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The effect of competitive sport anxiety on working memory: A Meta-Analysis

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THE EFFECT OF COMPETITIVE SPORT ANXIETY ON WORKING MEMORY: A META-ANALYSIS

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Resumo

A memória operatória tem sido um conceito central na psicologia cognitiva uma vez que tem um papel funcional em tarefas cognitivas como a aprendizagem, raciocínio e compreensão. No contexto do desporto competitivo, vários estudos se focam em explicar os mecanismos subjacentes às diminuições de performance induzidas pela pressão. No entanto, a relação entre a ansiedade competitiva e a performance em memória operatória ainda não é clara. Assim, o objetivo do presente estudo foi identificar a extensão em que a performance em memória operatória é afetada pela ansiedade na competição desportiva.

Para examinar diferenças do impacto da ansiedade na performance em memória operatória, foi realizada uma meta-análise de 16 estudos empíricos.

Os nossos resultados mostram que a ansiedade afeta negativamente a performance na componente de precisão da memória operatória e tem uma tendência para afetar negativamente a atenção.

Os resultados são então explicados à luz das diferentes teorias mencionadas na literatura, e que tentam explicar os mecanismos que regem a relação entre a ansiedade e a memória operatória.

Palavras-chave: memória operatória, ansiedade, performance, psicologia do desporto

Abstract

Working memory has been a central concept to cognitive psychology as it has a functional role in cognitive tasks such as learning, reasoning and comprehension. In the competitive sport context, several studies focus on explaining the mechanisms underlying pressure-induced decreases in performance. However, the relationship between competitive anxiety and working memory performance is still unclear. Thus, the aim of the present study was to identify the extent to which working memory performance is affected by sport competitive anxiety.

To examine anxiety differences in working memory performance, a meta-analysis of 16 empirical studies was conducted.

Our results show that anxiety negatively disrupts performance in precision component of working memory and has a tendency to negatively affect attention. The results are then explained in light of the different theories mentioned in the literature, which attempt to explain the mechanisms underlying the relationship between anxiety and working memory.

Key-words: working memory, anxiety, performance, sport psychology

1. INTRODUCTION

From an early age, memory has been the subject of investigation by those who wished to study the functioning of the brain and mind. In the 1960s the concept of memory as a unitary faculty began to be undermined by the idea that long-term memory and short-term memory would represent separate systems (Baddeley, Kopelman & Wilson, 2002). Since then, much work has been done in this field and a new model, replacing the simple and unitary concept of short-term memory by a more complex system, was proposed by Baddeley and Hitch (1974). To emphasize its functional importance in cognitive processing the system was called working memory (Baddeley and Hitch, 1974).

The work of Baddeley and Hitch (1974) highlighted the cognitive functions that occur in short-term memory, beyond the simple storage of information (Ferreira et al., 2007). Working memory structures and organizes information allowing the execution of important cognitive functions such as the ability to maintain mental content assets and develop a set of cognitive operations to monitor and control mental operations, select the proper processes and inhibit the inadequate ones, and the simultaneous processing capacity of different elements, establishing a relationship between them. According to these authors (Baddeley & Hitch, 1974), working memory would be composed of three components, without which it would not be possible to execute the cognitive commands described above: (1) the central executive system, seen as the attention control system, playing the general executive role of working memory; and two slave systems, (2) the phonological loop, the component that ensures the temporary storage of verbal material, which requires training or repetition, otherwise this information is likely to disappear in a matter of seconds; and (3) the visuo-spatial sketchpad, functioning in a similar way to the phonological loop, but operating on visual and spatial content. Baddeley (2000, 2007) has since developed the model to include a third storage system, the episodic buffer - a set of executive procedures and processes of anticipation, goal selection, planning and monitoring (Ferreira et al., 2007).

