motor behaviour (e.g., Wilson, Vine, et al., 2009) and neurological processes (e.g., Hatfield et al., 2013). The second assumption is that the performer must self-regulate to meet these elevated situational demands. This assumption reflects evidence of compensatory behavioural and psychophysiological responses to state anxiety, like those expected under ACT and PET (e.g., Vine & Wilson, 2011). Evidence of compensation was reported in chapter 5; golfers collected information for longer when experiencing cognitive anxiety. Four plausible pathways to choking are mapped through preparation and execution. Each is explained below.

**Conscious Interference (Pathway 1).** On this pathway (highlighted in Figure 6.2), pressure, inefficient information processing and sub-threshold self-regulation leaves a performer in an unsettled (noisy) state as the moment of execution arrives. Chapter 4 illustrated that this could mean strategic indecision (e.g., uncertainty about which way a putt breaks) or an inability to resolve doubts or commit to a plan (i.e., trust/commitment issues). This unsettled state might occur after a rushed preparation (Gucciardi et al., 2010; Hill et al., 2010b), or more specifically, a rushed information processing period (chapter 5). Alternatively or collaboratively, this unstable mentality could occur after a generally distracted preparation in which execution thoughts were not adequately organised (chapter 3). The proposed noisy mindset is the antithesis of the ideal ‘quiet mind’ proposed in Singer’s five step model for self-paced skills (Singer, 1988, 2001). In Singer’s model, a goal of the preparation is achieving an optimal (i.e., quiet) state for execution. Given self-regulatory failures and continuing unmanaged worry about the outcome, Conscious Interference predicts a greater propensity for a self-focused execution. Conscious attention can unravel the skill
because the performer summons slow explicit processing when much faster autonomous processing is necessary. The views of surveyed golfers are consistent. In chapter 4, a statistical connection was observed between a) worrying about the outcome and careful control of the execution (‘steering’) and b) worrying about technique and focusing on mechanics in execution. Self-focus is probably damaging relatively early in the execution. For example, the backswing of the golf stroke is thought to operate under open-loop control (i.e. consciously accessible), while the downswing operates under closed-loop control (Beilock & Gray, 2012). Performers primed by doubt or worry might judge a problem with their action in the open-loop (e.g., being out of position), react, and then consciously interject by hesitating, overcorrecting or rushing the finish. One golfer from chapter 4 alluded to this possibility: ‘If I take the club away some other way than what’s "normal" it breaks my zone and I become conscious’. Conscious Interference mixes distraction and self-focus principles, in that order. Inadequate task-focused attentional resources after unsuccessful self-regulation (distraction) exposes the performer to conscious processing throughout execution (self-focus). In this sense, self-focus could be framed as a problem of inhibition. According to Eysenck et al. (2007), anxiety impairs the inhibition function of the central executive (i.e., the proposed governing unit of working memory). A worn out inhibition system could make self-focus more likely. Eysenek and Wilson (2016) also suggest this possibility. Relatedly, self-focus could be framed as an issue of depleted self-control. Continued blocking of distractions might exhaust the resources needed to appropriately compensate (Englert, Zwemmer, et al., 2015), increasing the likelihood of self-focus.
Figure 6.2. Pathway from a distracted preparation to choking according to Conscious Interference.

**Distracted Action (Pathway 2).** Distracted Action shares with Conscious Interference that pressure, inefficient information processing and then inadequate self-regulation leaves the performer with untenable doubt at the point of execution. However, this pathway presents a different in-execution problem. On the Distracted Action trajectory (highlighted in Figure 6.3), continuing worry throughout execution triggers early attention to the outcome. In turn, this elicits a specific mechanical destabilisation. In golf (or similar aiming sports, e.g., a soccer penalty), the proposed manifestation is a premature lifting of the body, head or eyes as the athlete’s attention diverts to the results. In chapter 4, golfers noted that worry about the outcome could encourage bodily change through that shot (e.g., “*don’t maintain posture due to eagerness to see the result*”). This idea is philosophically similar to self-focus. However, the proposed expression of worry is not explicit monitoring or control of the overlearned movement. It is that shifting attention to the result changes the movement in a manner consistent with an early assessment of the outcome. There is evidence that expert and novice golfers normally move their heads differently when putting. Lee, Ishikura, Kegel, Gonzalez, and Passmore (2008) observed that novices tended to move their head away from the target during the takeaway and towards the target during the downswing. Experts exhibited the opposite pattern, moving their heads towards the target during the takeaway and
away from the target during the downswing. Distracted action would predict that experts would become more likely to exhibit the novice-like pattern on missed putts under pressure. This is a topic for future research (next section). Recent evidence suggests that shorter post-movement QE periods are associated with inferior putting performance under pressure (Vine et al., 2013). A shorter post-movement QE could reflect an impatient attentional shift to the outcome (due to worry) before the completion of the movement. This is as distracted action would predict.

Figure 6.3. Pathway from a distracted preparation to choking according to Distracted Action.

**Distracted Programming (Pathway 3).** This pathway (highlighted in Figure 6.4) deviates from the first two at the point of execution. This time, impaired self-regulation causes the performer to miss critical task-relevant information regardless of their established trust/commitment. This shortage of task-relevant input at the end of preparation leaves an incomplete motor program. This pathway to choking is supported by studies of visual attention, which show that eye movements stray towards irrelevant targets and overt threats during motor preparation under anxiety (Nieuwenhuys & Oudejans, 2011; Wilson, Vine, et al., 2009; Wilson, Wood, et al., 2009). Largely, these distraction events are thought to occur covertly. During execution, the poorly specified plan is expected to run without further interference. This is primarily the pathway to choking suggested by the Integrated Model (Nieuwenhuys & Oudejans, 2012 - see chapter 2). According to the Integrated Model, off-
task visual attention in preparation reduces the ability to plan movements with precision. It is also possible that the motor program is updated during execution until some point of no return (e.g., the downswing in golf). There are suggestions that expert golfers actively process (not necessarily consciously) the putter head and ball to promote good contact and/or functionally adjust throughout the movement (Vine et al., 2017). Accordingly, it is feasible that athletes miss critical programming information either during preparation or execution.

![Diagram of Distracted Planning (Pathway 4)](image)

**Figure 6.4.** Pathway from a distracted preparation to choking according to Distracted Programming.

**Distracted Planning (Pathway 4).** On this pathway (highlighted in Figure 6.5), a strategic failure attributable to unregulated anxiety occurs during preparation. The execution runs without interference but the result is damaging anyway. This independence between preparatory cognitive failures and the quality of execution reflects the distraction-based pathway to choking suggested by Beilock and Gray (2007) – see chapters 2 and 3.

Nieuwenhuys and Oudejans (2012) also raise this possibility when noting that action selection problems contribute to choking. Chapter 3 introduced a novel analytic method to identify how frequently cognitive interference causes Distracted Planning. This approach consisted of identifying high quality shots (using launch and flight indicators) that lacked distance control. Doing so allowed deduction of a strategic mistake – occasions in which skilful execution appeared to remain intact despite impaired planning.
**Figure 6.5.** Pathway from a distracted preparation to choking according to Distracted Strategy.

**Generality of the model.** Without needing the others, each pathway in Figure 6.1 specifies a plausible way that an interfered preparation could trigger a choking event. Nevertheless, some crossover between pathways is inevitable. For instance, Distracted Planning would inexorably co-occur with failures of execution (explained by the other pathways) on some occasions. Consider a risky golf shot. The performer may doubt the integrity of the decision yet go ahead without the internal agreement needed to commit. Alternatively, he/she could knowingly or unknowingly make a poor choice and also lose attentional control throughout execution. In a similar manner, Distracted Programming (i.e. convert inattention) could coincide with Conscious Interjection or Distracted Action. For example, a snooker player might be inattentive to a relevant target in preparation and also attempt conscious override during execution (perhaps escalating the damage). Likewise, a rugby goal kicker might noisily scan the ball and goal, then prematurely focus on the outcome during the kick. Distracted Programming and Distracted Action might intersect even more subtly here. If motor-programming does continue during execution (Vine et al., 2017), this premature outcome focus might break any in-execution control that is necessary to guide the motion. That is, Distracted Action could trigger Distracted Programming during the execution.
The model presented in Figure 6.1 is dedicated to self-paced activities. However, externally-paced activities with reliable waiting periods between executions are generally accommodated (e.g., cricket batting, baseball batting or receiving in tennis). Like self-paced activities, these tasks allow potentially damaging thinking, which requires management. For example, elite cricket batsmen use pre-performance routines to be sufficiently attentive for the next delivery (Cotterill, 2011), presumably to exploit anticipatory cues in expert fashion. Some nuance is necessary for these highly time-constrained tasks. The loss of attentional resources due to anxiety could damage expert anticipatory or predictive function. Gray (2006) demonstrated that the performance of expert baseball players suffered when cognitive load was applied to their preparation. This suggests that a reduction in task-focused cognitive resources can impair expert anticipation. A loss of predictive or anticipatory utility could force a novice-like reliance on the flight of the stimulus (e.g., a ball). Presumably, the scant perceptual information from the flight itself would prevent complete motor programming and make excellent performance unlikely (see chapter 2, Figure 2.4). Alternatively (or additionally), the performer may become aware of lost time. This could encourage conscious interjection, for example, rushing the action to catch up.

