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**The effect of trait emotional intelligence on working memory across athletic expertise**

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### Abstract

Research attests to the important contributions of emotional, athletic, and cognitive expertise for sport performance. However, little is known regarding the interplay between trait emotional intelligence, athletic expertise, and working memory. The aim of this research was to examine the interplay between working memory (emotional, capacity and ability), trait emotional intelligence and athletic expertise. In total, 437 participants aged between 18 and 27 years with a range of athletic expertise (i.e., non-athlete n = 96, novice n = 92, amateur n = 85, elite n = 83, and super-elite n = 81) completed the Trait Emotional Intelligence Questionnaire Short Form, an Emotion Recognition Task (i.e., working memory-emotional), a Spatial Span Task (i.e., working memory-capacity), and a Spatial Working Memory Test (i.e., working memory-ability). Structural equation modelling indicated a significant positive relationship between trait emotional intelligence and all three components of working memory (i.e., emotional, capacity and ability). Also, this differed over athletic expertise whereby those with more expertise reported larger effects than those with less expertise. These findings suggest that trait emotional intelligence is important for working memory in athletes. Moreover, the link between cognitive and affective processes are increasingly relevant as athletes develop expertise levels.

**Key Words:** *working memory ability; working memory capacity; working memory emotional; trait emotional intelligence; athlete expertise.*

## Introduction

Sport performance is dictated by an athlete's physiological prowess, cognitive expertise and ability to manage emotional information (Scharfen & Memmert, 2019). Research suggests that working memory (i.e., ability to store and mentally manipulate information) is important for sport performance (see Furley & Wood, 2016, for a review of working memory in sport) and may be particularly relevant for elite athlete performance (Moreau, 2013). Individual differences in managing emotional information are also related to an individual's ability to recall and process task specific information (Mikolajczak, Roy, Verstrynge, & Luminet, 2009). Emotional dispositions have been linked to an individual's cognitive processing given that a balance between emotion and cognition are likely to be beneficial for task performance (Gutiérrez-Cobo, Cabello, & Fernández-Berrocal, 2017). One of the most advanced conceptualisations in understanding trait characteristics of emotion is emotional intelligence (Petrides, Pita, & Kokkinaki, 2007). Recent work supports the association between trait emotional intelligence (TEI), a higher-order disposition reflecting competency in managing, utilising, and appraising emotions and emotional information, and athletic expertise (i.e., Laborde, Dosseville, & Allen, 2016; Vaughan & Laborde, 2018). Despite the importance of the separate links between working memory and sport performance, and TEI and sport performance, understanding of the cognitive underpinnings of TEI in athletes is lacking.

A paucity of research outside of sport suggests a positive relationship between working memory and TEI (e.g., Gutiérrez-Cobo et al., 2017). Specifically, higher TEI may facilitate working memory (Mikolajczak et al., 2009). For example, when athletes encounter stressful situations, higher TEI may assist recall of successful strategies thus improving performance. However much of this work is limited in application (e.g., measures of TEI that lack reliability and validity) and oversimplifies the complexity of the constructs (e.g., single

measure of working memory). Whilst research supports the importance of athletic, emotional, and cognitive expertise in sport (Vaughan, Laborde, & McConville, 2019), little is known regarding the interplay between TEI, athletic expertise, and working memory in athletes – a gap addressed in the current study.

### **Working Memory**

Baddeley's (2003) working memory model proposes a system which includes both storage (i.e., short-term memory) and control (i.e., central executive) mechanisms thus critical in using existing knowledge with new information. Undoubtedly, working memory is one of the most important cognitive processes in everyday life (Baddeley, 2003). For example, retaining information in an active state for use in ongoing tasks, such as stringing together thoughts and replies when having a conversation, and remembering coach's instructions for potential offensive moves in team sport (Furley & Wood, 2016). The importance of cognitive processes to athlete expertise and sport performance has been demonstrated in studies examining executive function (e.g., Krenn, Finkenzeller, Würth, & Amesberger, 2018; Vestberg et al., 2017). Executive functions or processes which govern goal-directed and future-orientated behaviour, include shifting (i.e., shifting of attentional resources), inhibition (i.e., withholding a dominant response), and updating (i.e., storing and manipulating information in working memory; see Miyake et al., 2000). Baddeley (2003) reasoned that the ability to retain and update information (i.e., working memory) also governs cognitive control (i.e., the ability to shift and inhibit attention). There is now increasing evidence for the notion that working memory acts as a mechanism in the control of attention in sports (Furley & Wood, 2016).