Working memory capacity is essential for important cognitive skills, including reasoning, understanding, and problem solving (Engle, 2002). While related to short-term memory capacity, working memory capacity additionally reflects general executive attention, ensuring that memory is maintained despite interference or distraction. This enables attention control ability in situations involving distractions during memory and

cognition control tasks (Engle, 2002). Working memory capacity is therefore an important individual difference variable and is responsible for a significant portion of variance in numerous general capacity tasks, namely when the ability to control attention to maintain information in an active, quickly retrievable state is required. Greater working memory capacity does mean that more items can be maintained as active, but this is a result of greater ability to control attention, not a larger memory store (Engle, 2002). Thus, according to the author (Engle, 2002), greater working memory capacity also means greater ability to use attention to avoid distraction.

The attentional control theory (ACT) of working memory also concerns working memory as a multi-component system (Badeley & Hitch, 1974) responsible for the permanence of active information in the face of processing and / or distractions in process, but emphasizes the aspect of working memory processing (Furley & Memmert, 2010). Fundamental to the theory is the notion that working memory has a limited capacity that restricts cognitive performance. This theory states that working memory capacity is a general domain measure that reflects individual attention control capabilities (Conway et al., 2005).

According to Kane and Engle (2002), the fundamental principle the ACT is that span tasks, which are reliable and valid measures of working memory capacity, predict complex behaviours due to the general attention control component shared by these tasks and working memory tasks. Kane and Engle (2002) describe controlled or executive attention as an attention span that maintains mnemonic representations (eg action plans, objectives, or task-relevant stimuli) in a highly active state in the face of interference (Furley & Memmert, 2010). For example, Conway, Cowan and Bunting (2001) showed that individuals with high working memory were better able to actively maintain relevant information and block irrelevant information in a dichotomous listening task (Furley & Memmert, 2010).

Considering the importance of working memory as a central cognitive mechanism, it is expected to have a key role in the field of sports (Furley & Memmert 2010). In fact, the concept of working memory is often found in studies explaining the mechanisms underlying pressure-induced decreases in performance (Furley et al., 2010). In particular, the "choking under pressure" phenomenon, that describe situations in which subjects perform poorly than expected, given the level of their skills, received a great deal of attention (Baumeister 1984; Baumeister & Showers, 1986; Beilock & Carr, 2001). For example, Beilock et. al. (2004) explored the cognitive processes that govern the "choking under pressure" phenomenon and state that it occurs in situations where the desire for high-level performance is very high (Beilock & Carr, 2001). Ashcraft and Kirk (2001) suggested that anxiety raises intrusive

concerns about the situation, which occupy a part of working memory capacity that is normally devoted to the execution of skills. Furthermore, studies by Gray (2001) and Gray, Braver, & Raichle (2002) indicate a "double whammy, because anxiety is an unpleasant emotion, and unpleasant emotional states reduce working memory capacity accessible to any visual information. Beilock et. al. (2004) found that, like anxiety, pressure creates mental distractions that compete for a reduced working memory capacity that would otherwise be allocated to the task. Overall these results suggest that compromising working memory causes failures in performing tasks that depend on this system (Beilock et. al., 2004).

In fact, working memory is associated with numerous relevant domains in sports psychology, such as anticipation, perception, attention, decision making and skills acquisition. It allows us to be able to drive the car while monitoring speed, watching the road, or talking to the person next to us. It also allows a basketball player to dribble the ball while being aware of his opponent and his team-mates at the same time, all while assessing whether or not to hoop the ball (Furley & Memmert, 2010).

There is substantial evidence that anxiety reduces working memory accessibility and capacity (Schoofs, Preuß, & Wolf, 2008; Furley & Memmert, 2010). Specifically, in the competitive sport context, Moraes (1990) states that there is evidently a relationship between anxiety and performance, and these seem to vary according to various other factors such as type of sport, task difficulty, athlete's personality trait, environment and audience stimulation. Eysenck and Calvo (1992) described how worry / anxiety and working memory interact to affect performance through the processing efficiency theory (PET), to provide an explanation for the effects of state anxiety on performance. According to this theory, worry-related thoughts seem to occupy the limited attention resources of working memory, and therefore it is less available for the task. Regulation of the effects of anxiety on processing and performance is, according to this theory, performed by a self-regulating control system that responds to indications regarding the level of performance employed in the task (Gaspar, 2011). The theory predicts that the main effects of worry or anxiety are on the central executive, and therefore the effects of anxiety on performance tend to be greatest in tasks that place substantial demands on the treatment and storage capacity of working memory (Eysenck & Calvo, 1992). Therefore, the negative effects of anxiety on cognition arise as a result of thoughts about non-task concerns that deplete working memory support / aids that would normally be accessible (Shackman et al., 2006).