**Future studies**

**Does pressure trigger self-focus?** Validation for self-focus theories (including Conscious Interference – Figure 6.2) requires a demonstration that a) pressure makes conscious processing more probable and that b) conscious processing interferes with the motor skill. Numerous studies suggest the latter without suggesting the former. Nevertheless, Gray (2004) and Gray and Cañal-Bruland (2015) both provide an experimental indication that pressure triggers self-focused attention. In Gray and Cañal-Bruland (2015), golfers putted while a tone from the left or right speaker was played during their backswing. After the stroke, golfers were cued to indicate (a) if the tone emerged from a speaker to the left or right...
of the target or (b) if the tone was played closer to the start or end of their backswing. To do well, golfers had to process the tone’s location (the distraction task) and their club’s motion (the self-focus task). The task was completed under lower and higher pressure. For the golfers who felt more pressure (higher cognitive anxiety, heart rate and kinematic response), both secondary tasks were handled similarly without pressure. When pressure was applied, the pressure-affected golfers became better at the self-focus task and worse at the extraneous distraction task. For golfers unaffected by pressure, secondary task performance was similar across pressure conditions.

Gray and Cañal-Bruland’s (2015) results suggest that the experience of pressure primes self-focused processing. Nevertheless, Wilson, Chattington, et al. (2007) obtained conflicting findings with a timed driving task (noted in chapter 2). In their study, drivers had to either indicate (a) if a tone was higher, lower or the same as a reference tone or (b) if their left hand was higher, lower or in the same vertical position as their right hand upon hearing the tone. Wilson, Chattington, et al. (2007) found that secondary task performance was universally degraded under pressure. Bypassing the differences between putting and driving, a key manipulation difference between the studies was that Wilson et al.’s drivers knew that nature of the secondary task upfront, which presumably lowered the attentional demands of their task. For Gray and Cañal-Bruland’s (2015) pressure-affected golfers, more is happening. They are experiencing pressure (handicapping their information processing), listening for the orientation of a tone, monitoring the position of their putter and putting. The results show that their attention gravitated to the self-focus task, but this might not be spontaneous. For example, if the self-focus task is the harder of the two (or it is perceived as such), players might use a strategy: focus on the harder self-focus task and use echoic memory to respond to the tone discrimination task if necessary. To address this issue, a future study could vary Gray and Cañal-Bruland’s (2015) procedure by revealing the nature of the secondary task up
front (in the manner of Wilson et al.). In this new format, golfers could be asked to either a) identify the nature of a tone or b) an aspect of the putter movement, but the tone or club task would be cued beforehand. Reducing the overall attentional demands would be interesting because the need for economic strategies would be reduced. Under these new circumstances, if pressure improved the performance of the self-focus task (and not the extraneous task), there would be relatively strong and convergent evidence for self-focus priming under pressure.

What kind of self-focus is a problem? While a number of studies indicate that conscious processing (as a broad concept) interferes with expert-level motor skills, some conscious thinking in execution appears innocuous. Reports of deliberate technical and part-process thinking in chapter 4 and elsewhere (e.g., Hill et al., 2010b) imply that self-focus theories lack precision. One unexplored possibility is that the interpretation of the conscious thought could affect how damaging it is. For example, a golfer might deliberately consider an aspect of their technique during the backswing believing it is helpful (perhaps due to endorsement from a coach). If this thinking creates the desired feeling in the backswing, the free release of the club may follow (actual technical advantages aside) since the process is going to plan. In contrast, a golfer who monitors the execution and notes an unwanted feeling (e.g., a sense of being ‘out of position’) might be compelled to interject with conscious adjustment and interfere with the release. The relevance of the performer’s interpretation could be tested using a dual-task framework. In one condition (the neutral-judgement condition), participants could undertake a self-focus dual-task (e.g., identify if the putter is moving away or towards the target upon hearing a tone). In a second condition (the positive judgment condition), before undertaking the same dual task, participants could be told (mislead) that the dual-task is known to improve performance. Better performance in the positive-judgment condition would suggest that the danger of explicit thought is influenced
by how welcome that thought is. A third negative-judgement condition could also be included to assess if the self-focus dual-task interferes even more than usual.

Under Conscious Interference (Figure 6.2), explicit thought should become more detrimental if the mental preparation is inadequate (due to pressure). In chapter 3, there was evidence that distraction in preparation inhibited golfers’ ability to implement some explicit control to calibrate distance on short shots. Pressure may have a similar effect but a variant of the study described in chapter 3 is required. This time, golfers could prepare similar short shots (e.g., 60-70m or known ‘in between shots’), with or without cognitive interference and under lower and higher pressure (i.e., four conditions). If the combination of pressure and interference in preparation was most damaging to distance control, this would suggest that explicit control is harder to implement due to attentional deprivation in preparation (also see Lewis & Linder, 1997 for the use of this argument). Alternatively, the participant group could be divided into those who regularly use explicit cues and those who use other foci (or this could be instructed). In chapter 4, it was evident that some golfers preferred a technical focus and others preferred no conscious involvement (see also Maurer & Munzert, 2013). If the explicit-cue group were the most affected when subjected to the combination of interference in preparation and pressure, there would be evidence that access to attentional resources in preparation dictates the ability to implement explicit control.

Is self-focus a problem of inhibition? Conscious Interference (Figure 6.2) proposes that inadequate self-regulation in preparation makes the performer vulnerable to self-focus in execution. Accordingly, a key prediction of Conscious Interference is that impaired self-regulation would increase the propensity for a conscious execution. One way to test this prediction is to a) exhaust an athlete’s attentional control then b) test for the priming of self-focus. The first part of this equation has been previously achieved using a transcription task that required omitting the letters ‘e’ and ‘t’ (Englert, Bertrams, Furley, & Oudejans, 2015),
forcing effortful override of habitual processes. The second part of the equation, as just mentioned, has been achieved by examining the accuracy of self-focused or extraneous dual-task responses under pressure (Gray, 2004; Gray & Cañal-Bruland, 2015). Evidence that self-focus is an inhibitory problem would be obtained if attentional depletion facilitated better processing of the self-focus task (with no effect in a control condition). The addition of a pressure manipulation to the experiment would be additionally informative. According to Conscious Interference, a self-focus priming effect should be greatest under conditions of cognitive depletion and pressure.

**The issue of rushing.** All four pathways in Figure 6.1 stem from ineffective self-regulation. A hasty preparation is one explanation for unsatisfactory mental preparation; however, the evidence is currently sketchy. Most golfers from chapter 4 indicated that rushing the preparation under pressure was an important reason for past chokes. Similar self-report evidence has been gathered elsewhere (e.g., Gucciardi et al., 2010). While athletes might believe they have sped up, no study (to the knowledge of the author) has tested their perceptions. One criticism levelled at self-report of mental processes is that the data is unverifiable (Nisbett & Wilson, 1977). However, whether or not athletes can judge the relative pace of their preparation (i.e., perceptions of rushing) could be verified. In a simple experiment, participants could be asked to estimate (or rate) their preparation speed under low and high pressure. Any bias under pressure could then be assessed. For golfers in chapter 4, the experience of rushing seemed to be its own distraction. If athletes’ perceptions are inaccurate, practitioners would have good reason to challenge the rushing narrative.