Athletes are required to process new information and make decisions in relation to stored information under time constraints, highlighting the need for efficient working memory processes (see Furley & Wood, 2016 for a review). In accord, some studies have

demonstrated a positive association between working memory, athletic expertise and sport performance (e.g., Krenn et al., 2018, Moreau, 2013; Vestberg et al., 2017). However, other work has reported no differences in working memory along the expertise continuum (e.g., Buszard & Masters, 2018; Furley & Wood, 2016; Vaughan & Edwards, 2020). The lack of consistency questions the cognitive component skills approach whereby experts report more efficient and effective cognitive processing on standardised cognitive tasks (Scharfen & Memmert, 2019). It is plausible that conflicting findings may be due to methodological inconsistencies, such as lack of an accepted framework of athletic expertise with studies adopting different definitions of expertise (Scharfen & Memmert, 2019). Swann, Moran, and Piggott (2015) identified eight different ways of defining elite/expert athletes from their review of 91 studies of expertise in sport (see Swann et al., 2015, for a review). As such, it is likely that the lack of standardisation among researchers investigating athletic expertise, may contribute to the equivocal results.

Much of the sport literature takes a limited approach in conceptualising working memory. Baddeley (2003) differentiated between the ability (i.e., central executive) and capacity functions (i.e., the episodic buffer) which are rarely concurrently examined in sport. Working memory-ability refers to the manipulation of information as described by the central executive responsible for processes such as updating (e.g., manipulating incoming information and replacing old information; Miyake et al., 2000), whereas working memory-capacity refers to the storage of information whilst in transit (e.g., the amount of information that can be handled as described by the episodic buffer; Engle, 2002). It is suggested that these processes operate in tandem in order to complete both simple and complex tasks (Baddeley, 2003).

Recent neuropsychological work reports that affective stimuli may have specific effects on working memory whereby the manipulation of emotional information is managed

by specific aspects of working memory (i.e., working memory-emotional; Schweizer, Grahm, Hampshire, Mobbs, & Dalgleish, 2013). That is, any stimuli-neutral measure of working memory cannot fully capture the emotionally laden challenges frequently encountered in the complex sports environment (Vaughan et al., 2019). For example, Shih and Lin (2016) reported that recognition of facial emotions resulted in better action anticipation in elite athletes. While research attests to the importance of working memory and emotional recognition to sport performance (e.g., Petri, Bandow, Salb, & Witte, 2019), no research to date has examined working memory-emotional ability in athletes. Assessment of working memory-emotional in athletes will help determine whether there are individual differences in athlete's ability to process neutral versus emotionally-laden information (see Schweizer et al., 2013).

### **Trait Emotional Intelligence**

Although emotions are examined at the state level, emotional intelligence captures stable characteristics in emotion (Petrides et al., 2007). Emotional intelligence describes a cognitive ability responsible for processing and manipulating emotional information for behaviour (Mayer, Salovey, & Caruso, 2008). Emotional intelligence examined as a higher-order personality trait (e.g., TEI), has been shown to have explanatory power in sport (Laborde et al., 2016) and a relationship with cognitive processing in athletes which differs as a function of expertise (Vaughan et al., 2019). Previous work supports the importance of TEI in sport reporting a positive relationship with emotional regulation, performance under pressure, performance satisfaction, more adaptive coping strategies, and practice volume (Laborde et al., 2016; Laborde, Guillén, & Watson, 2017).