Anxiety can arise in the most varied contexts, and sports competition is no exception. According to Cruz (1996), anxiety in sports performance is presented as a relational process

and a system of interdependent psychological variables and processes, cognitive and motivational in nature, experienced in sports contexts. Additionally, anxiety in sport is experienced in learning moments (training, preparation for competition), in competitions and also in the various assessment situations that occur throughout a performance cycle (Cruz, 1996). Throughout sports, anxiety can arise when the athlete anticipates that he will not be able to successfully respond to the demands of competition (Pena, 2005). Several studies show the high incidence of stress and anxiety in sports settings experienced by many athletes, regardless of age and competitive level. Equally clear are the often-harmful effects on performance (Cruz, 1996). One of the most notable influences of anxiety is the tendency to extract thoughts, to avoid or to escape events (e.g., Frischknecht, 1990, quoted by Pena, 2005). According to Fox, Houston, & Pittner (1983), anxiety has the worst effect on inducing fatigue, which is the direct result of weakness and imbalance in the legs, increased heart rate and irregular oxygen consumption.

Martens (1977) defined competitive anxiety as a construct that describes individual differences in the tendency to perceive competitive situations as threatening and to respond to such situations with varying intensity anxiety state reactions. According to this one-dimensional model of anxiety, sport competition is more threatening for athletes with higher trait anxiety levels than athletes with lower trait anxiety, since, in specific competitive situations, the trait anxiety competitive, represents an important mediator of state anxiety responses. The state of anxiety has thus been subdivided into two components: somatic anxiety and cognitive anxiety (Rushall, 1979; Martens, 1987). This conceptual model of competitive anxiety was later reviewed by Martens et al. (1990), when developing the CSAI-2, recognizing in this new version, the multidimensional nature of competitive anxiety: cognitive anxiety, somatic anxiety and self-confidence. According to these authors (Martens et al., 1990), cognitive anxiety and somatic anxiety represent opposite poles in a cognitive assessment continuum, self-confidence being seen as the absence of cognitive anxiety or, conversely, as cognitive anxiety seen as lacking self-confidence. Somatic anxiety consists of physiological symptoms such as increased heart rate, increased blood pressure, rapid breathing, increased muscle tension. Cognitive anxiety, on the other hand, should be viewed as a series of negative performance concerns that lead to decreased self-confidence and mismanagement of some cognitive processes such as attention, concentration and memory (Cattell & Scheier, 1961).

Particularly, top level competition, for all that is inherent to it, has the potential to generate high levels of stress and anxiety, leading to disruptive consequences in athletes'

performance (Hanin, 2004; Rushall, 1979; Cratty & Hanin, 1980). According to Nordell and Sime (1993), this is because competition in these athletes is seen as a threat to their self-esteem. In his opinion, athletes who view the situational demands of competition as a challenge and a source of excitement feel anxiety as a state that can enhance their performance. According to Cruz (1996), the major difference between athletes is that the most successful athletes have learned to regulate, tolerate and use anxiety more effectively.

Considering the importance of working memory as a central cognitive mechanism (Furley & Memmert, 2010), and its relationship with anxiety (Schoofs, Preuß, & Wolf, 2008), it is essential to systematically investigate the working memory system in sports where competitive anxiety is present. The present meta-analysis aims to clarify how anxiety experienced in a sport context affects working memory performance. In light of PET, which predicts negative effects of anxiety on performance of tasks substantially demanding working memory (Eysenck & Calvo, 1992), we expect to find worst working memory performance in the group with high anxiety. Given that most sports require various higher-order cognitive skills and are performed under extreme stress circumstances (Furley et al., 2010), the present study can provide information on the effects of competitive sport anxiety on working memory performance.