The consequences of rushing are also somewhat unclear. In chapter 5, golfers who compensated for worry by slowing their information collection performed better in a pressure condition than those who sped up their information collection. However, only three anxious golfers sped up, limiting the conclusions. In contrast, Beilock, Bertenthal, et al. (2004)
demonstrated that asking golfers to putt within three seconds assisted performance under pressure. They concluded that this speedy preparation prevented overthinking (e.g., self-focus). Nevertheless, their golfers undertook simple putts on carpet which probably required minimal preparation, and no pressure was applied. Two future studies would bring more clarity. The first would repeat the observational work presented in chapter 5 but with a larger pool of participants (and/or a stronger pressure manipulation). Doing so would allow identification of more participants who had elevated anxiety and a faster preparation. The second would repeat Beilock, Bertenthal, et al.’s (2004) study in a task that required serious preparatory consideration (e.g., a range of putts with slopes to judge) and/or applied pressure (i.e., a reason for self-regulation). Doing so would help to generalise the relationship between speeded preparation and performance.

Examining visual search before/during self-focus. The Distracted Programming model (Figure 6.4) is based on evidence that inefficient visual search under anxiety or pressure (directed at overt threats or otherwise) is associated with poor performance. Although this evidence suggests that motor skill failure is caused by task inattention and a correspondingly imprecise motor plan, self-focus could co-occur. One way to test this is to force self-focus (e.g., in the manner of Gray, 2004) and concurrently monitor gaze behaviour. Given a self-paced task like a golf-putt, visual attention could be examined with a mobile eye-tracker under a control condition, a self-focus condition (secondary task requiring bodily or implement focus) and a distraction condition (extraneous secondary task). Possibly, distraction principles could explain all the results – evident if scanning efficiency predicted putting accuracy, regardless of condition. If so, this would build the case that self-focus (at least in the induced form) is a redundant problem. The results might also show that scanning is especially inefficient in the self-focus condition, implying that self-focus is especially distracting. Consequently, the experiment would provide a method to examine the relative
distractibility of self-focus and distraction secondary tasks (an issue noted in Hill et al., 2010a). If scanning efficiency cannot account for poorer performance in the self-focus condition, this would suggest that problems after preparatory visual scanning (e.g., late conscious interference) are at play.

**Lifting the head or body under pressure.** The Distracted Action model predicts that experts of certain aiming-based sports (e.g., golfers putting or soccer players taking penalties) would lose bodily posture in a manner consistent with premature attention to the outcome. Given evidence that expert golfers tend to move their head away from the target during the putting downswing while novices do the opposite (Lee et al., 2008), future research could assess if a pressure manipulation elicited the novice-like head movement towards the target. Stronger evidence would be obtained if the target-oriented head movement could be linked to outcome-based attention. Examining post-contact eye fixations might achieve this. The co-occurrence of head movement towards the target and earlier fixations on either the ball’s movement or the target following execution (and a significant performance decline) would suggest that distracted action had occurred.

**Development of the model.** This section has identified several future studies to test the predictions of the model presented in Figure 6.1. Future research could also enhance the development of the model itself using qualitative methods. One approach would be to seek consensus on the model’s pathways (and elements) from a panel of experts with an understanding of (or investment in) the psychology of choking. The use of an expert panel for this purpose, often referred to as a Delphi process (Brown, 1968), involves a) carefully planned questioning of a group of experts (often via an open-ended questionnaire), b) chances for experts to give feedback on the questions asked and then c) opportunities for experts to critique each other’s responses and reconsider their own. This process is typically conducted iteratively, over several rounds of questioning, until a consensus is reached (Hsu & Sandford,
2007). In the examination of the causes of choking, an interesting panel would include a sports psychologist working in the field, an experienced academic in the field, an elite coach and an elite player. Consensus from such a cross-section would be appropriate, given that the choking field to-date has sought similarly broad theoretical input. Experts could be asked to generally reflect on internal contemplations of self-paced athletes in the preparation-execution timeline and how pressure and anxiety might create cascading problems. Additionally, experts could be asked to consider each pathway in Figure 6.1, explore missing or unnecessary components and suggest alternative pathways. The integration of these responses would facilitate model improvement.

**Summary of future research.** This section has highlighted a series of opportunities to learn more about how distraction, self-focus or their combination might unravel a self-paced skill – now summarised below. First, future studies could usefully revisit Gray’s (2004) test of self-focus priming under pressure to rule out alternative explanations. Given clarification of the priming effect, Gray’s test could also be used to examine if cognitive depletion primes self-focused processing. In turn, this would test if distraction and self-focus can operate in the same execution, in the manner predicted by Conscious Interference. Second, there is an opportunity to test which forms of explicit processing are most damaging (e.g., endorsed vs. unendorsed forms). Doing so would allow better specification of the self-focus mechanism. Third, it would be informative for future research to examine gaze behaviour before and during self-focused processing (e.g., as elicited by a dual-task). Research of this nature could a) assess the association between self-focused processing and characteristic eye behaviour and b) assess if self-focus and extraneous dual-tasks differentially impact visual attention. Fourth, future work could usefully examine if athletes’ perception of rushing is consistent with their actual behaviour and if rushing (when it occurs) is detrimental to performance under pressure. Research of this kind could result in pragmatic
advice to self-paced athletes to manage their preparation pace, or alternatively, discredit distracting beliefs about preparation speed. Fifth, there is a chance to investigate the intuitive possibility that preoccupation with the outcome (due to pressure) leads to premature examination of the outcome (i.e., Distracted Action). Research of this nature could reveal another way that off-task thought can negatively impact performance. Finally, future research could be conducted to better specify the model outlined here (Figure 6.1) using a Delphi process. Work of this type could obtain consensus about the pathways to choking from a variety of relevant stakeholders, and realise a model with broader applicability.

In this discussion, and in most of the thesis to this point, the broad goal has been to better understand how attentional disturbances cause choking. A logical next step is to consider how the aetiological knowledge accrued to date can be used to intervene in susceptible athletes. Accordingly, to round out this thesis, potential choking treatments – both taken from the extant literature and this thesis – are critically reviewed. In this process, opportunities for future intervention research are highlighted.

**Choking Interventions**

After presenting evidence for self-focus, Beilock, Bertenthal, et al. (2004) surmised that there is truth in the classic Nike motto ‘Just do it’ (p379). While avoiding overthinking clearly seems like a good idea, an athlete could reasonably ask, how do you ‘just do it’ while experiencing a wave of negative emotional thoughts? The sports psychology literature contains several possibilities, summarised below, that are relevant to the research conducted and examined in the thesis. The strategies covered are the pre-performance routine, deliberate use of execution cues (e.g., external cues), transfer of training (e.g., acclimatisation), implicit learning, mindfulness and commitment approaches, quiet eye training and hemispheric priming.
Pre-performance routine. A well-known approach to managing a variety of self-paced situations, including pressurised situations, is the consistent use of a PPR that contains purposeful cognitive and behavioural elements is (e.g., Boutcher & Rotella, 1987; Moran, 1996). Some have classified the PPR as an intervention based on distraction theory (e.g., Gröpel & Mesagno, 2017; Mesagno et al., 2008). Principally, this is because the PPR is designed to direct attention to task-relevant aspects (Mesagno & Mullane-Grant, 2010), which might help to trigger the appropriate motor program (Cohn, 1990). Nevertheless, establishing a useful execution mentality (e.g., a quietened state) is also a viable outcome of a routine (Singer, 1988, 2000) and a desirable one for performers (see chapter 4) – which could help to prevent self-focus (Figure 6.2).

Several studies have evaluated the PPR as a pressure-management tool (e.g., Hazell et al., 2014; Mesagno, Hill, & Larkin, 2015; Mesagno et al., 2008; Mesagno & Mullane-Grant, 2010). In one example, Mesagno et al. (2008) had choking-susceptible tenpin bowlers complete two separate pre-post evaluations. In each evaluation, the pre-phase was a control and the post-phase was completed under pressure. In the first evaluation, bowlers prepared for all (pre and post) shots in their usual way. In the second evaluation, bowlers again completed the pre phase normally before being taught a PPR with steps to adjust arousal levels, improve attentional control and use cue words. After practicing the PPR to a suitable standard, the bowlers again executed shots under pressure. All bowlers improved their bowling accuracy under pressure following learning the PPR (group average of 29%). Other evaluations have yielded a mixture of null and positive effects (Gröpel & Mesagno, 2017; Mesagno et al., 2015). One difficulty in surmising the generic value of the PPR is that routine development approaches have differed considerably across studies. For example, PPR training has been varied between 20 minutes and seven days (Hazell et al., 2014). Furthermore, the PPR is an individual process; hence the elements will differ between study
participants within and across evaluations. To breakdown some of this complexity, Mesagno and Mullane-Grant (2010) examined the effectiveness of some typical PPR elements in an Australian rules football goal kicking study. In their research, three groups developed a PPR based around a) deep breathing, b) cue words and c) temporal consistency (a five second countdown). A fourth group developed an extensive PPR involving arousal modification, behavioural steps, external focus and cue words. A fifth group received no treatment. The extensive PPR group was the most effective under pressure, implying that a comprehensive approach is best. Nevertheless, All PPR groups coped better than the control group.