However, TEI's association with athletic expertise is inconsistent as no differences (Laborde et al., 2016), and significant differences (i.e., TEI increases with more expertise; Vaughan & Laborde, 2018) have been reported. The contrast in findings may be due to

different operationalisations (e.g., Trait Emotional Intelligence Questionnaire vs Emotional Intelligence Scale, Petrides, 2009; Schutte et al., 1998). Thus, the current work will clarify this inconsistency by using the Trait Emotional Intelligence Questionnaire Short Form (TEIQue-SF) to examine differences across an accepted framework of athletic expertise (Swann et al., 2015).

### **Working Memory and Trait Emotional Intelligence**

The cognitive underpinnings of TEI may offer important understanding regarding their respective contributions to sports performance. For example, similar parts of the brain are involved with emotional recognition and executive functions and modulated by concussion in athletes (e.g., amygdala, hippocampus, and prefrontal cortex; Léveillé, Guay, Blais, Scherzer, & De Beaumont, 2017). Athletes encounter various emotional stressors during competitive performance (Laborde et al., 2016). Research suggests that individuals with higher TEI use emotional related ability to enhance recall in stressful situations resulting in better task performance (Mikolajczak et al., 2009). We reason that it is likely that this relationship is more relevant for those with more athletic expertise who engage in more frequent and challenging competitive situations compared to those with less athletic expertise (Swann et al., 2015). Moreover, Vaughan et al. (2019) reported a positive relationship between TEI and a hot decision-making task (i.e. gambling task) in elite, amateur and non-athletes. The findings demonstrated that elite athletes with higher TEI reported more effective and efficient decisions with less latency compared to those with less TEI.

Research has shown that a balance between cognition and emotion (e.g., individuals with higher emotional regulation who are able to devote more attentional resources to cognitive processes) is linked to better performance, whereas those with lower emotional regulation struggle to process emotional stimuli resulting in an overload in cognitive processing and in turn poorer performance (Gutiérrez-Cobo et al., 2017). Work outside of

sport revealed associations between cognition and emotion using hot (i.e., those with emotionally laden stimuli) and cold cognitive tasks (i.e., those with neutral stimuli). For example, Checa and Fernández-Berrocal (2019) reported that emotionally intelligent individuals scored higher on a hot cognitive task (e.g., Iowa Gambling Task) but not on a cold cognitive task (e.g., Flanker Task). Furthermore, Gutiérrez-Cobo and colleagues (2017) reported significant relationships between an emotionally laden 2-back test of working memory-capacity (i.e., less inaccurate hits) and an emotional intelligence test and the TEI scale. These findings were not replicated in a cold 2-back test of working memory-capacity. The authors suggested that while emotional intelligence and cognition neurologically overlap (e.g., both processes are related to the prefrontal cortex), emotional intelligence may influence task performance independently from cognition, but only on emotionally laden tasks.

Nonetheless, this line of research is limited for two reasons. First the use of a median split to create high and low ability groups is sample specific. Second, and perhaps more importantly, both studies used tasks that could be categorised as either simple or complex and may require multiple executive functions (e.g., decision-making, inhibition, and working memory for the Iowa Gambling Task, Flanker Task, and *N*-back Task, respectively). The use of single measures and lack of a clear theoretical framework of cognition (e.g., Baddeley, 2003) makes comparison across studies difficult. Nonetheless, it is likely given their respective importance to sport performance that TEI, working memory-emotional, working memory-capacity, and working memory-ability are positively related and linked with athletic expertise (Furley & Wood, 2016; Laborde et al., 2016; Gutiérrez-Cobo et al., 2017).

Previous work has indicated a positive relationship between TEI and various measures of working memory-emotional. For example, Austin (2005) reported a positive relationship between the Emotional Intelligence Scale and scores on an emotional inspection

time task (i.e., discriminating between emotional faces). Dodonova and Dodonov (2012) also reported a positive relationship between a self-report TEI scale and the emotional sensitivity task (i.e., recognition of a previously seen or unseen emotional faces). Petrides and Furnham (2003) reported that individuals with higher TEI responded quicker and required fewer phases for the correct identification of facial emotions on a video sequence task of facial expressions (e.g., happiness, surprise, etc.). These initial findings, whilst limited in their operationalisation of TEI (i.e., weak construct validity; Austin, 2005; Petrides & Furnham, 2003), indicate the importance, even at the trait level, of emotional intelligence for information processing and may sit within a larger framework of working memory (i.e., sensory component). Finally, Schweizer et al. (2013) reported that training on a working memory-emotional task improved participant's ability to regulate their emotions, thus indicative of a possible causal link between TEI and working memory-emotional.