2. METHODS

2.1. Literature search

A computer-based search of the PubMed, Web of Science, and EBSCOhost (including the Academic Search Complete, PsycARTICLES, Psychology and Behavioral Sciences collection) was conducted in April 2019 by two researchers. The search expression was «anxiety AND "working memory" AND sports» AND «anxiety AND "working memory" AND competition». The search was limited to titles and abstracts. A total of 73 non-duplicated articles were found. Additionally, the references of the included articles were searched manually to identify other relevant studies (n=16).

2.2. Selection criteria

Studies assessing anxiety in a competitive context and studies assessing components of working memory, or working memory in specific (criterion 1) were included. Also, only studies that allowed effect size data (i.e., sample sizes, means, and standard deviations) to be directly recorded, calculated, or measured (i.e., from a graph) were included. Studies that did not present descriptive statistics and the information requested was not provided, were excluded (criterion 2). After screening for relevant studies (n=73), considering the title and abstract, two researchers read the full-text of the studies that were retained (n=34) and, independently, decided their eligibility for further analysis. Detailed information on the study selection process is described in Figure 1.

2.3. Recorded variables and data collection

The data of each included paper were added to an extraction sheet, developed for this meta-analysis and refined when necessary.

When present, the following variables were extracted from each paper: sample size, experimental design, and performance measure of working memory component. In this study we discriminated performance in terms of precision and attention and we considered that precision was measured by accuracy in passes, targets and throws, and attention by the response time and fixations (number and duration).

The studies using a between-subjects experimental design had a sample of low anxiety subjects and high anxiety subjects, whose performance was compared. In studies with a within-subjects design, participants experienced low and high anxiety conditions when performing the tasks.

