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Choking interventions in sports: A systematic review

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Choking under pressure, in general, describes suboptimal performance in stressful situations, which has led to two fundamental ‘choking’ models: distraction and self-focus. The purpose of this review was to systematically identify and evaluate theory-matched choking interventions used to alleviate choking. The systematic review includes 44 empirical studies published up to October 2016, including experimental, quasi-experimental, and single-case studies with athletes. These studies encompassed a variety of interventions (n = 13) that were either distraction based or self-focus based. In addition, a third group – acclimatization interventions – was identified. The results indicate that, in general, choking interventions provide a benefit to performance under pressure. The most effective interventions were pre-performance routines, quiet eye training, left-hand contractions, and practicing under self-consciousness and mild anxiety conditions. The use of dual task was beneficial for performance under pressure but harmful when used in training. Mixed evidence was found for analogy learning and null effects were observed for goal setting, neurofeedback training, and reappraisal cues. These results may help athletes and coaches select and implement effective strategies and methods to improve performance under pressure.

Keywords: choking under pressure; skilled performance; self-focus; distraction; intervention

Introduction

Tim Borowski, a German national soccer player, is ready to take a penalty kick. If he fails to score, he would have to serve tonight’s dinner to his teammates. Just before he shoots, however, something strange happens: Tim turns to his coach and teammates and shouts where he will kick the ball. To be sure, he also tells the goalkeeper. Another teammate is behind the goal jumping and waving his hands to distract Tim’s attention. As Tim strikes the ball, the goalkeeper moves immediately to the corner where Tim shouted and where the ball is kicked, but Tim still scores. This is an example of another training day for the German soccer team. By practicing these types of situations, the sport psychologist working with the team aims to adapt players to the performance pressure in case the match ends in a penalty shoot-out. Only days later, Germany beat Argentina 4-2 in a penalty shoot-out to reach the semi-final at the FIFA World Championships 2006. All German shooters, including Borowski, scored (Feikes, Hadding, Kremin, & Spieß, 2006).

Although it could be implied from this example that the previous training was successful, the intriguing question is whether or not such interventions indeed help performers to achieve their best performance in high pressure situations. Given the occurrence of decisive moments in almost every competition, the ability to perform successfully under pressure is a crucial aspect of sport performance (Mesagno & Mullane-Grant, 2010). Is there empirical evidence, however, that interventions actually optimize individual performance under pressure? In this paper, we review the existing literature on "choking under pressure" (referred to simply as *choking* hereafter) interventions and discuss their effectiveness. Generally, choking refers to the occurrence of inferior performance in pressure situations despite the existence of superior skills and individual strivings for best performance (Baumeister, 1984). In sport, choking is commonly linked to motor skill failure in moments when it counts most, such as missing a decisive penalty shot in soccer. In the following paragraphs, we begin by describing choking and underlying mechanisms. After this, we present a systematic review of choking interventions and discuss how to prevent motor skill failure under pressure.

Choking definition

Choking has been initially defined as the occurrence of suboptimal performance in pressure situations (Baumeister, 1984), where pressure refers to any factor or combination of factors that increases performers' anxiety and includes features such as competition, the presence of audience, reward or punishment contingency, and ego relevance (Baumeister & Showers, 1986). Two aspects are inherent in this choking definition: an existent skill and motivation to perform well. A performance can be labelled choking only if it is obvious that the performer had the intention to do better and that better performance would have normally occurred. A missed penalty shot by an unskilled novice, therefore, does not constitute choking, whereas a shot wide of the goal taken by an experienced soccer player may constitute choking. Hence, choking is neither a skill problem nor a motivational problem.

Recently, Mesagno and Hill (2013) initiated a choking definition debate, which was based on Hill, Hanton, Fleming, and Matthews (2009) study, which questioned whether any performance decrement in performance should be classified as choking. Mesagno and Hill explained that improved clarity in the choking definition was needed. During this debate, Mesagno and Hill defined choking as 'an acute and considerable decrease in skill execution and performance when self-expected standards are normally achievable, which is the result of increased anxiety under perceived pressure' (p. 273). This definition is a further extension of other definitions because it attempts to include key components involved in choking (e.g., motivation, skilled performance, increases in the performer's anxiety, and a resulting performance decrease), but Mesagno and Hill cautions that this is only a minimal step in advancing the choking definition until further research is conducted on under-performance and choking differences. Thus, the subsequent systematic review includes studies that either explicitly mention choking or demonstrate a considerable decrease in skill execution (Mesagno & Hill, 2013) in terms of significantly worsened performance in control conditions under pressure.

Choking theories

Optimal performance in sport generally occurs when an athlete focuses attention on relevant information, processes, and behaviours, while concomitantly blocking out irrelevant cues (Nideffer, 1992). According to Nideffer, maintaining focus on relevant cues assists an athlete to optimize performance through appropriate attention processes. The two attention-based models that researchers have formulated are the distraction and self-focus models of choking.

Advocates of the *distraction* based explanations (e.g., Eysenck & Calvo, 1992; Eysenck, Derekshan, Santos, & Calvo, 2007; Hardy, Mullen, & Martin, 2001; Hill, Hanton, Matthews, & Fleming, 2010a; Mullen, Hardy, & Tattersall, 2005; Oudejans, Kuijpers, Kooijman, & Bakker, 2011) suggest that choking occurs because attention shifts from task-relevant to irrelevant cues as a result of heightened anxiety. Athletes who experience choking become distracted easily, resulting in the athlete disregarding important task-relevant cues. Distraction model explanations could be either internal or external distractions. Attention could shift from task-relevant cues to internal distractions (e.g., internal attentional interference effect) whereby worry and explicit self-instruction exceed a threshold of attentional capacity, thereby diminishing the potential attentional space for high level performance to occur (Hardy et al., 2001; Mullen et al., 2005). Alternatively, external distractions (e.g., distraction effect) could allow shifts in attention to other irrelevant external cues when anxiety increases (e.g., distracting fans, crowd noise, etc.). Eysenck et al. (2007) believe that cognitive processing is likely to be diverted to task-irrelevant cues automatically despite whether they are external or internal distractions. Support for the distraction model comes from qualitative research in which athletes reported worries and negative thoughts under high pressure situations and attributed their inferior performance to such distracting factors (e.g., Hill & Shaw, 2013; Oudejans et al., 2011).