In chapter 5, evidence was obtained that lengthening the period of information collection in a self-paced task was a potentially adaptive response to elevated worry. Similar conclusions (i.e., avoiding rushing) have been reached in other observational work (e.g., Jordet, 2009; Mesagno & Mullane-Grant, 2010) and qualitative work (e.g., Gucciardi et al., 2010 and in chapter 4). These results suggest that building (situation dependent) temporal flexibility into PPRs is a reasonable approach. To this end, the idea of preparing for longer when stressed warrants further investigation as a simple intervention strategy. Performers could be instructed to respond to pressure by taking the necessary time to scan their targets thoroughly and reach internal agreement on their plan for execution (noting the time-limits of each sport). Notably, slowing preparation contradicts the advice of Beilock, Bertenthal, et al. (2004), who advocate that skilled performers would benefit from speeding up to avoid the dangers of overthinking (e.g., self-focus). As mentioned previously, replication of their work in more stringent settings (e.g., challenging putts with slopes) or testing the approach in competition (e.g., via case studies) would be useful to clarify the effects.

In chapter 4, the establishment of an unequivocal plan for execution was identified as an important goal for golfers – but not one they could always achieve under stress. The ‘think box, play box’ (Marriott & Nilsson, 2011), mentioned in chapter 4, is an existing intervention
strategy that could assist. Designed for golf, but applicable in other self-paced tasks, the method requires the player to establish a signal (e.g., a loosening of the grip, a smile, an imaginary line to cross) that will clearly demark the end of preparatory thinking (i.e., the locking in of choices) and a switch to intuitive execution. The approach is time invariant and behavioural consistency is not emphasised. The crucial aspect is that the performer stops deliberating on cue. The authors have anecdotal evidence for their approach but future scientific evaluation would be a useful contribution to the field.

**Extraneous focus, holistic cues and external cues.** Experimental evidence demonstrates that motor skill experts can tolerate cognitive load (e.g., tone monitoring) while executing their skills, due to cognitive capacity freed by extensive practice (e.g., Beilock et al., 2002 - see chapter 2). Results from the dual-task experiment in chapter 3 (distraction in execution conditions) support the same narrative. Some of the previous dual-task work also indicates that the combination of pressure and extraneous cognitive load (i.e., not self-focused attention) allows the preservation of performance under stress (e.g., Jackson et al., 2006). That being the case, extraneous distraction seems a plausible choking intervention. Nevertheless, asking players to undertake arbitrary cognitive tasks (e.g., counting backwards) in competition might be unreasonable (Mesagno et al., 2009) or at least a hard sell. Perhaps more palatably, there is some evidence that focusing extraneously on colours (Gucciardi & Dimmock, 2008) or song lyrics (Balk et al., 2013; Mesagno et al., 2009) is helpful. Interestingly, Land and Tenenbaum (2012) demonstrated that random letter generation or saying ‘hit’ at impact were similarly helpful for golfers putting under pressure. That is, the nature of the extraneous focus might not matter, as long as attention is diverted away from the process of execution.

Intuitively, an arbitrary extraneous focus (e.g., lyrics) during competition seems suboptimal. For one, an arbitrary focus deviates strongly from descriptions of flow states,
which emphasise immersion in the task (Jackson & Csikszentmihalyi, 1999). Two task-
relevant approaches are the use of holistic cues (Jackson & Willson, 1999 - alternatively
fluency cues, see Gröpel & Mesagno, 2017) and external cues (Wulf, 2013). Holistic cues
(e.g., ‘smooth’ or ‘drive’) are thought to chunk explicit knowledge into manageable task-
relevant concepts that can guide execution. Gucciardi and Dimmock (2008) and Mullen and
Hardy (2010) both found that holistic cues were more effective under pressure than a
technical focus (e.g., part-process cues – see chapter 4). External cues are thoughts about the
‘intended movement effect (including an implement)’ (Wulf, 2013, p.77). Thus, external cues
are both external and task-relevant. A body of work indicates that an external focus facilitates
better balance (Wulf et al., 1998), more powerful movements (An et al., 2013), more accurate
movements (Wulf & Su, 2007) and greater agility (Porter, Nolan, Ostrowski, & Wulf, 2010),
among other similar benefits. Mechanistically, an external focus is thought to promote
automaticity by avoiding a detrimental internal (or self-focused) thought pattern (Wulf &
Prinz, 2001). However, focusing on colours could also do this. Offering an alternative
explanation, Davids (2007) argued that a task-relevant outward orientation could allow ‘self-
organising’ processes to govern task performance (p286). The precise reason that an external
focus works remains unknown (Wulf, 2013). Few studies have assessed the use of external
cues under pressure. In one, Hill et al. (2010b) found that ‘clutch’ golfers mostly adopted an
external focus, whereas choking-susceptible golfers relied on an internal focus. More
evaluations are necessary to establish external cues as a choking treatment.

**Transfer of training.** A long-standing principle of expertise is that the transfer of a
skill to a different context is dictated by the similarity of training and transfer contexts
(Lewandowsky et al., 2007). In putting forward the original self-focus theory (Conscious
Control), Baumeister (1984) proposed that regular exposure to self-consciousness could
protect against self-focus under pressure. In support, Lewis and Linder (1997) and Beilock
and Carr (2001), both found that near-novices practicing golf putts under video surveillance and evaluation threat maintained performance in a pressure transfer test, while those trained under extraneous distraction declined under pressure. Considering long-run acclimatisation, Oudejans and Pijpers (2009) demonstrated that five weeks of free-throw training under a mixture of anxiety-inducing manipulations (audience, video-taping, expert evaluation, punishment) protected against choking. More abstractly, the same authors showed that experts practicing darts at height (to create anxious feelings) avoided choking, whereas experts practicing nearer the ground choked. This suggests that generally mimicking the physiological symptoms of anxiety could be enough to acclimatise the performer.

The elite basketball player, Stephan Curry, uses overloading drills in practice (e.g., bouncing two balls at once) to make information processing easier when competing (Masterclass, 2017). If sub-threshold information processing does explain choking, overloaded practice seems a sensible treatment option. Doing so could theoretically strengthen the ability to selectively attend to relevant stimuli and/or inhibit self-focus through execution. Some have argued that building attentional self-control is analogous to building muscle (e.g., Gailliot, Plant, Butz, & Baumeister, 2007) – there is short-term fatigue but long-term gain. For example, Schmeichel, Vohs, and Baumeister (2003) found that asking students to ignore irrelevant words while comprehending a video harmed their performance in a follow-up analytical test. Considering longer term effects, Muraven, Baumeister, and Tice (1999) observed that two weeks of exercising self-control (e.g., maintaining good posture while walking) facilitated improved performance on an unrelated self-control task (persisting for longer on a hand grip exercise).

While demonstrations outside the choking domain suggest that managing distraction can benefit long-term attentional control, published work in the choking domain has not supported the value of overloaded practice. Beilock and Carr (2001), Lewis and Linder
(1997) and Reeves et al. (2007) all found that practicing self-paced tasks under extraneous load offered no benefit in follow-up pressure tests. Only Reeves et al. (2007) used skilled athletes, and cognitive load training was exclusively restricted to the execution phase. Two issues warrant more consideration. The first is that no study has assessed the long-term benefits of cognitive load training, which is perhaps when benefits are most likely (Gailliot et al., 2007). The second (echoing a major theme of this thesis) is that the execution phase of a self-paced skill is arguably the wrong time for skilled performers to practice. Stephan Curry overloads while dribbling because this is a cognitive moment; he has to decide to pass (who to? on what trajectory/speed?) or shoot (in what manner? from where?). Once movement initiation occurs, experts (in the normal course of events) reduce verbal/analytical cognition (Hatfield, 2018). Overloading practice makes more sense during cognitively busy phases (e.g., golf shot preparation) and less sense in autonomous phases (e.g., golf shot execution).