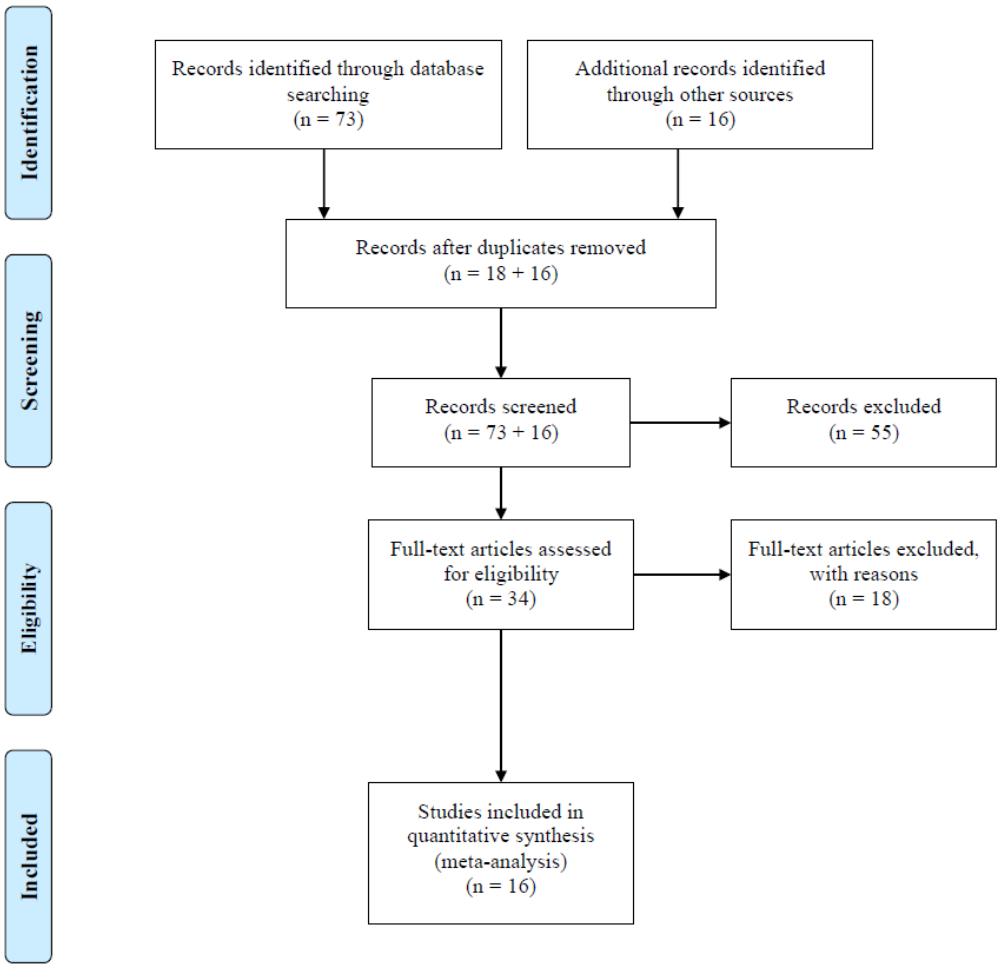


Figure 1

PRISMA Flow Diagram

2.4. Statistical analysis

The Standard Mean Difference (SMD), based on Hedges' adjusted g formulation, was used to assess the association between the two variables of interest, i.e., how much anxiety-groups' performance differ on a working memory task. The SMD was pooled across studies to derive an estimate of the mean (i.e., effect size based on Hedges' g), with each effect

weighted for precision to correct for sampling error. To do so, a random-effects model was adopted.

Heterogeneity across the studies was tested using the I^2 and Q statistics. The characteristics of the studies included in the meta-analysis are detailed in Table 1. Publication bias was assessed by visual inspection of the funnel plot.

The unrestricted maximum likelihood random-effects meta-regression of the effect size was performed for testing experimental design as moderator.

Statistical analyses were performed using Cochrane Collaboration Review Manager 5.3 (The Nordic Cochrane Centre, The Cochrane Collaboration, 2014) and SPSS version 22.0 (IBM Corp, 2013) software.

Table 1

Characteristics of the studies included in the meta-analysis

Study	Title	Performance Measure	Design	Sample Size		
				Low Anxiety	High Anxiety	Total
Alarcon et. al. (2018)	Mental workload impairs the pass precision in soccer players	Precision	Within-subjects	×	×	28
Angelidis et. al. (2019)	I'm going to fail! Acute cognitive performance anxiety increases threat-interference and impairs WM performance	Attention, Precision	Between-subjects	41	45	86
Causer et. al. (2011)	Anxiety, movement kinematics, and visual attention in elite-level performers	Precision	Within-subjects	×	×	16
Ducrocq et. al. (2017)	Adaptive Working Memory Training Reduces the Negative Impact of Anxiety on Competitive Motor Performance	Precision	Between-subjects	15	15	30
Ducrocq et. al. (2016)	Training Attentional Control Improves Cognitive and Motor Task Performance	Attention, Precision	Between-subjects	11	11	22
Englert & Oudejans (2014)	Is choking under pressure a consequence of skill-focus or increased distractibility? Results from a tennis serve task	Precision	Between-subjects	28	25	53

Table 1 (continued)