Self-focus approaches have largely been expanded from Baumeister's (1984) automatic execution hypothesis. Baumeister explains that choking occurs because, when anxiety increases, the athlete allocates conscious attention to movement execution. This conscious attention interferes with the otherwise automatic nature of the movement execution, which results in performance decline. Masters (1992) then expanded Baumeister's hypothesis to explicit and implicit motor learning by suggesting that the method in which a skill is learned may affect their ability to 'reinvest' in the explicit knowledge gained. Masters' conscious processing hypothesis (or Reinvestment theory as mentioned recently; Masters & Maxwell, 2008) indicates that anxiety encourages attention to shift from task-relevant information toward explicit rule-based knowledge for further conscious controlled processes. To further investigate the conscious processing involved with self-focused attention, Beilock and Carr (2001) found evidence for an explicit monitoring hypothesis, whereby awareness of step-by-step procedures when executing well-learned behaviours under pressure because pressure apparently leads to the conscious control of more complex, procedural knowledge that should already operate automatically outside of working memory. Jackson, Ashford, and Norsworthy (2006) also explained that poor performance occur when an athlete attempts to consciously monitor *and* control movements, rather than monitor movements alone. Thus, advocates of self-focus models of choking believe that the combination of monitoring and controlling skilled performance leads to choking. Support for the self-focus model comes from experimental studies in which participants experienced choking after being asked to focus on the step-by-step execution of a motor task (e.g., Hossner & Ehrlenspiel, 2010; Liao & Masters, 2002; Snyder & Logan, 2013). From the information presented, it appears there is support for both choking models in the perceptual-motor domain and in sport.

Perhaps a reason for the similar results is that these two ‘competing’ theories, as explained in most reviews, are not mutually exclusive but overlap somewhat. Drawing on other choking researchers suppositions (e.g., Buszard, Farrow, & Masters, 2013; Nieuwenhuys & Oudejans, 2012), Mesagno, Geukes, and Larkin (2015) argued that aspects of the distraction and self-focus models could be integrated. That is, attentional shifts toward threatening stimuli using self-focus methods may ultimately be a type of task-irrelevant focus and can be categorized within distraction models, which may lead to overlap of theories. Nevertheless, choking interventions are still being tested within laboratory and real-world settings.

Choking interventions

According to the above models of choking, athletes who experience choking do not ‘lose’ their physical ability, technical skills, and strategic knowledge during an important competition. Rather, they adopt maladaptive attentional processes in response to pressure. In a qualitative research study, Hill et al. (2009) asked applied sport psychologists, who were experts in the field of stress and performance, what potential interventions may help to alleviate choking in sport. Using their applied experiences with elite athletes, the experts primarily suggested general, and not theory-matched, interventions aimed at encouraging a positive appraisal of the situational demands and building self-confidence such as self-talk, imagery, goal setting, attribution re-training, and attentional training, which may be a product of the applied nature of the sample interviewed.

Previous review papers on choking have primarily focused on choking theories and the rationale for the application of these theories to choking prevention and reviewing illustrative intervention studies (Beilock & Gray, 2007; Hill, Hanton, Matthews, & Fleming, 2010b; Mesagno et al., 2015). Mesagno et al. (2015) is the only review, to date, who proposed and reasoned that researchers should focus on developing theory-matched choking interventions for the predominantly supported two choking theories. They classified choking interventions as *‘distraction based’* and *‘self-focus based’*. The aim of distraction based interventions is to prevent internal or external distractions and promote a task-relevant focus of attention during skill execution. These interventions may include the use of pre-performance routines consisting of features such as cognitive and behavioural preparation, deep breathing, cue words, or countdown to performance (Mesagno, Marchant, & Morris, 2008; Mesagno & Mullane-Grant, 2010). A central tenet of self-focus based interventions is to minimize the reinvestment of explicit knowledge and the conscious control of skill execution. This may be achieved through a more distal way such as by minimizing the accumulation of explicit knowledge during skill acquisition (Liao & Masters, 2001; Masters, 2000) or through ad-hoc interventions aimed at diverting attention away from self-focusing thoughts through use of, for example, task-irrelevant dual-tasks (Beilock, Carr, MacMahon, & Starkes, 2002; Mesagno, Marchant, & Morris, 2009).

Although many choking interventions have been proposed, a systematic review of interventions and their effectiveness to alleviate choking is lacking. Empirical research on choking interventions has burgeoned in recent years, which warrants a more comprehensive and systematic review of empirical data. Thus, the purpose of this systematic review was to identify and evaluate choking interventions used to prevent motor skill failure under pressure. The present review includes 44 empirical studies published up to October 2016. The interventions included in this review are those that tested choking within experimentally manipulated or ‘real-world’ performance pressure.

Method

Sources and procedure

The systematic review is limited to empirical articles written in English and published in peer-reviewed journals. It includes both laboratory and field studies, using artificially induced or actual performance pressure, and employing diverse quantitative methodological approaches. A systematic literature search was undertaken on the computerized psychological and sport databases PsycARTICLES (1894 to present), SPORTDiscus (1970 to present), and Web of Science (1898 to present). Keyword combinations used were: TX (*'choking under pressure'* OR *'performing under pressure'* OR *'performance under pressure'* OR *'paradoxical performance'* OR *'skill failure'*) AND TX (*intervention* OR *preventing* OR *prevent* OR *prevention*). Limiters were: Scholarly (peer-reviewed) journals, English language, and empirical study. This search yielded 103 articles. Sifting was carried out in three stages. First, abstracts were read and, of those, all potentially relevant full manuscripts were retrieved (*n* = 32). At this stage, studies were excluded that did not test perceptual-motor skills (accounting for most of the excluded studies), that used participants with low levels of the skills tested, and that did not include a high-pressure condition. The second stage involved searching reference lists of retrieved articles, previous review articles and book chapters, and manual searches in the databases and journals for authors who regularly publish in choking research. This search yielded seven additional research papers, totalling 39 potentially relevant papers with 49 separate intervention studies (eight research papers were multi-study papers). Finally, studies were read and the following inclusion criteria employed to select the final set of articles: effective pressure manipulation (as validated by increased anxiety) or 'real-world' pressure (e.g., actual competition); inclusion of techniques aimed to reduce choking; outcomes included sport behaviours and objective performance. A total of 33 papers (44 studies) fulfilled all inclusion criteria and were thus included in the systematic review.