In chapter 3, skilled golfers battled to calibrate distance appropriately on shorter shots when cognitive interference challenged their preparations. Practicing under cognitive load at this time could improve their capacity to cope with interference. Longitudinal research is warranted to understand the effects of overloading preparation in self-paced skills.

**Implicit Learning.** There is evidence that learning a motor skill without verbal instruction (i.e., implicitly) can protect against choking (Hardy, Mullen, & Jones, 1996; Masters, 1992; Masters & Maxwell, 2008; Maxwell, Masters, & Eves, 2003). For example, Masters (1992) found that novices who learned to putt while their working memory was overloaded with random letter generation (suppressing verbal rule production) were able to perform well under pressure. Novices trained with verbal rules were contrastingly fragile under stress. These results, and similar findings elsewhere (Maxwell et al., 2000) indirectly support Reinvestment Theory, which blames choking on a reliance on verbal rules under pressure. The implicit learning approach sounds useful as a premeditated intervention;
however, implicit learning under cognitive load is slow (Maxwell et al., 2000), perhaps
because working memory is important for motor learning (MacMahon & Masters, 2002).
This problem is predictable under traditional skill acquisition frameworks (Anderson, 1982;
Fitts & Posner, 1967; Logan, 1988), in which verbal encoding is regarded as essential in the
ey early stages of learning. Similarly, according to deliberate practice theory (Ericsson, 2003),
mastery requires constant updating of verbal rules.

Two alternative implicit learning approaches avoid the issue of slow skill acquisition.
The first is learning by analogy. This approach involves guiding motor skill learning with
relatable imagery, for example, learning a topspin table tennis forehand by moving ‘the bat as
if it is traveling up the side of a mountain’ (Poolton, Masters, & Maxwell, 2006, p.681). In
one evaluation of this method, Lam et al. (2009) instructed novices to take basketball shots
‘as if you are trying to put cookies in a cookie jar’ (p.344) or with technical instructions. The
analogy learning group learned at a comparable rate, collected less declarative knowledge
and (unlike the technical group) maintained performance in a pressure test. The second
implicit learning alternative is called errorless learning. This approach, taken from cognitive
psychology, involves acquiring knowledge in circumstances in which errors are prevented
(Kessels & Haan, 2003). In one evaluation, Maxwell, Masters, Kerr, and Weedon (2001) had
novice golfers commence putting practice very close to the hole (labelled the errorless
learning group) or two metres from the hole (labelled the errorful learning group). The
errorless group progressively putted from further distances while the errorful group
progressively moved closer to the hole. The errorful group developed more verbal rules and
suffered under cognitive load. In contrast, the errorless group developed fewer rules and were
impervious to cognitive load. Investigators are yet to demonstrate protection against choking
from errorless learning, hence, this remains a topic for future research.
**Mindfulness and commitment approaches.** A contemporary alternative to Cognitive Behavioural Therapy in the mainstream treatment of clinical disorders (e.g., abnormal anxiety) are mindfulness and commitment (MAC) approaches (e.g., Hayes & Strosahl, 2004). In the sporting context, MAC therapy departs from more traditional psychological skills training (e.g., positive self-talk, imagery, arousal control) by making no specific attempt to lessen negative thoughts or feelings (Gardner & Moore, 2004). Instead, energy is invested in changing an athlete’s relationship with negative thoughts or feelings (Bernier et al., 2009) – essentially, becoming less engaged with them. The athlete is encouraged to develop a non-judgmental awareness of his/her mental state (Gardner & Moore, 2012). This skill is developed with mindfulness exercises designed to a) create psychological space from negative thoughts (e.g., naming or characterising certain thoughts) and b) reinforce that positive action can coincide with negative emotional states (Harris, 2011). This might lessen negative thoughts and feelings, but that is not the goal. The treatment of distraction and self-focus are both in the scope of MAC. Successful learning of non-judgmental awareness is thought to result in both more task immersion and less self-consciousness (Gardner & Moore, 2004).

Perhaps due to its recency, published applications of MAC to sport are in short supply. In one example, Bernier et al. (2009) integrated MAC with elite junior golfers. Over three months, golfers incorporated awareness of external states (e.g., scanning the environment) and internal states (physiological and psychological states) into their PPRs and practiced committing to an external focus (e.g., the target) regardless of those states. The most convincing result was that the MAC group elevated their national ranking relative to no-treatment controls. In another example, Gardner and Moore (2012) described an unpublished randomised control trial involving two NCAA Division I athletic departments. An MAC
treatment group showed more improvement (as judged by coaches) compared with a group receiving more traditional psychological skills training (e.g., positive self-talk).

Two findings from chapter 4 encourage the use of MAC as a treatment for choking. First, golfers associated worry about the outcome with conscious control. MAC offers tools to erode the connection between negative emotion (e.g., worry about the outcome) and any particular behaviour (e.g., steering the ball). Second, losses of trust/commitment emerged as a theme among golfers explaining past chokes. MAC is specifically focused on developing committed action in any emotional state. Given a) the potential coupling of outcome-based worry and conscious control issues identified in chapter 4; b) the issues of trust/commitment identified in chapter 4 and elsewhere (Gucciardi et al., 2010) and c) evidence that MAC can generally boost athletic performance, there is merit in further evaluation of MAC amongst choking-susceptible performers.

**Quiet Eye (QE) Training.** Since longer QE periods are associated with better performance in aiming tasks, a logical follow-up is to examine if deliberately lengthening the QE can bring about these desired results. In the first step, Vine and Wilson (2010) demonstrated that lengthening the QE was teachable. Over eight days, they taught one group of novice golfers (the QE group) to use a structured fixation pattern that included a lasting QE before, during and after execution. Over the same period, they taught a second group to putt with traditional technical instructions (the technical group). The authors found that the QE group exhibited longer QE periods than the explicit group and (unlike the explicit group) maintained performance under pressure. Vine and Wilson (2011) obtained similar results with novice basketball players shooting free-throws. The QE trained group elevated their performance (and their QE duration) above a technical instruction group in a retention test and under pressure. Encouraging results have also been obtained with experts. Using an elite sample of golfers, Vine, Moore, and Wilson (2011) either trained participants to use a longer
QE and offered gaze behaviour feedback (the QE group) or simply offered gaze behaviour feedback (the control group). The QE group outperformed controls in a pressure putting test (in the laboratory) and showed (unlike controls) significant putting improvement over 10 rounds of competitive golf. While the results of QE training appear promising, it is unclear that the QE drives the benefit. Training a longer QE could stabilise the movement (Gallicchio et al., 2018), leading to better performance. Apart from simply improving the motion, this might help to avoid premature examination of the results (Figure 6.3 – Distracted Action pathway).

**Hand contractions (hemispheric priming).** Some researchers are investigating a possible short-cut to better performance under pressure by manipulating brain activity with hand contractions (Beckmann, Gröpel, & Ehrlenspiel, 2013; Cross-Villasana, Gröpel, Doppelmayr, & Beckmann, 2015; Gröpel & Beckmann, 2017). In one study, Beckmann et al. (2013) had one group of (right-handed) soccer experts squeeze a ball with their left hand and another group squeeze a ball with their right hand, before taking pressurised penalty shots. Compared to a control group (no-squeezing), the left-hand group maintained performance under pressure whereas the right-handed group’s performance suffered. The effect has been replicated with badminton experts (in the same study, Beckmann et al., 2013) and with gymnasts (Gröpel & Beckmann, 2017). The operating mechanism is unclear. Generally speaking, a reduction in left-hemisphere activity is associated with superior aiming performance (e.g., Janelle & Hatfield, 2008). Contracting the left hand is known to generally increase activity in the right brain hemisphere (Kim et al., 1993). Activating the right hemisphere might prime useful motor-related process (Beckmann et al., 2013) or lead to left hemisphere noise reduction (Gröpel & Beckmann, 2017). There is also evidence that left hand contractions (and not right hand contractions) produce a prolonged reduction in cortical activity (i.e., higher alpha power) over the entire scalp (Cross-Villasana et al., 2015). Cortical
relaxation is also associated with superior perceptual-motor performance (Hatfield et al., 1984). In the context of the attentional theories, the use of hand contractions is regarded as a method to inhibit self-focus (Gröpel & Mesagno, 2017), since a reduction in analytical (i.e., verbal) processing is hypothesised. However, it is feasible that this verbal processing could be devoted to distracting features of the situation, such as the prospect of failing. Further work is necessary to understand the effects, though the intervention evidence to date appears promising.