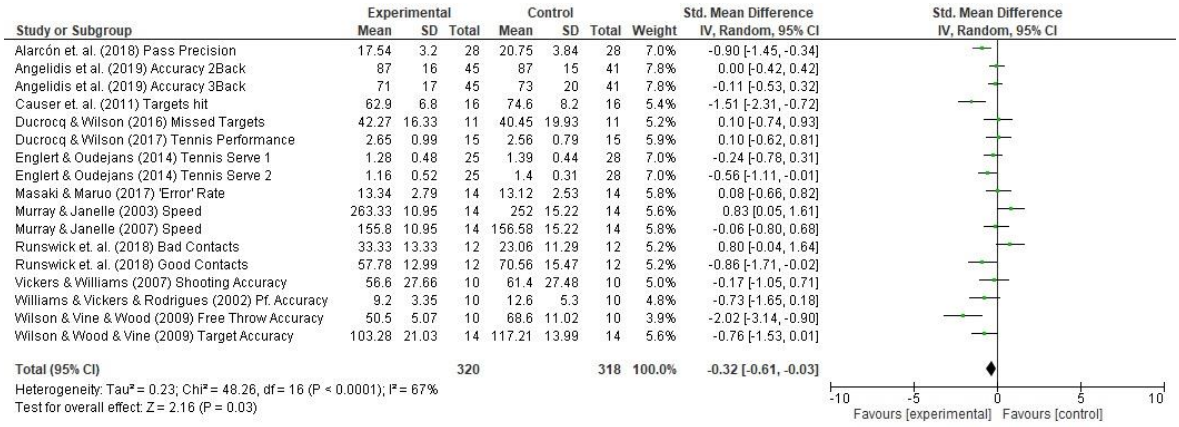
Han et. al. (2014)	Anxiety and attention shifting in professional baseball players	Attention	Within-subjects	×	×	33
Jackson et. al. (2006)	Attentional focus, dispositional reinvestment, and skilled motor performance under pressure	Attention	Within-subjects	×	×	34
Masaki et. al. (2017)	Neural Correlates of Choking Under Pressure: Athletes High in Sports Anxiety Monitor Errors More When Performance Is Being Evaluated	Attention, Precision	Between-subjects	14	14	28
Murray & Janelle (2003)	Anxiety and performance: A visual search examination of the Processing Efficiency Theory	Attention, Precision	Between-subjects	14	14	28
Murray & Janelle (2007)	Event-related potential evidence for the processing efficiency theory	Attention, Precision	Between-subjects	14	14	28
Runswick et. al. (2018)	The effects of anxiety and situation-specific context on perceptual-motor skill: a multi-level investigation	Attention, Precision	Within-subjects	×	×	12
Vickers & Williams (2007)	Performing under pressure: The effects of physiological arousal, cognitive anxiety, and gaze control in biathlon	Precision	Within-subjects	×	×	10
Williams et. al. (2002)	The Effects of Anxiety on Visual Search, Movement Kinematics, and Performance in Table Tennis: A Test of Eysenck and Calvo's Processing Efficiency Theory	Precision	Within-subjects	×	×	10
Wilson et. al. (2009)	Anxiety, attentional control and performance impairment in penalty kicks	Attention, Precision	Within-subjects	×	×	14
Wilson et. al. (2009)	The influence of anxiety on visual attentional control in basketball free throw shooting	Precision	Within-subjects	×	×	10

3. RESULTS

The combined effect sizes showed that participants of the high anxiety group performed worst on the precision component of working memory than participants of the low anxiety group (*M*=-0.32; see Figure 2). Regarding the performance on the attention component, no significant differences were found between the two anxiety groups (Figure 2). Significant heterogeneity was found for both working memory components, indicating that the effects contributing to each of the estimates differ substantively (Figure 2).

The meta-regression analyses showed no significant association between participants' performance by anxiety-group and experimental design as moderator on precision (Q(1) = 0.55, p = .458) and attention performance (Q(1) = 0.02, p = .893).

Precision



Attention

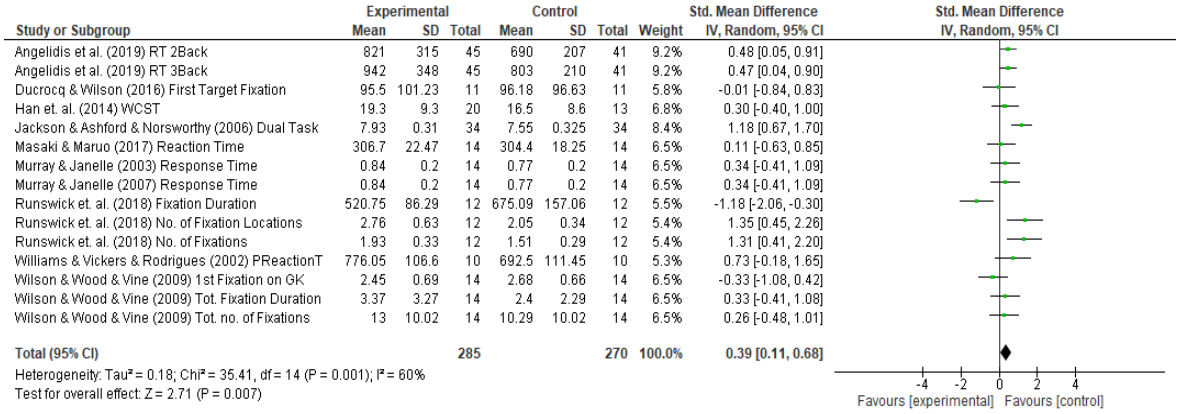


Figure 2. *Forest plots for the random-effects meta-analysis on the anxiety effects on working memory components*

Visual inspection of the funnel plots showed no asymmetry for the included studies across working memory components, indicating the inexistence of publication bias (Figure 3).