Studies were initially coded with a bibliography number, but independent samples (*K*) were considered as the unit of analysis in the present review since a few studies (*n* = 9) reported analyses on multiple samples. Sample characteristics, research design, pressure manipulation, performance task, type of intervention, and effect of the intervention are summarized in the Appendix.

Classification of choking intervention

Following Mesagno's reasoning (Mesagno et al., 2008, 2009, 2015; Mesagno & Mullane-Grant, 2010) for theory-matched classification of interventions, choking interventions were organized based on the two choking models. Results concerning distraction based interventions are listed first, followed by findings reporting the effects of self-focus based interventions. In addition to these two intervention groups, a third group of interventions was identified that aimed to adapt individuals to pressure and its effects (and are itemized last). These *'acclimatization'* interventions did not focus on preventing distractions or minimizing self-focus, but rather on reducing the performance-harming effects of pressure that otherwise may lead to distraction or self-focus. The theory-matched interventions were categorized according to the way the authors interpreted how the intervention fit within existing choking models. In such cases where the authors did not state which model the intervention was related to, we used the Mesagno et al. (2015) categorization for that intervention.

Data coding and analyses

Data were analysed to create summary tables (Tables 1 and 2). Sample characteristics (i.e., sample size, age, gender) were summarized using a tallying system and resulted in total counts (see Table 1). The percentage of independent samples presenting each characteristic from the total number of samples was also included. A summary of the literature for each type of choking intervention was determined through a calculation of the percentage of independent samples supporting each effect, based on the significant or non-significant effect (see Table 2). The direction of intervention effects was coded positive (+), negative (–), or no effect (0) on performance under pressure. A sum code was built for each choking intervention based on the following classification system: $K \leq 33\%$ representing no effect; K between 34-59% representing inconsistent or undetermined effect; and $K \geq 60\%$ showing either positive or negative effect (Goodger, Gorely, Lavallee, & Harwood, 2007; Sallis, Prochaska, & Taylor, 2000). In all studies, significance level was set at 0.05 (two-tailed). The measure of effects varied across the studies' statistical methods including the slope of celeration lines (single-case design), *t*-test or Analysis of Variance (ANOVA) group differences (e.g., between intervention and comparison groups), and ANOVA with repeated measures (e.g., between low pressure and high pressure phases).

Results

Study characteristics

The 44 located studies comprised a total of 53 independent samples. A summary of the demographic characteristics of participants and samples is presented in Table 1. In terms of the sample sizes gathered for each of the studies, 47 samples (89%) included between 1 and 50 participants and only two samples (4%) included more than 100 persons. The mean age of participants ranged from 20 to 40 years for over half of the intervention research (K = 31; 59%). Thirty-two samples (60%) comprised experienced athletes, recruited mostly from collegiate sports and nonprofessional leagues. Studies with trained novices (*K* = 18; 34%) were included when the intervention study design required a sample with no initial knowledge of the skill tested such as when investigating implicit learning or quiet eye (QE) training. Two studies (*K* = 3; 6%) did not provide sufficient information about the competitive standard of the participants but reported that the participants were skilled athletes with approximately 10 years of experience (Land & Tenenbaum, 2012; Lautenbach et al., 2015). An analysis of the research design revealed that most studies used experimental designs (*K* = 44; 83%). Of the remaining studies, three studies (*K* = 3; 6%) used quasi-experimental designs and six studies (*K* = 6; 11%) used single-case designs.

The studies eligible for this review included 14 different sports (see Appendix) such as golf (*K* = 21; 40%), soccer (*K* = 7; 13%), basketball (*K* = 5; 9%), tenpin bowling (*K* = 4; 8%), field-hockey (*K* = 3; 6%), darts (*K* = 2; 4%), artistic gymnastics (*K* = 2; 4%), Australian football (*K* = 2; 4%), badminton (*K* = 1; 2%), cricket (*K* = 1; 2%), motor sport (*K* = 1; 2%), tennis (*K* = 1; 2%), table tennis (*K* = 1; 2%), and taekwondo (*K* = 1; 2%). In most of these studies (*K* = 49; 92%), pressure was induced artificially with a combination of reward contingency (*K* = 31), ego relevance (*K* = 22), videotaping (*K* = 20), simulated competition (*K* = 20), the presence of audience (*K* = 9), performing at height (e.g., from a climbing wall; *K* = 2), and a math task (*K* = 1) (see Appendix). Only four studies (*K* = 4; 8%) analysed in-game performance during an actual competition. When further analysing choking interventions, seven studies (*K* = 7; 13%) implemented distraction based interventions, 29 studies (*K* = 33; 62%) implemented self-focus based interventions, and 10 studies (*K* = 13; 25%) used acclimatization interventions. Studies conducted by Balk, Adriaanse, de Ridder, and Evers (2013) and Lewis and Linder (1997) tested both self-focus based and acclimatization interventions using independent samples, and were therefore included in both intervention categories.