In this section, a series of ways to treat choking were examined. For each intervention, inconsistent results and/or a shortage of published evaluations remain an issue, although one that is potentially resolvable with ongoing work. Each of the treatments described has been connected to self-focus or distraction, implying that the success of the intervention is driven by a specific avoidance of distraction or self-focus. For example, the PPR is preferentially considered a distraction-based intervention because it helps to avoid off-task focus, whereas hemispheric priming is preferentially considered a self-focus-based intervention because it helps to avoid verbal-analytic processing. However, in most cases, there is reasonable argument that the intervention is alternatively (or additionally) avoiding the other mechanism. Designing a treatment that works does not require a precise understanding of the causes of choking, but it could help. For example, understanding when off-task thought is most damaging (e.g., in preparation or execution) could inform the best transfer of training treatment. Likewise, understanding the ultimate reason that a motor skill fails under pressure could help to develop a better PPR, in which resources are deployed more strategically. This might mean, for example, that the performer devotes more resources towards attaining a committed execution mindset and less to features like temporal or behavioural consistency.
Summary of thesis

Using the example of golf, this thesis a) revisited dual-task and self-report work on choking by closely examining the mental events along the preparation-execution timeline b) assessed if pressure impacted preparation behaviours and consequent performance and c) mapped the plausible chain of events between impaired mental preparation and motor skill failure in self-paced sport. Doing so resulted in several contributions to the existing research on choking. First, cognitive load during preparation was discovered to impair golfers’ ability to control distance on shots requiring conscious calibration. This demonstrates that a distracted preparation can harm some aspects of expert motor skill performance. Future work might examine if manipulated pressure exacerbates the problem. Second, the relationship between inference in preparation and impaired distance control was found to be complex. Cognitive interference in preparation appeared to disrupt high-level cognition (e.g., poor decisions) at some times and disrupt execution quality at others (e.g., affect timing). Future research might use more advanced kinematic analyses to index execution quality and also sketch how impaired motor preparation triggers a poor result. Third, asking golfers to consider pressure-affected processing in preparation and execution uncovered new self-report evidence that golfers a) recognise self-focus as an important contributor to choking and b) intertwine concepts of distraction and self-focus in explaining choking. These findings challenge the accepted stance that self-focus is an unusual explanation for choking and the idea that distraction and self-focus are competing concepts. From the same study, evidence was gathered that losses of trust and commitment (connectable to distraction and self-focus) are important explanations for failure under pressure and that these issues are sometimes deliberately addressed in preparation. Future research might conduct interviews using a similar preparation-execution framework to obtain richer detail. Fourth, detailed analysis of golfers’ routines under lower and higher pressure revealed that a common and potentially
adaptive response to elevated worry was collecting golf shot information over a longer period. Similar flexibility was observed before more difficult shots and when performance levels were relatively high. These results challenge the popular idea that self-paced preparation should be highly consistent. Future research might endeavour to apply more pressure (e.g., stronger evaluation threat) or examine information collection times in actual tournament play to validate the effects. In considering the results of the present and other contemporary findings, four ways that a disrupted preparation could trigger a motor-skill failure were described. Three of the four rely entirely on distraction principles. The fourth proposes that the involvement of self-focus would be late and precipitated by distraction.

Concluding remarks

A number of recent commentators doubt that self-focus and distraction are contradictory accounts (e.g., Christensen et al., 2015; Christensen et al., 2016; Gröpel & Mesagno, 2017). Nevertheless, the collaborative involvement of the two mechanisms is yet to be established. While highlighting several ways that distraction alone may cause choking, this thesis has developed the argument that distraction and self-focus can occur sequentially in the same execution. The proposed mapping of events is that an inadequate cognitive preparation leaves the athlete mentally disorganised at the point of execution and consequently unable to resist conscious interjection throughout the motion. This idea departs from suggestions that task parameters (e.g., the extent that the activity relies on cognition) will dictate whether or not self-focus or distraction causes choking (Beilock & Gray, 2007; Christensen et al., 2016). Even though choking interventions are not reliant on the resolution of the self-focus/distraction debate, understanding the causes would facilitate precise treatments and perhaps explain why a treatment did or did not work. This thesis demonstrates that closer attention to adaptive and maladaptive processing on the preparation-execution timeline can
help to understand the causes of choking, and consequently, signposts a path towards more effective and better understood interventions.
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Appendix I – Fitted vs. Residual plots for models of vertical and horizontal error.

Two methods to correct the structure evident in the HE model were trialled (removing zero cases and the method described in Appendix III). Neither method impacted the results hence the output is not reported. The fitted/residual pattern in the VEls and VEss could also be improved with a square root transformation, but this also did not affect the results.
Appendix II – Considerations in the accuracy of deriving the horizontal and vertical error.

The HE model’s plot of residual/fitted values has a linear structure, caused numerous zero horizontal error values. The zero values were a by-product of lost resolution from deriving the horizontal error from rounded quantities (distance travelled and radial error are rounded to the nearest metre; set distance is a true quantity). Considering Figure 3.8, take a shot where SD=100m, DT=105m and RE=5m. In this case VE=5 and HE=0. However, if the true RE was 5.4999m (still rounded to 5m by the system, leaving the calculated HE at zero), and assuming the true DT was 105m, the HE would be calculated as 2.34. So in the case that the true RE is almost 5.5 but treated as 5, the recorded HE of 0 could have error of up to 2.34m. When the true horizontal error was higher, accuracy increased. For example, if SD=100m, DT=105m and RE=10m, HE= 8.85. If the true RE was 10.4999, HE would be 9.45 – error of up to 0.6m. HE is more severely underestimated as \( true \ RE \rightarrow true \ VE \), hence the pileup of zero HE calculations. VE is different. If SD=100, DT=100 and RE=5m then VE=0.13. If the true RE was 5.49999m, assuming the true DT was100, the VE would be 0.15 – a maximum error of 0.02. VE has the opposite problem. It loses resolution when RE becomes very high, but the issue is not even noticeable until RE reaches about 100m, which never occurred in the study. VE is more severely underestimated as the \( true \ RE \rightarrow true \ HE \).
Appendix III – An alternative horizontal error measure

The alternative HE measure was created by simply adding the signed angle of the swing path (+ for a swing path angling to the right of the target; – for a swing path angling to the left of the target) to the signed angle of the club face (+ for a swing path angling to the right of the target; – for a swing path angling to the left of the target), then taking the absolute value. The mathematical effect provides a useful continuous measure (in net degrees), with the effect that a high number indicates a more laterally errant shot than a low number. The table below displays probable outcomes for the various sign combinations.

<table>
<thead>
<tr>
<th>Swing Path Angle (relative to target; SP)</th>
<th>Face Angle (relative to target; FA)</th>
<th>Probable Result (affected by bounce)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Straight</td>
</tr>
<tr>
<td>0</td>
<td>+</td>
<td>Spins right, finishes right</td>
</tr>
<tr>
<td>0</td>
<td>–</td>
<td>Spins left, finishes left</td>
</tr>
<tr>
<td>–</td>
<td>+</td>
<td>SP&gt;FA: shot spins right, finishes left</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FA&gt;SP: shot spins right, finishes right</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FA=SP: shot ≈ straight</td>
</tr>
<tr>
<td>+</td>
<td>–</td>
<td>SP&gt;FA: shot spins left, finishes right</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FA&gt;SP: shot spins left, finishes left</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FA=SP: shot ≈ straight</td>
</tr>
</tbody>
</table>
Appendix IV – Questionnaire

Open-ended questions have been denoted as OE. Forced-choice questions have been denoted as FC. The subheadings displayed here were not displayed to golfers. In the presentation of the questionnaire, all forced choices were randomised (except ‘other’ options which were always displayed last).

**Demographics**

1) Age in years (OE)
2) Gender (FC)

**Skill level**

3) Choose the category most applicable to you right now (FC):

   (1) Amateur - club golfer (2) Amateur - club and tournament golfer (3) Elite Amateur - state squad or higher (4) Professional - plays part-time (5) Professional – plays full-time unaffiliated (6) Touring professional

4) [only shown to amateurs] What is your exact Golf Australia handicap right now? If handicap is not GA [Golf Australia], please note the system (OE)

**Choking definition and general cause**

5) What does the phrase ‘choking under pressure’ mean to you? (OE)

6) Choking can be defined as ‘a significant drop in performance under pressure’.