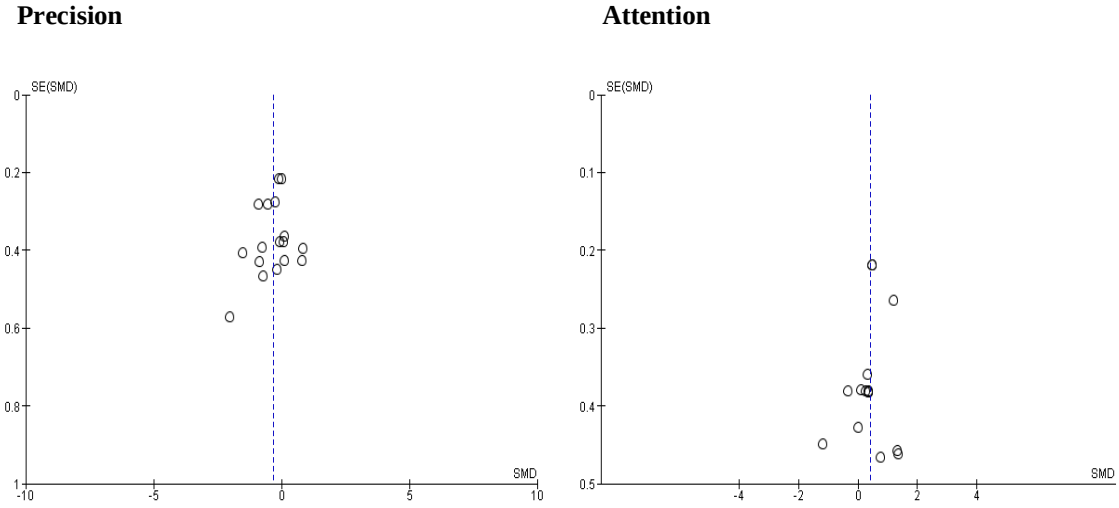


Figure 3. *Funnel plots for the random-effects meta-analysis on the anxiety effects on working*

4. DISCUSSION

The aim of the present study was to identify the extent to which working memory performance is affected by anxiety that arises in a sport context.

Using a meta-analytic approach with a random-effect model, our results reveal a negative effect of competitive sport anxiety on performance in terms of precision and a tendency for a negative effect in attention. In our study, a positive mean effect size in the attention component means that high anxious participants had higher values in the attention measures, which translates to worst performance in the attention component. This is because in the sport psychology context, the measures used to assess attention usually have higher values when impacting negatively on performance. For example, higher response time was exhibited by the high anxiety group, compared to the low anxiety group in Murray & Janelle studies (2003, 2007), indicating a negative effect of anxiety on attention in the first group. It

should be noted that the effect of anxiety on the attention component of working memory was almost significant (Figure 2) and possibly would reach significance with a larger number of studies.

These findings are consistent with the literature referring that anxiety disrupts working memory, leading to worst performance. Eysenk, Derkshan, Santos & Calvo (2007) assum that the effects of anxiety on cognitive processing focus on the central executive component of Baddeley's (1986, 2001) working memory system. The authors claim that Processing Efficiency Theory (PET) and Attentional Control Theory (ACT) best explain this assumption.

The PET provides a mechanistic explanation for how anxiety may influence performance through its impact on attentional resources (Wilson, 2008) by postulating that cognitive anxiety in the form of worry influences performance by pre-empting storage and processing resources from working memory, producing performance decrements in tasks that impose high levels of mental demand (Eysenck, 1992).