Distraction based interventions

All analysed studies within this intervention category (K = 7) implemented a pre-performance routine (PPR) to prevent choking. A PPR has been defined as a set of cognitive and behavioural elements an athlete systematically engages in prior to performance execution, which helps to maintain task-related attention (Cotterill, 2010). In the analysed studies, the content of PPRs consisted of a combination of the following: relaxing, mental imagery, cue words, external focus, and temporal consistency. When assessing the overall effectiveness for PPRs, we found that 5 K (71%) provided evidence for positive effect and 2 K (29%) showed null effect (Table 2).

Of the reported distraction-based studies, four were experimental and three employed single-case designs. Two experimental studies showed no significant effect of PPR on performance under pressure (Hazell, Cotterill, & Hill, 2014; Mesagno, Hill, & Larkin, 2015), whereas studies conducted by Lautenbach et al. (2015) and Mesagno and Mullane-Grant (2010) showed positive effects. In particular, Lautenbach et al. found that tennis players worsened their performance under pressure before they used a PPR, but not after they learned the PPR. Mesagno and Mullane-Grant found that the use of deep breathing, cue words, temporal consistency, and a combination of these (the extensive PPR) improved Australian football players' shot accuracy under pressure, with the extensive PPR having the strongest effect, whereas control participants experienced choking. Regarding the single-case studies, Mesagno et al. (2008) provided three 'choking-susceptible' tenpin bowlers with an individualized PPR. The PPR helped the athletes improve performance by an average of 29% under pressure to an initial, high pressure phase with no intervention. In sum, performance under pressure was either better or the same, but not worse after using a PPR than when no PPR was implemented.

Self-focus based interventions

Within self-focus based intervention studies (*K* = 33), the content of treatments consisted of dual task, QE training, analogy or implicit learning, left-hand contractions, fluency cues, task-irrelevant cues, process goal, and neurofeedback training. Of those, the most tested were analogy or implicit learning (*K* = 5), QE training (*K* = 7), the use of a dual task during performing under pressure (*K* = 7), and left-hand contractions (*K* = 5). Table 2 illustrates the summary of effects for self-focus based interventions on performance under pressure. We found 25 (76%) positive effects and 8 (24%) null effects.

Three of five studies (60%) on analogy or implicit learning showed positive effects. Implicit learning represents a distal choking intervention to minimize the accumulation of explicit knowledge during skill acquisition to reduce the likelihood of reinvestment (Masters, 1992). Masters found that golfers who had acquired golf putting skills without any explicit instructions on how to putt a golf ball (i.e., implicit learning) improved their performance under pressure, whereas those who had received specific instructions during the skill acquisition phase (i.e., explicit learning) worsened their performance. Participants, however, in the implicit learning group learned the golf putting skill rather slow in comparison to the explicit learning group. To accelerate motor skill learning while minimizing explicit rules, Masters (2000) introduced analogy motor learning which uses biomechanical metaphors to teach complex actions (e.g., hitting a table tennis forehand as if ‘drawing a right-angled triangle’). Teaching novice athletes to hit topspin this way, Liao and Master (2001; Study 2) found that the analogy learning group showed the same learning rate as the explicit learning group did, but the former outperformed the latter when performing under pressure. Similar findings have also been reported (Vine, Moore, Cooke, Ring, & Wilson, 2013). In contrast, Schücker, Ebbing, and Hagemann (2010) and Schücker, Hagemann, and Strauss (2013) found no effect of analogy learning among novice golfers.

Regarding QE training, 6 of 7 studies (86%) provided support for this choking intervention. Quiet eye is defined as the final visual fixation toward a relevant target prior to the execution of a movement (Vickers, 2007). Notably, QE training may be considered as a form of implicit learning that can help to limit the explicit knowledge accumulated over time (Vine et al., 2013), thereby reducing the likelihood of reinvestment and choking. In their initial study, Vine and Wilson (2010) trained novice golfers to putt a golf ball using either QE instructions or technical instructions (the control group). Vine and Wilson found no differences in the learning rate between the groups, but the QE group outperformed the control group when putting under pressure. These findings have been replicated and extended with both novice athletes (Moore, Vine, Cooke, Ring, & Wilson, 2012; Vine & Wilson, 2011; Vine et al., 2013) and experts (Vine, Moore, & Wilson, 2011; Wood & Wilson, 2012) indicating robustness of this intervention.

Researchers have also developed interventions for skilled athletes who have already accumulated explicit knowledge during the skill acquisition process. Of these interventions, using a dual task under pressure helped to prevent choking in all seven analysed studies (*K* = 7; 100%). The dual tasks involved either reacting to a tone that sounded on a variable-interval schedule by verbally generating a random letter of the alphabet during performance (Jackson, et al., 2006, Study 1; Land & Tenenbaum, 2012), saying the word 'hit' aloud at the moment a golf club struck the golf ball (Land & Tenenbaum, 2012), counting backwards from 100 by two's (Lewis & Linder, 1997), and focusing attention on the words of a song during basketball free-throw shooting (Mesagno et al., 2009). When performing a dual task, athletes focus attention toward the dual task rather than skill execution, which facilitates the smooth execution of the motor task without the interference of reinvestment and explicit monitoring. Similar to dual task, researchers have also found that using task-irrelevant cues (*K* = 2) such as thinking about a favourite song (Balk et al., 2013) or focusing on colours while golf putting (Gucciardi & Dimmock, 2008) optimized performance under pressure.