It is important to note the distinction between working memory-emotional and the emotional recognition component of TEI. Whilst research suggests a relationship between the two, the constructs are theoretically distinct. Much TEI research utilises self-report measures to gauge emotional regulation whereas working memory-emotional is typically assessed via cognitive tasks tapping unique cognitive (i.e., ability) and non-cognitive (i.e., self-efficacy) characteristics. However, research often reports non-significant relationships between self-report measures of cognition and cognitive ability tests and self-report measures of cognition have also been shown to have overlap with existing personality scales (Herreen & Zajac, 2018). Moreover, researchers propose that the relationship between cognitive abilities and emotional intelligence differ depending on type of cognitive task (Checa & Fernández-Berrocal, 2019; Gutiérrez-Cobo et al., 2017). For example, those with higher emotional intelligence outperformed those with lower emotional intelligence on a hot task (e.g., Iowa gambling task assessing decision-making), whereas no difference between those with higher

or lower emotional intelligence was found on a cold task (e.g., flanker task assessing inhibition; Checa & Fernández-Berrocal; Gutiérrez-Cobo et al.). In the current work we selected a working memory-emotional task requiring participants to recall emotional states after the fact and the TEI scale to capture self-efficacy of emotion related skills, such as self-control. Therefore, we expect a positive association between working memory-emotional and TEI to highlight the cognitive basis of TEI.

### **The Current Study**

In sum, research is unclear regarding the importance of TEI and working memory to athletes (Furley & Wood, 2016; Laborde et al., 2016; Vaughan & Laborde, 2018).

Reconciliation of existing work is difficult due to methodological inconsistencies, such as differences in operationalisation of TEI, and variations in design (e.g., group differences vs. cross-sectional). Previous work has failed to fully capture working memory by examining either the capacity or ability functions (e.g., Krenn et al., 2018; Moreau, 2013; Vestberg et al., 2017), but not emotional. Emotional stimuli have been shown to effect cognitive processing (Schweizer et al., 2013), yet to date no study has examined working memory-emotional in sport. The current work extends and clarifies previous work by providing a complete estimation of working memory in line with Baddeley's (2003) conceptualisation, including a measure of working memory-emotional to detangle the effect of hot (i.e., Emotion Recognition Task) and cold (i.e., Spatial Span Task and Spatial Working Memory Test) tasks, examining the cognitive underpinnings of TEI, and utilising a more appropriate measure of TEI with athletes. We predicted:

1. Individuals with more athletic expertise will score higher than those with less expertise on measures TEI, working memory-emotional, working memory-capacity, and working memory-ability.

2. A significant positive relationship between TEI, working memory-emotional, working memory-capacity, and working memory-ability.
3. This relationship will differ on a function of athletic expertise indicating possible moderation.

## Methods

### Participants

Four hundred and thirty-seven participants were recruited from universities in the \*country removed for review\* ( $M_{age} = 21.47 \pm SD_{age} = 1.91$ ; 58% male). All participants spoke English as a first language and reported no impairments in visual acuity or cognitive function (i.e., RTs within normative range of 0-4000ms for healthy adults on the CANTAB Motion Screening Test). Participants were recruited via sports coaches and university tutors as gatekeepers.