The ACT assumes that the effects of anxiety on attentional processes are of fundamental importance in understanding how anxiety affects performance (Wilson, 2008). This theory purports that anxiety reduces attentional control by increasing the influence of the stimulus-driven attentional system at the cost of goal directed control. According to this theory, anxiety leads to attention shifts attempting to detect the source of the threat causing the anxiety (Wilson, 2008). In this respect one might argue that anxiety-induced worries held in working memory direct the focus of attention towards threatening stimuli.

Furthermore, other researches account for a different explanation for this phenomenon. According to Beilock & DeCaro (2007), for example, pressure affects well learned sensorimotor skills by causing a reinvestment of attentional resources to step-by-step skill execution. The reinvestment of attentional resources to an automized skill results in dechunking of the movement as a whole into smaller independent units resembling a similar representation of the skill in early learning stages (Masters, 1992).

The Processing Hypothesis (CPH), designed by Masters (1992), is a self-focus theory which proposes that performance deterioration under pressure occurs because the athletes become overly self-conscious, beginning to think about how the skill should be executed. As a result, the attempt to control movements disrupts the normal and automatic processing, and the performance regresses to an earlier stage of skill acquisition. In sum, highly skilled performance will break down in competitive situations because anxiety causes the performer to consciously invest effort in controlling previously learned and automatized movement in

a step-by-step fashion, ultimately interfering with the success of its execution (Masters, 1992).

It has further been suggested that the intensity level of anxiety might not be the most determinant factor for sports performance, but rather the individual's consistency of anxiety intensity across competitions (Raglin, 1992). This suggests that the investigation of single anxiety scores by adopting group comparisons might not be the most appropriate approach when competitive anxiety is to be investigated.

Some athletes may also be consistent in anxiety values across competitions (either low, medium or high) whereas others may vary considerably from competition to competition (Raglin & Hanin, 2000) Hence, it is likely that the impact of anxiety on performance differs depending on the degree of anxiety variability. Research in which pre-competition states are assessed repeatedly across a full season and intra-individual variability explored is lacking (Gould et al., 2002) and, given the multitude of aspects that seem to mediate the relationship between anxiety and performance, further research in this area might be of interest.

Another aspect that is worth mention is the fact that not always has anxiety shown to be disruptive on performance throughout the literature. Some studies show that anxiety can, in fact, be viewed as positive and therefore facilitative on performance, emphasizing the fact that further research in this field is needed to clarify the different aspects involved in the anxiety-performance relationship.

Also noteworthy, is the fact that besides the mobile and flexible methods available to measure visual attention (i.e., gaze behavior; e.g., Behan & Wilson, 2008; Edwards et. al., 2002; Wilson, Vine, & Wood, 2009; Wilson, Wood, & Vine, 2009), it is impossible to directly measure the internal focus of attention of athletes. Another concern is the difficulty of measure attention close to or during actual competition, which is the event of interest. Consequently, most studies use experimental settings with attentional manipulations and artificially induced anxiety that produce only indirect evidence on possible effects of increasing anxiety in internal attention (Oudejans et al., 2001). Future research is needed to explore the attentional mechanisms in pressure circumstances that elicit responses more similar to those taking place in settings in which choking arises under natural conditions (cf. Gucciardi et. al. 2010).

It should be noted that our meta-analysis included studies with different experimental designs (i.e., between- and within-subjects). This could be viewed as a limitation of the study, but no significant effects were found when assessing experimental design as a moderator.

Despite an extensive search for papers of interest, we emphasize that the current meta-analysis is based on a small number of studies and caution is needed when drawing conclusions. Furthermore, the theories mentioned above provide varied and different explanations for the impact of anxiety on performance by focusing on different mechanisms that mediate this relationship indicating that more studies in this field are necessary to unravel this issue and strengthen the existing body of evidence.

Sport offers a fruitful domain for exploring the validity of models developed in other fields, because most sports require various higher-order cognitive skills and are performed under extreme stress circumstances, where the limits of human behaviour and achievement are continually being challenged and extended (Furley & Memmert 2010).

In sum, the present meta-analysis reveals that the literature in this matter is very scattered and limited and there is still much work to be done. We hope, however, to have brought important evidence to light, which may help future research on the cause-effect relationship between anxiety and working memory in a competitive sport context.

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