Of the remaining self-focus based interventions, left-hand contractions (*K* = 5; Beckmann, Gröpel, & Ehrlenspiel, 2013; Gröpel & Beckmann, 2016) and fluency cues (*K* = 3; Ashford & Jackson, 2010; Gucciardi & Dimmock, 2008) showed positive effects, whereas goal setting (*K* = 3; Jackson et al., 2006, Study 2; Mullen, Faull, Jones, & Kingston, 2015) and neurofeedback training (*K* = 1; Ring, Cooke, Kavussanu, McIntyre, & Masters, 2015) showed null effects. Left-hand contractions (also called 'hemisphere-specific priming') have been proposed to prime the visuospatial processes of the right hemisphere necessary for motor performance and to suppress the analytical processes of the left-hemisphere linked to self-focus (Beckmann et al., 2013; Cross-Villasana, Gröpel, Doppelmayr, & Beckmann, 2015). In all five studies, researchers (e.g., Beckmann et al., 2013; Gröpel & Beckmann, 2016) found that skilled athletes who squeezed a soft ball in their left hand for 30 seconds prior to performing under pressure maintained stable performance under pressure, whereas control participants who squeezed the ball with the right hand experienced choking. Other researchers used fluency cues to prime optimal skill execution (Ashford & Jackson, 2010; Gucciardi & Dimmock, 2008). For example, Ashford and Jackson asked athletes to form grammatically correct four-word sentences (e.g., 'the movement was smooth') from randomly presented five-word items, each of which included a fluency word (e.g., ‘smooth’, ‘spontaneously’, ‘balanced’). Using such fluency primes helped to improve performance under pressure in 2 of 3 conducted studies (67%).

Acclimatization interventions

Within acclimatization intervention studies (*K* = 13), the content of treatments consisted of training under mild anxiety, self-consciousness (i.e., self-focus) or distraction conditions, and with reappraisal cues. The purpose of acclimatization interventions are to adapt athletes to competition pressure and its consequences. We found eight (62%) positive, two (15%) null, and three (23%) negative effects on performance under pressure (Table 2).

Positive effects were found only for self-consciousness and anxiety training. Self-consciousness training (*K* = 4) consisted of practicing golf putting in front of a video camera (Beilock & Carr, 2001; Lewis & Linder, 1997) and paying attention to what part of the foot was used to kick a soccer ball (Reeves, Tenenbaum, & Lindor, 2007). Anxiety training (*K* = 5) was more complex and consisted of punishment contingency for disciplinary and performance failures (Bell, Hardy, & Beattie, 2013) or a combination of videotaping, ego relevance, reward contingency, and the presence of audience (Beseler, Mesagno, Young, & Harvey, 2016; Oudejans & Pijpers, 2009, 2010). All studies with the exception of Beseler et al. (2016) provided positive evidence for the effectiveness of practicing under self-consciousness and anxiety conditions; the Beseler et al. study showed null effect.

Studies with distraction training (*K* = 3) indicated negative effects. Distraction training consisted of practicing with a dual task, such as listening to a recorded list of spoken words and reacting to a target word while practicing golf putting (Beilock & Carr, 2001), and commenting on distraction cues while practicing penalty shots in soccer (Reeves et al., 2007). Each time, athletes worsened their performance in a posttest under pressure.

Discussion

The aim of the current systematic review was to synthesize and evaluate the current choking interventions literature based on theory-matched categories. A total of 53 independent samples among 44 studies were analysed, with most (9 out of 13) theory-matched interventions having a positive (using the sum code score) effect on performance under pressure. For distraction based interventions, the use of PPRs, such as deep breathing or cue words, were helpful for skilled motor performance under pressure. Among self-focus based interventions, quiet eye training, left-hand contractions, and the use of dual task were the most effective interventions. Caution should be used when interpreting the results for the neurofeedback training study considering the limited number of studies (*n* = 1) conducted. The results of the acclimatization samples were more equivocal depending on the training purpose, with anxiety and self-consciousness training having positive effects and with distraction (dual task) or reappraisal training having a negative or no effect, respectively. These results generally indicate that choking interventions provide a benefit to performance under pressure.

Sample characteristics

When analysing study characteristics, we highlight three key points: experimental design, unequal number of studies examining self-focus models, and limited number of studies using elite athletes and real-world competitions. First, it is not surprising that the experimental design is the most widely used considering all studies are investigating interventions to successfully ameliorate choking. Experimental designs are the best method of answering causal questions such as whether a given intervention affects behaviour. Second, it seems from the unbalanced numbers of intervention studies concentrating on self-focused models of choking, researchers have favoured empirical investigations on self-focus explanations more than distraction models. Experimental evidence supports the primary tenets of self-focus explanations (Beilock & Carr, 2001; Gucciardi & Dimmock, 2008; Jackson et al., 2006; Mesagno et al., 2009), however, recent qualitative choking investigations (e.g., Hill et al., 2010b; Oudejans et al., 2011) question the ubiquity of the self-focus model, suggesting that distraction based explanations remain viable. If distraction based explanation are still possible, additional distraction based interventions besides PPRs should be developed to reduce choking. One explanation to why additional distraction interventions may not have been tested yet is that research has not progressed far enough to determine what distractions should be included within distraction models. Finally, most choking intervention studies have used trained novices, club or collegiate participants, with less studies focused on elite athletes. If choking interventions are to progress enough so that we can robustly recommend them to athletes within applied consultations, researchers need to empirically test these interventions with elite athletes in laboratory and real-world competitions.

Pressure manipulation

This investigation included choking intervention studies that predominantly induced pressure artificially with the review comprised of only studies where pressure manipulations were 'successful' at increasing anxiety. That is, studies that did not show a significant increase in anxiety in a high-pressure compared to a low-pressure condition were not included. These would not technically be choking intervention studies because, by definition (e.g., Mesagno & Hill, 2013), a statistically significant anxiety increase was not evident under high-pressure. Furthermore, we included interventions tested in actual competitions because it could be argued that competition is a true pressure situation (Baumeister & Showers, 1986). This inclusion indicates that the effective interventions identified in this review indeed help athletes to perform well under pressure; however, we cannot make any conclusion of whether the same interventions would also be beneficial in situations where athletes are not anxious or pressured to perform.

Although it was not the focus of the present review, we observed that the most effective pressure manipulations were reward contingency, ego relevance, simulated competition, and videotaping, which were mostly applied in combination with each other. This 'combination strategy' may be an important implication for choking researchers because single elements such as reward contingency or videotaping per se need not automatically increase anxiety levels (Gröpel, 2015; Mesagno, Harvey, & Janelle, 2011). For example, video analysis has become an integral part of sports training, and thus many athletes have become accustomed to the presence of a video camera. Indeed, Mesagno et al. (2011) demonstrated that the performance-contingent monetary incentives or presence of video camera alone did not sufficiently increase anxiety, whereas the combination and the addition of an ego relevance instruction did.