Participants' athletic expertise were classified based on Swann et al.'s (2015) recommendations which resulted in a sample of non-athletes ( $n = 96$ ), novice ( $n = 92$ ), amateur ( $n = 85$ ), elite ( $n = 83$ ) and super-elite ( $n = 81$ ). Swann et al. considers the athletes highest standard of performance, success at the respective highest level, experience at the respective highest level (in years), the competitiveness of the sport in the athlete's country, and the global competitiveness of the sport. Scores are obtained for each of these characteristics and are categorised in line with previous research (e.g., non-athlete, novice, amateur, elite or super-elite; e.g., Vaughan & Edwards, 2020). Participants who fail to score on each criterion are classified as non-athletes. Those classified as athletes participated in a range externally-paced team sports such as basketball, hockey, rugby, and soccer (Singer, 2000). Monte Carlo simulation for estimation of sample size with no missing data, standard error biases that do not exceed 10%, and coverage of confidence intervals set at 95%,

indicated that sufficient power (80%) could be achieved with a sample size of 395 (Muthén & Muthén, 2017).

## **Materials**

The Emotion Recognition Task (ERT), Spatial Span Task (SSP) and Spatial Working memory Test (SWM) from the Cambridge Neuropsychological Test Automated Battery (CANTAB, Cambridge Cognition Ltd) was utilised to assess working memory-emotional, working memory-capacity, and working memory-ability, respectively. The CANTAB has been reported as a robust measure of cognition in sport (Vaughan & Edwards, 2020; Vaughan et al., 2019).

Working memory-emotional was assessed with the ERT. The ERT assesses participants' recall ability to correctly identify six basic emotional facial expressions: happiness, sadness, anger, disgust, fear, and surprise. Participants were presented with a series of computer-morphed images (facial expressions of real individuals) conveying one of the six basic emotions, with the same level of emotional intensity. Two blocks of 90 images were completed, totalling 180 images, with each image displayed for 200ms, then immediately covered to avoid residual processing. Participants were asked to recall which of the six emotions they thought was just conveyed by touching one of the six boxes presented on screen. The outcome measure for this task was the percentage of correctly recalled emotions across trials (i.e., higher scores indicate better working memory-emotional).

Working memory-capacity was assessed with the SSP. The SSP measures visuospatial memory span length. In each trial, there are 10 white boxes on the screen, and the colour of a specified number of boxes changes one by one. Participants were required to reproduce the sequence by touching the same boxes in the same order that the boxes changed colour. If the participant produced the correct sequence, the difficulty increased whereby one more box was added to the sequence. The task started with a two-box sequence and ended

with a nine-box sequence. The outcome measure, referred to as span length, is based on the maximum sequence correctly recalled (i.e., larger sequences indicate higher working memory-capacity).

Working memory-ability was assessed with the SWM. The SWM is a measure of retention and manipulation of visuospatial information. An increasing number of boxes in a random pattern were presented on screen. Participants were instructed to search for tokens, opening boxes by touching them, and advised not to return to a box that had already yielded a token. As participants move through trials the position of boxes changed and the number of boxes increased to increase difficulty. The outcome measure was the number of times the participant started a new search by touching a different box. Lower scores suggest that the participant used a predetermined sequence by beginning with a certain box, and when a token was found, they returned to that box to start a new search (i.e., lower scores indicate more efficient working memory-ability).

Recent work suggests that the Profile of Emotional Competence scale (Brasseur, Grégoire, Bourdu, & Mikolajczak, 2013) may offer a better conceptualisation of emotional intelligence. However, it is yet to be fully validated with athletes despite some use in the literature (Campo, Laborde, Martinent, Louvet, & Nicolas, 2019). For example, Aouani, Slimani, Bragazzi, Hamrouni and Elloumi (2019) provided support only for the two higher-order factors (i.e., interpersonal and intrapersonal factors) via exploratory factor analysis with athletes and did not test the scales one, five or ten factor solutions (Brasseur et al., 2013). Moreover, there is debate regarding the suitability of existing TEI measures with athletes whereby the Emotional Intelligence Scale may lack validity compared to the TEIQue-SF. That is, research suggests that the Emotional Intelligence Scale is unsuitable (Vaughan & Laborde, 2018) whilst both long and short forms of the TEIQue have been validated with athlete samples (Laborde, Dosseville, Guillén, & Chávez, 2014; Laborde et al., 2017).