   Consider a time when you were playing competitive golf and you had an opportunity to achieve a much-desired goal and felt great pressure to perform, but your performance faltered significantly.
What do you think caused your skills to decline? (OE)

Normal preparation - drive

7) Many golfers undertake similar physical behaviours and mental preparations before hitting a shot. When competing, how do you **mentally** prepare for a **drive off the tee**? (OE)

8) Below are some mental preparation activities that you might undertake when preparing for a shot during competition. Choose any which are part of your preparation for a **drive off the tee**:

   (1) Visualisation (2) Focus on intermediate and final target (3) Block negative thoughts (4) Positive self-talk (5) Use cue words (e.g., "target", "process", "smooth") (6) Assess and adjust arousal levels (7) Assess and adjust muscular tension (8) Rehearse swing thoughts for execution (9) Rehearse swing feelings for execution (10) Focus on breathing (11) Other (please note) (OE)

Normal execution - drive

9) When competing, describe what you normally think about (if anything) in those brief moments between taking the club away and following through (i.e., thoughts during shot execution) when playing a **drive off the tee** (OE):

10) Below is a list of things that you might focus on while executing a **drive off the tee** during competition. Choose those which capture your usual execution focus:

   (1) Ball or ball motion (2) The club or club pathway (3) Tempo (4) Body positioning/motion (feelings related to shoulders, hands, wrists, arms, hips, legs, head) (5) 'Thoughtless' (6) Desired force (7) Target (8) Other (please describe)
Normal preparation – putt

11) Many golfers undertake similar physical behaviours and mental preparations before hitting a shot. When competing, how do you **mentally** prepare for a **short putt**? (OE)

12) Below are some mental preparation activities that you might undertake when preparing for a **short putt** in competition. Choose any which are part of your preparation:

(1) Visualisation (2) Focus on intermediate and final target (3) Block negative thoughts (4) Positive self-talk (5) Use cue words (e.g., "target", "process", "smooth") (6) Assess and adjust arousal levels (7) Assess and adjust muscular tension (8) Rehearse thoughts for execution (9) Rehearse feelings for execution (10) Focus on breathing (11) Other (please note) (OE)

13) When competing, describe what you normally think about (if anything) in those brief moments between taking the club away and following through (i.e., thoughts during shot execution) when playing a **short putt** (FC):

(1) Ball or ball motion (2) The club or club pathway (3) Tempo (4) Body positioning/motion (feelings related to shoulders, hands, wrists, arms, hips, legs, head) (5) 'Thoughtless' (6) Desired force (7) Target (8) Other (please describe)

14) Thinking back to any experiences of choking in competitive golf, describe any changes (from normal) you noticed to your mental preparation (OE):
15) Considering mental preparation, rate the importance of the following possible occurrences as causes of your past choking experiences (FC):

<table>
<thead>
<tr>
<th>Occurrence</th>
<th>Not at all important (0)</th>
<th>Somewhat important (1)</th>
<th>Quite important (2)</th>
<th>Very important (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor club choice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor shot choice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worry about the upcoming shot outcome and its consequences</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worry over your technique for the upcoming shot</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worry about your ability to play the upcoming shot</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Felt like you were rushing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Felt like you were taking too long</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noticed a pre-shot routine change</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Could not generate positive imagery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Felt mentally overloaded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Felt helpless to stop a poor shot</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

16) Thinking back to any experiences of choking in competitive golf, describe any changes (from normal) you noticed to your thoughts during execution (OE).
17) Considering the very brief moments of execution, rate the importance of the following execution occurrences as causes of your past choking experiences (FC):

<table>
<thead>
<tr>
<th></th>
<th>Not at all important (0)</th>
<th>Somewhat important (1)</th>
<th>Quite important (2)</th>
<th>Very important (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tried to 'steer' the ball</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Became too focused on swing mechanics</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Became very aware of swing movements</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Worried about the shot outcome and its</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>consequences during the execution</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doubted technique during execution</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Doubted strategic choices during</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>execution)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Too many thoughts during execution</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Lost focus on desired swing thoughts</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Appendix V – Fitted vs. Residual plots for Drive\textsubscript{prep}, Putt\textsubscript{prep}, Drive\textsubscript{exe} and Putt\textsubscript{exe}.
Appendix VI – Fitted vs. Residual plots for reported open-ended handicap models.

The pileups in the plots above indicate that only certain handicaps were predicted from the inputted data. This reflects the fact that only subset of golfers made the relevant open-ended comments (hence only a subset of handicap values were predictable).
Appendix VII – Fitted vs. Residual plots for the Choke\textsubscript{exe} and Choke\textsubscript{prep} models.
Appendix VIII – Fitted vs. Residual plots for timing models.

The RI model was unable to predict certain values, hence the pileup in several locations.
Appendix IX – Fitted vs. Residual plots for timing-performance models.

All fitted/residual distributions involving radial error (also see Appendix IX an Appendix X) could be improved with a square root transformation, however, this did not affect the pattern of results.
Appendix X – Dispersion tests for Poisson Models

DHARMa (Hartig, 2018) takes a simulation-based approach (similar to bootstrapping) to obtain standardised residual values for mixed-models that are easily interpreted and can be formally tested for overdispersion or underdispersion. DHARMa’s underdispersion test resulted in the following; Screen looks model (dispersion=0.65, p<0.05); Settle model (dispersion=0.84, NS); Rehearse model (dispersion=0.49, p<0.05); Loosen model (dispersion=0.90, NS).
Appendix XI – Fitted vs. Residual plots for behaviour-performance models.
Appendix XII – Fitted vs. Residual plots for behaviour-change models under pressure.
Participant Information Sheet and Consent Form

Project Title: Choking Under Pressure in Self-paced Sport: Revisiting the Effects of Distraction

Investigators:
Leo Roberts, BSc (Hons)
Dr Mervyn Jackson BSc(Hons),MBehSc
Dr Ian Grundy, BSc (Hons),MTech(Information Technology),PhD

You are invited to participate in an RMIT University research project. Please read this sheet carefully and be confident that you understand its contents before deciding whether to participate.

Who is involved in this research project?
The research is a PhD project being undertaken by Leo Roberts, supervised by Dr Mervyn Jackson and Dr Ian Grundy. The project has approval from the RMIT Human Research Ethics Committee.

Why have you been approached?
We have sought your participation as a skilled golfer with a Golf Australia handicap <=5.

What is the project about? What are the questions being addressed?
We are investigating how distraction and pressure affects golfers’ skill preparation and execution. We are interested in (1) your golfing background and experiences under pressure, (2) your accuracy under distraction and pressure conditions in a simulated golf environment and (3) your performance process under those distraction/pressure conditions. We expect approximately 35 golfers to participate.

If I agree to participate, what will I be required to do?
If you choose to participate, there are two components to complete. The first is a web-based questionnaire (approximately 15 minutes long). The second is an experiment at the House of Golf (340 Flinders Street, Melbourne). The experiment takes approximately one hour and requires you to hit 60 shots with your own clubs. Following each shot, you will receive feedback about accuracy and distance obtained. Sometimes you will prepare and execute shots under distracting conditions (while performing a second mental task). At other times, there will be no distraction or you will be offered monetary incentives for superior performance. You will be given a short questionnaire to assess how you are feeling twice during the session. Video will be taken during the experiment because we are interested in your performance process throughout. The images from the video will not be used for publication. Audio will also be taken during throughout the experiment because some distractions will involve you giving a verbal response, and we would like to assess this later. After participation in both components, you will be reimbursed $15 to support travel/parking expenses.

What are the possible risks or disadvantages?
There are no foreseeable physical or psychological risks of participation beyond those experienced in the normal golf practice or play. The data you provide are confidential and can be disclosed only if (1) it is to protect you or others from harm, (2) if specifically required or allowed by law, or (3) you provide the researchers with written permission. Identifying information will only be used to invite you to participate in a second study. Only the researchers listed will be able to identify you for this study.
purpose. The de-identified results of this study will be published in a PhD thesis, held in the RMIT Repository – a publicly accessible online library of research papers. The results may also be published in scientific journals and presented at conferences. In any publication, the data will be grouped such that individuals cannot be identified.