Choking interventions

Overall, there was a beneficial effect of using choking interventions to improve performance under pressure, irrespective of the model for which the intervention was matched. The most effective interventions were PPR, quiet eye training, left-hand contractions, the use of dual task, and practicing under self-consciousness and mild anxiety conditions. The dual task intervention, however, seems to have different effects on performance depending on whether used in training or during a competition. While using a dual task was an effective choking intervention during actual performance under pressure, it paradoxically had performance-harming effects when used in learning and training phases. In contrast, enhanced self-consciousness and anxiety are usually detrimental to actual performance under pressure, but practicing under self-consciousness and mild anxiety conditions helped athletes to become more resistant to the otherwise harmful effects of pressure.

In many of the reviewed interventions (e.g., PPR, dual-task, etc.), a short education and development session allows the researcher to engage the athlete on how to apply the intervention to help improve attentional deficits under pressure. Becoming aware of dysfunctional attentional allocation and applying a more functional method of attentional control may help in acute (i.e., non-clinical and occasional) choking experiences, as indicated by the present results. The identified interventions, however, may not be as effective when an athlete has chronic (i.e., repeated) choking episodes. Mesagno and Mullane-Grant (2010) first proposed that perhaps education and development of a PPR, an intervention based largely in attention-based choking models, for performance under pressure may not decrease the likelihood of choking re-occurring if potentially clinical, anxiety-based models underlie the choking response. Simply put, attention-based models may only be a 'Band-Aid fix' for the underlying clinical origins of the anxiety issues the chronic 'choker' experiences.

Mesagno and colleagues (Mesagno et al., 2015; Mesagno, Mornell, & Quinn, 2016) further differentiated between attention- and anxiety-based choking models whereby attention-based choking models focus on what happens to attention when anxiety increases, whereas anxiety-based models attempt to explain the origins of the anxiety increase, which leads to attention shifts and performance decreases. One anxiety-based choking model is the self-presentation model (Mesagno et al., 2011;

2012) which states that anxiety originates from an individual's sensitivity to situational cues, which can affect self-esteem. Development of anxiety-based interventions to counterregulate the rise of anxiety may help 'chronic chokers' to compensate for the 'oversensitivity' from threatening cues and prevent the subsequent maladaptive attentional shifts. Thus, anxiety-based choking interventions should be proposed and explored to contest dysfunctional anxiety-based fears that may ruminate in athletes, but could also be partially supplemented by some of the other attention-based models explained in this systematic review.

Applied Implications

The systematic review was dedicated to understanding the effects of choking interventions on athlete performance and sport psychology researchers will benefit from the dissemination of the knowledge, thus, we also provide applied implications for the current review. We categorized the interventions based on the authors' expectation of choking effects, thus, we recommend that applied practitioners understand the underlying reasons for possible choking effects and attempt to match the particular intervention to the athlete's needs. Furthermore, it may be important to convince athletes of the benefits of the intervention when the athlete attempts to use it. For example, self-focus interventions where diverting attention away from task-relevant thoughts are counterintuitive to an elite athlete's perception of optimal concentration (e.g., dual-tasks) or where it may be difficult for the athlete to understand the reasons for the interventions effectiveness (e.g., left-hand contraction), educating and persuading the athlete about possible adoption of the intervention before implementation in real-world competition should be managed.

Limitations

Although we took every effort in ensuring uniformity within out systematic review, we should also highlight some of the possible limitations. First, we included only peer-reviewed published studies with significant anxiety effects in our review, which limits the amount of studies we retrieved especially with negative effects. Publication bias (an editorial preference for publishing particular, positive findings, leading authors to not submit negative results for publication; Thornton & Lee, 2000) may have affected our results because articles where interventions did not achieve significant performance results were not reviewed favourably (or published) and thus could have led to different effects if unpublished research was included in the systematic review.

Second, we attempted to categorize the choking interventions based on attention-based models, which was challenging considering that all studies did not indicate which model the intervention was best suited to and we could have debated with the authors the categorization of the intervention into the model. For example, QE training was categorized into self-focus choking interventions based largely on the authors' categorization. We could argue, however, that QE training should have be a distraction-based choking models because QE training help to focus attention to relevant cue, which is a key deficit within distraction-based models of choking. Thus, we acknowledge there are some minor limitations in our systematic review.

Future research

Finally, we offer suggestions for future research based on the results of this review. Most of reviewed studies tested the short-term effect of the respective choking intervention, which indicates performance was measured either immediately or within a few days after learning and applying the intervention. It is unclear whether the intervention effect remain stable over a longitudinal period. Researchers may therefore profitably include follow-up measurements in their designs in future studies. Also, future research should specify whether choking-susceptible athletes benefit from the reviewed choking interventions more than other athletes. A few studies (e.g., Mesagno et al., 2008; 2009) focused on choking-susceptible athletes rather than on the 'general' athlete population, showing that performance improved for these choking-susceptible athletes following the intervention, but a moderation analysis of 'choking-susceptibility' on intervention effect has not yet been examined. Thus, researchers may specify whether choking-susceptible athletes may sufficiently benefit from the attention-based interventions, or whether additional (e.g., anxiety-based) interventions should be developed and applied.

The present review identified a number of effective interventions. The intriguing question is whether a combination of these interventions may have a cumulative positive effect on performance under pressure. For example, distraction based interventions, such as PPR, could be combined with self-focus based interventions, such as dual-task or left-hand contractions. Beckmann et al. (2013) reported that athletes perceived left-hand contractions as not being disturbing and easily integrated into their PPRs. Hence, left-hand contractions may become a useful part of athletes' PPRs in addition to imagery, deep breathing, or cue words, which may potentially strengthen the intervention effect.