Therefore, TEI was measured using the Trait Emotional Intelligence Questionnaire Short Form (TEIQue-SF; Petrides, 2009). The 30-item, self-report scale captures four dimensions of TEI to create a composite factor: Well-being e.g., *On the whole, I'm pleased with my life*; Self-control e.g., *Others admire me for being relaxed*; Emotionality e.g., *I often pause and think about my feelings*; and Sociability e.g., *I would describe myself as a good negotiator*. Participants provide responses on a 7-point Likert scale from 1 = *Completely disagree* to 7 = *Completely agree*. Higher scores represent higher TEI. Previous research has supported the scales reliability and validity with athlete samples (Laborde et al., 2014). The short form demonstrates similar performance in comparison to the longer 153-item scale (Laborde et al., 2017) and convergence with other similar scales such as the Profile of Emotional Competence at the global level ( $r = .78$ ; Brasseur et al., 2013). The internal consistency for the total scale was acceptable in the current data ( $\alpha = .82$ ).

### **Procedure**

The study was approved by the university ethics committee in the \*country removed for review\*. First, participants read an information sheet and provided informed consent. Testing was completed individually in designated laboratories under test conditions. Participants undertook the cognitive tests first in a counterbalanced order followed by the TEIQue-SF. Testing was completed on a GIGABYTE 7260HMW BN touchscreen computer running a Pro Windows 8 operating system with a high resolution 13-inch display. Testing lasted approximately 30 minutes. Following testing, participants were debriefed and thanked. Data was retrieved from CANTAB and entered onto the SPSSv24 for preliminary analysis.

### **Design and Analysis**

The study adopted a quasi-experimental design with purposive sampling. Data missing at random (1.1%) was replaced with the item mean using ipsatised item replacement (Tabachnick & Fidell, 2007). Box's M test assessing the variance-covariance matrices of

male and female participants was non-significant thus analyses were collapsed across gender. Age did not correlate significantly with ERT, SSP, SWM or TEIQue-SF scores therefore was not entered as a covariate. Multivariate skewness and kurtosis coefficients (Muthén & Muthén, 2017) indicated no departure from normality ( $p > .05$ ). Descriptive statistics, ANOVA testing differences across expertise groups, and zero-order correlations exploring relationships were requested.

Structural equation modelling (SEM) with MPlus 7.4 (Muthén & Muthén, 2017) was used to examine the relationship between working memory-emotional, working memory-ability, working memory-capacity, and TEI. We selected SEM following Miyake et al. (2002) recommendations to examine executive function data under the same model capturing the unique and shared variance between indexes. The analysis was conducted using robust maximum likelihood estimation (Muthén & Muthén, 2017), with multigroup analysis to assess whether the relationship differed across athletic expertise and indicated possible moderation (See Figure 1). Group differences were explored whereby invariance was tested between a configural model (i.e., the same pattern of factors and loadings across groups), metric model (i.e., invariant loadings), and scalar model (i.e., invariant factor loadings and intercepts). In combination with the likelihood ratio statistic (e.g., Chi-Square [ $\chi^2$ ]), a model was deemed acceptable if the Root Mean Square Error of Approximation (RMSEA) and Standardised Root Mean Residual (SRMR) was .06 or less, and the Comparative Fit Index (CFI) and Tucker Lewis Index (TLI) were .90 or greater (Hu & Bentler, 1999). Chen (2007) suggests that changes below .010 and .015 in the CFI and RMSEA, respectively, would be supportive of an invariant model in relation to the previous model.

## Results

### Preliminary Analysis

Descriptive statistics, ANOVA models, and zero-order correlations were calculated (see Table 1). First, TEI, ERT, and SSP, showed medium positive correlations, whereas SWM showed medium negative correlations with the other variables. Next, ANOVA modelling produced small effect sizes for TEI, ERT, and SSP indicating higher score amongst those with more expertise in comparison to those with less expertise. Scores on the SWM were reversed with lower scores indicating more efficient processes, thus improved performance was again associated with greater expertise.