If you are unduly concerned about your responses to any questionnaire items or if you find participation in the project distressing, you should contact Dr Mervyn Jackson as soon as convenient. Dr Jackson will discuss your concerns with you confidentially and suggest appropriate follow-up, if necessary.

What are the benefits associated with participation?
You will receive feedback about the accuracy, distance and quality of your golf shots via the simulation technology.

What will happen to the information I provide?
The research data (questionnaire and golf experiment data) will be held securely on the RMIT server for 5 years. The golf experiment data will be collected at the House of Golf. Upon experiment completion, data will be transferred to and stored on the RMIT server, then deleted from any House of Golf computer system. Please note that this study includes a web-based survey. Users should be aware that the World Wide Web is an insecure public network that gives rise to the potential risk that a user’s transactions are being viewed, intercepted or modified by third parties or that data which the user downloads may contain computer viruses or other defects.

What are my rights as a participant?
As a participant of this research, you have the right to (1) withdraw from participation at any time (2) Request that any recording cease and (3) have any unprocessed data withdrawn and destroyed, provided it can be reliably identified, and provided that so doing does not increase the risk for the participant. If you have any questions relating to the study, please do not hesitate to contact Leo Roberts.

Yours sincerely,

Leo Roberts (BSc (Hons)), Dr Mervyn Jackson (BSc(Hons),MBehSc) and Ian Grundy (BSc (Hons),MTech(Information Technology),PhD)

If you have any concerns about your participation in this project, which you do not wish to discuss with the researchers, then you can contact the Ethics Officer, Research Integrity, Governance and Systems, RMIT University.
Consent Form

I have read the information sheet and agree:

- to complete the questionnaires and experiment outlined
- that my voice will be recorded during the experiment
- that I will be video-recorded during the experiment

In relation to video-recording during the experiment, please note that:

- Images will not be published
- Video will only be used for the current research project
- Not all video that is recorded will be used
- All video, used and unused will be securely stored on the RMIT University Server
- The participant is free to withdraw from the project and to withdraw any video of themselves, prior to the publication of the project report or thesis

I acknowledge that:

(a) I understand that my participation is voluntary and that I am free to withdraw from the project at any time and to withdraw any unprocessed data previously supplied (unless follow-up is needed for safety).
(b) The project is for the purpose of research. It may not be of direct benefit to me.
(c) The privacy of the personal information I provide will be safeguarded and only disclosed where I have consented to the disclosure or as required by law.
(d) The de-identified results of this study will be published in a PhD thesis, held in the RMIT Repository – a publicly accessible online library of research papers. The results may also be published in scientific journals and presented at conferences. In any publication, the data will be grouped such that individuals cannot be identified.

Participant’s Consent

Participant: ___________________________ Date: _______________________

__________________________
(Signature)
Participant Information Sheet and Consent Form

Project Title: Choking Under Pressure in Self-paced Sport: Revisiting the Effects of Distraction

Investigators:
Leo Roberts, BSc (Hons)
Dr Mervyn Jackson BSc(Hons),MBehSc
Dr Ian Grundy, BSc (Hons),MTech(Information Technology),PhD

You are invited to participate in an RMIT University research project. Please read this sheet carefully and be confident that you understand its contents before deciding whether to participate.

Who is involved in this research project?
The research is a PhD project being undertaken by Leo Roberts, supervised by Dr Mervyn Jackson and Dr Ian Grundy. The project has approval from the RMIT Human Research Ethics Committee.

Why have you been approached?
We have sought your participation as a golfer with a handicap of 15 or better

What is the project about? What are the questions being addressed?
We are investigating how distraction and pressure affects golfers' skill preparation and execution. We are interested in (1) your golfing background and experiences under pressure, (2) your performance process under pressure. We expect approximately 100 golfers to participate.

If I agree to participate, what will I be required to do?
A web-based questionnaire - approximately 15 minutes long.

What are the possible risks or disadvantages?
There are no foreseeable physical or psychological risks of participation beyond those experienced in the normal golf practice or play. The data you provide are confidential and can be disclosed only if (1) it is to protect you or others from harm, (2) if specifically required or allowed by law, or (3) you provide the researchers with written permission. Identifying information will only be used to invite you to participate in a second study. Only the researchers listed will be able to identify you for this purpose. The de-identified results of this study will be published in a PhD thesis, held in the RMIT Repository – a publicly accessible online library of research papers. The results may also be published in scientific journals and presented at conferences. In any publication, the data will be grouped such that individuals cannot be identified.

If you are unduly concerned about your responses to any questionnaire items or if you find participation in the project distressing, you should contact Dr Mervyn Jackson as soon as convenient. Dr Jackson will discuss your concerns with you confidentially and suggest appropriate follow-up, if necessary.

What are the benefits associated with participation?
Reflection on own performance process

What will happen to the information I provide?
The research data (questionnaire and golf experiment data) will be held securely on the RMIT server for 5 years. The golf experiment data will be collected at the House of Golf. Upon experiment completion, data will be transferred to and stored on the RMIT server, then deleted from any House of Golf computer system. Please note that this study includes a web-based survey. Users should be aware that the World Wide Web is an insecure public network that gives rise to the potential risk that a user’s transactions are being viewed, intercepted or modified by third parties or that data which the user downloads may contain computer viruses or other defects.

**What are my rights as a participant?**
As a participant of this research, you have the right to (1) withdraw from participation at any time (2) Request that any recording cease and (3) have any unprocessed data withdrawn and destroyed, provided it can be reliably identified, and provided that so doing does not increase the risk for the participant. If you have any questions relating to the study, please do not hesitate to contact Leo Roberts.

Yours sincerely,

Leo Roberts (BSc (Hons)), Dr Mervyn Jackson (BSc(Hons),MBehSc) and Ian Grundy (BSc (Hons), MTech(Information Technology), PhD)

If you have any concerns about your participation in this project, which you do not wish to discuss with the researchers, then you can contact the Ethics Officer, Research Integrity, Governance and Systems, RMIT University.
Consent Form (as presented online)

I have read the information sheet and agree to participate in survey component of the study as it is outlined above.
I acknowledge that:

(a) I understand that my participation is voluntary and that I am free to withdraw from the project at any time and to withdraw any unprocessed data previously supplied (unless follow-up is needed for safety).
(b) The project is for the purpose of research. It may not be of direct benefit to me.
(c) The privacy of the personal information I provide will be safeguarded and only disclosed where I have consented to the disclosure or as required by law.
(d) The de-identified results of this study will be published in a PhD thesis, held in the RMIT Repository – a publicly accessible online library of research papers. The results may also be published in scientific journals and presented at conferences. In any publication, the data will be grouped such that individuals cannot be identified.

☐ Yes

☐ No
Appendix XV – Letter of Ethics approval

17th November 2015

Merv Jackson

Dear Merv,

ASEHAPP 51.15 JACkSON ROBERTS Choking under pressure in self-paced sport: revisiting the role of distraction

Thank you for submitting your amended application for review.

I am pleased to inform you that the CHEAN has approved your application for a period of 2 Years from the date of this letter to 17th November 2015 and your research may now proceed.

The CHEAN would like to remind you that:

All data should be stored on University Network systems. These systems provide high levels of manageable security and data integrity, can provide secure remote access, are backed up on a regular basis and can provide Disaster Recover processes should a large scale incident occur. The use of portable devices such as CD’s and memory sticks is valid for archiving data transport where necessary and for some works in progress. The authoritative copy of all current data should reside on appropriate network systems and the Principal investigator is responsible for the retention and storage of the original data pertaining to the project for a minimum period of five years.

Please Note: Annual reports are due on the anniversary of the commencement date for all research projects that have been approved by the CHEAN. Ongoing approval is conditional upon the submission of annual reports failure to provide an annual report may result in Ethics approval being withdrawn.

Final reports are due within six months of the project expiring or as soon as possible after your research project has concluded.

The annual final reports format can be found at: www.rmit.edu.au/medresearch/human-research-ethics

Yours faithfully,

Dr Linda Jones
Chair, Science Engineering & Health
College Human Ethics Advisory Network

Ct - CHEAN Members: To Van Pong School of Aerospace, Mechanical & Manufacturing Engineering RMIT University
Student Investigators: Lao Robins School of Health Sciences RMIT University
Other Investigators: Ian Grundy School of Mathematics & Geospatial Sciences RMIT University