Finally, benefits of the reviewed interventions and implications of the present review are not limited to sport. The same principles may be applied to other performance under pressure occupations, for example, to musicians performing in front of a large audience, surgeons completing difficult surgical operations, or soldiers during dangerous army operations. In addition, choking interventions may help those who have balance and movement disorders (e.g., persons after a stroke, those with Parkinson's disease) because these individuals may have a higher propensity to consciously monitor their movements, which may likely increase the possibility of movement dysfunctions (Masters, Pall, MacMahon, & Eves, 2007). Furthermore, choking interventions have been efficiently transferred to shooting performance of police officers (acclimatization training; Oudejans, 2008) and keyboard-playing performance of novice musicians (self-consciousness training; Wan & Huon, 2005). A further transfer to other potentially relevant performance and occupations remains an avenue of future research.

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Appendix. Description of reviewed studies.

Reference	Design	Sample		Pressure manipulation	Performance task	Intervention	
		Features	Size (F)			Type	Effect
I. Distraction based interventions							
Hazell et al., 2014	Experimental	Soccer players (*M* = 19.5 yr)	20 (0)	Ego relevance, Videotaping	Penalty shot	Pre-performance routine	0
Lautenbach et al., 2015	Experimental	Tennis players (*M* = 24.0 yr)	29 (14)	Serial subtraction task, Number sequencing task	Tennis serves	Pre-performance routine	+
Mesagno et al., 2008, Case 1	Single-case design	Tenpin bowler (21 yr)	1 Man	Videotaping, Audience, Rewards	Bowling accuracy	Pre-performance routine	+
Mesagno et al., 2008, Case 2	Single-case design	Tenpin bowler (41 yr)	1 Man	Videotaping, Audience, Rewards	Bowling accuracy	Pre-performance routine	+
Mesagno et al., 2008, Case 3	Single-case design	Tenpin bowler (28 yr)	1 Woman	Videotaping, Audience, Rewards	Bowling accuracy	Pre-performance routine	+
Mesagno & Mullane-Grant, 2010	Experimental	Australian football players (22.9 yr)	60 (0)	Audience, Rewards	Football shots	Pre-performance routine	+
Mesagno et al., 2015	Experimental	Tenpin bowlers (*M* = 40.5 yr)	36 (not reported)	Actual competition	In-game performance	Pre-performance routine	0
II. Self-focus based interventions							
Ashford & Jackson, 2010, Study 1	Experimental	Field-hockey players (*M* = 22.0 yr)	34 (18)	Ego relevance, Videotaping	Field-hockey dribbling	Fluency priming	+
Ashford & Jackson, 2010, Study 2	Experimental	Field-hockey players (*M* = 21.5 yr)	30 (14)	Ego relevance, Videotaping	Field-hockey dribbling	Fluency priming	0
Balk et al., 2013*	Experimental	Golfers (*M* = 59.6 yr)	38 (12)	Ego relevance, Videotaping, Competition, Rewards	Golf putt	Task-irrelevant cues	+
Beckmann et al., 2013, Study 1	Experimental	Soccer players (*M* = 24.3 yr)	29 (0)	Audience, Competition, Rewards	Penalty shot	Left-hand contractions	+
Beckmann et al., 2013, Study 2	Experimental	Taekwondo fighters (*M* = 15.6 yr)	19 (6)	Ego relevance, Videotaping	Taekwondo kicks	Left-hand contractions	+
Beckmann et al., 2013, Study 3	Experimental	Badminton players (*M* = 35.6 yr)	18 (6)	Ego relevance, Videotaping, Competition, Rewards	Badminton serves	Left-hand contractions	+

Gröpel & Beckmann, 2016, Study 1	Quasi-experimental	Gymnasts (*M* = 22.9 yr)	28 (15)	Actual competition	In-game performance	Left-hand contractions	+
Gröpel & Beckmann, 2016, Study 2	Experimental	Gymnasts (*M* = 13.8 yr)	21 (21)	Audience, Competition, Rewards	Balance beam performance	Left-hand contractions	+
Gucciardi & Dimmock, 2008**	Experimental	Golfers (*M* = 25.3 yr)	20 (1)	Competition, Rewards	Golf putt	Fluency cues	+
						Task-irrelevant cues	+
Jackson et al., 2006, Study 1	Experimental	Field-hockey players (*M* = 22.2 yr)	34 (19)	Ego relevance, Videotaping	Field-hockey dribbling	Dual task	+
Jackson et al., 2006, Study 2	Experimental	Soccer players (*M* = 20.4 yr)	25 (0)	Ego relevance, Videotaping	Soccer dribbling	Process goal	0
Land & Tenenbaum, 2012**	Experimental	Golfers (*M* = 21.2 yr)	20 (15)	Ego relevance, Videotaping	Golf putt	Dual task (irrelevant to golf putt)	+
						Dual task (relevant to golf putt)	+
Lewis & Linder, 1997*	Experimental	Trained novices (Age not reported)	112 (0)	Rewards	Golf putt	Dual task	+
Liao & Masters, 2001, Study 2	Experimental	Trained novices (*M* = 21.5 yr)	36 (20)	Ego relevance	Topspin hitting (table tennis)	Analogy learning	+
Masters, 1992	Experimental	Trained novices (*M* = 27.2 yr)	40 (not reported)	Ego relevance, Rewards	Golf putt	Implicit learning	+
Mesagno et al., 2009, Case 1	Single-case design	Basketball player (18 yr)	1 Woman	Videotaping, Audience, Rewards	Basketball free throw	Dual task	+
Mesagno et al., 2009, Case 2	Single-case design	Basketball player (19 yr)	1 Woman	Videotaping, Audience, Rewards	Basketball free throw	Dual task	+
Mesagno et al., 2009, Case 3	Single-case design	Basketball player (20 yr)	1 Woman	Videotaping, Audience, Rewards	Basketball free throw	Dual task	+
Moore et al., 2012	Experimental	Trained novices (*M* = 19.6 yr)	40 (not reported)	Ego relevance, Competition, Rewards	Golf putt	Quiet Eye training	+
Mullen et al., 2015**	Experimental	Trained novices (*M* = 19.6 yr)	24 (0)	Ego relevance, Competition	Race-driving task	Process goal (holistic)	0
						Process goal (part)	0
Ring et al., 2015	Experimental	Golfers (*M* = 22.0 yr)	24 (0)	Ego relevance, Competition, Rewards	Golf putt	Neurofeedback training	0
Schücker et al., 2010	Experimental	Trained novices (*M* = 32.7 yr)	51 (18)	Ego relevance	Golf swing	Analogy learning	0

Schücker et al., 2013	Experimental	Trained novices (*M* = 21.4 yr)	41 (18)	Competition, Rewards	Golf putt	Analogy learning	0
Vine & Wilson, 2010	Experimental	Trained novices (*M* = 20.3 yr)	14 (0)	Ego relevance, Competition, Rewards	Golf putt	Quiet Eye training	+
Vine et al., 2011	Experimental	Golfers (*M* = 21.0 yr)	22 (0)	Ego relevance, Competition, Rewards; Actual competition	Golf putt (Lab); In-game performance	Quiet Eye training	+
Vine & Wilson, 2011	Experimental	Trained novices (*M* = 20.5 yr)	20 (0)	Ego relevance, Competition, Rewards	Basketball free throw	Quiet Eye training	+
Vine et al., 2013**	Experimental	Trained novices (*M* = 21.2 yr)	45 (not reported)	Ego relevance, Competition, Rewards	Golf putt	Quiet Eye training	+
						Analogy learning	+
Wood & Wilson, 2011	Experimental	Soccer players (Age not reported)	20 (not reported)	Competition, Rewards	Penalty shot	Quiet Eye training	0
Wood & Wilson, 2012	Experimental	Soccer players (*M* = 20.2 yr)	20 (not reported)	Competition, Rewards	Penalty shot	Quiet Eye training	+
III. Acclimatization interventions							
Balk et al., 2013*	Experimental	Golfers (*M* = 59.6 yr)	38 (12)	Ego relevance, Videotaping, Competition, Rewards	Golf putt	Reappraisal cues	0
Beilock & Carr, 2001, Study 3**	Experimental	Trained novices (Age not reported)	54 (not reported)	Rewards	Golf putt	Distraction training	-
						Self-consciousness training	+
Beilock & Carr, 2001, Study 4**	Experimental	Trained novices (Age not reported)	32 (not reported)	Rewards	Golf putt	Distraction training	-
						Self-consciousness training	+
Bell et al., 2013	Quasi-experimental	Cricket players (*M* = 16.9 yr)	41 (0)	Actual competition	In-game performance	Anxiety training	+
Beseler et al., 2016	Experimental	Australian football players (20.6 yr)	12 (0)	Ego relevance, Videotaping, Competition, Rewards	Football shots	Anxiety training	0
Lewis & Linder, 1997*	Experimental	Trained novices (Age not reported)	112 (0)	Rewards	Golf putt	Self-consciousness training	+
Oudejans & Pijpers, 2009, Study 1	Quasi-experimental	Basketball players (*M* = 23.0 yr)	17 (0)	Ego relevance, Videotaping, Competition, Rewards	Basketball free throw	Anxiety training	+

Oudejans & Pijpers, 2009, Study 2	Experimental	Dart players (*M* = 26.0 yr)	17 (0)	Heights	Dart throw	Anxiety training	+
Oudejans & Pijpers, 2010	Experimental	Trained novices (*M* = 22.5 yr)	24 (8)	Rewards, Heights	Dart throw	Anxiety training	+
Reeves et al., 2007**	Experimental	Soccer players (*M* = 17.5 yr)	37 (37)	Ego relevance, Videotaping, Competition, Rewards	Penalty shot, Breakaway situation	Distraction training	-
						Self-consciousness training	+

Note. F = female participants. Positive (+) was used for positive intervention effect on performance under pressure, negative (-) for negative intervention effect on performance under pressure, and zero (0) for no effect of intervention.
*Studies that tested two interventions in two different categories.
**Studies that tested two interventions within the same category.

Table 1. Summary of samples characteristics.

Characteristics	Samples *K*	%
Sample size		
1	6	11.3
2-20	14	26.4
21-50	27	50.9
51-100	4	7.5
>100	2	3.8
Gender		
Women only	7	13.2
Men only	18	34.0
Combined	17	32.1
Not reported	11	20.8
Mean age (in years)		
<20	11	20.8
20-40	31	58.5
>40	4	7.5
Not reported	7	13.2
Competitive standard		
Trained novices	18	34.0
Collegiate	8	15.1
Club (nonprofessional)	11	20.8
Regional (nonprofessional)	7	13.2
Semiprofessional	4	7.5
Elite (international, Olympic, professional)	2	3.8
Not reported	3	5.7
Design		
Single-case design	6	11.3
Quasi-experimental design	3	5.7
Experimental design	44	83.0
Type of intervention		
Distraction based	7	13.2
Self-focus based	33	62.3
Acclimatization	13	24.5
Total *K*	53	

Table 2. Summary of effects for choking interventions.

Intervention	*K*	Positive effect (+)	No effect (0)	Negative effect (-)	Sum code
Distraction based					
Pre-performance routine	7	5	2		+
Self-focus based					
Analogy/Implicit learning	5	3	2		+
Dual task	7	7			+
Fluency priming/cues	3	2	1		+
Left-hand contractions	5	5			+
Neurofeedback training	1		1		0
Process goal	3		3		0
Quiet eye training	7	6	1		+
Task-irrelevant cues	2	2			+
Acclimatization					
Anxiety training	5	4	1		+
Distraction training	3			3	-
Self-consciousness training	4	4			+
Reappraisal cues	1		1		0

Note. As summary (sum) code, positive (+) was used for percentage $K \geq 60\%$ reporting positive effects; negative (-) for percentage $K \geq 60\%$ reporting negative effects; (0) for no effect.