### Structural Equation Modelling

The hypothesised model yielded unsatisfactory fit, therefore, based on modification indices we allowed correlated errors between ERT, SSP, and SWM. The final model fit was acceptable  $\chi^2 (3) = 20.47, p < .01, RMSEA = .032, SRMR = .031, TLI = .947, CFI = .935$ .

We examined whether this model differed over athletic expertise using invariance testing (see Table 2). Comparison of the configural model (e.g., all parameters allowed to be unequal across groups) against the metric model (e.g., holding loadings equal across groups) indicated significantly poorer fit  $\chi^2 (7) = 10.71, p < .01$  with changes in both  $\Delta RMSEA = .016$  and  $\Delta CFI = .011$ . Comparisons against the scalar model (e.g., constraining factor loadings and intercepts across groups) also produced poorer fit  $\chi^2 (11) = 13.45, p < .01$  with further changes in both  $\Delta RMSEA = .017$  and  $\Delta CFI = .012$ , thus providing evidence of moderation via athletic expertise. Path coefficients of separate multigroup models highlighted differences in estimates across athlete expertise groups. For example, estimates were larger for the super-elite groups indicating a moderating effect (see Table 3).

## Discussion

The present study had three objectives. First, to examine differences across athletic expertise on TEI, working memory-emotional, working memory-capacity, and working memory-ability. Second, to model the relationship between TEI, working memory-emotional, working memory-capacity, and working memory-ability. Third, to determine whether this model differed across athletic expertise (Furley & Wood, 2016; Moreau, 2013; Swann et al., 2015). Results supported our predictions whereby those with more expertise scored higher on TEI, working memory-emotional (measured via the ERT), working memory-capacity (measured via the SSP), and lower on working memory-ability (measured via the SWM with lower scores reflecting more efficient strategy) compared to those with less expertise. Our findings clarify inconsistencies in the literature. Regarding the second and third hypotheses, TEI was positively correlated with working memory-emotional, working memory-capacity, and negatively with working memory-ability indicating the importance of hot and cold cognitive processes, also our model indicated non-invariance between multi-group models suggesting moderation as a function of athletic expertise highlighting the relevance of affective and cognitive expertise to athletes. These differences suggest that participation in elite level sport is at least partially related to better working memory and emotional intelligence (cf. Laborde et al., 2016; Moreau, 2013).

Our findings demonstrate innovation and provide clarity for previous work. For example, the current study is the first to examine athletes working memory-emotional and to suggest a positive association with expertise. Working memory-emotional may facilitate certain cognitive processes, such as anticipation (Shih & Lin, 2016), and may be advantageous for more complex processes such as risk-related decision-making required by elite athletes (Vaughan et al., 2019). While previous research has provided mixed accounts for the association between working memory-ability and working memory-capacity with

athletic expertise (Furley & Wood, 2016; Vestberg et al., 2017) the current data suggests that those with more expertise display more efficient working memory-ability and larger working memory-capacity compared to those with less expertise (Moreau, 2013). This finding indicates that those with more expertise utilise both capacity and ability functions to store and manipulate information in accord with Baddeley's model (2003). The association between working memory and athletic expertise may be explained by a cognitive-engagement hypothesis whereby greater cognitive processing is associated with increased engagement in cognitively demanding physical activities such as those experienced by elite level athletes (de Greeff, Bosker, Oosterlaan, Visscher, & Hartman, 2018).

Similarly, previous research examining TEI differences in athletes across expertise levels has reported inconsistent effects (Laborde et al., 2016; 2017; Vaughan & Laborde, 2018). Our findings align with research suggesting that those with more expertise display greater TEI (e.g., competency in managing, utilising, and appraising emotions, and emotional information). Whilst perhaps not directly related, it is possible that higher TEI may facilitate expertise development indirectly. For example, athletes with higher TEI possess better coping appraisals and see competition as an opportunity to challenge themselves, which in turn develops greater expertise by increasing opportunity for success (Laborde et al., 2016). Moreover, it is possible that partitioning variance based on the framework of expertise provided by Swann et al. (2015) enabled greater precision in detecting effects whereas other work used less robust groupings (Furley & Wood, 2016; Laborde et al., 2016; Scharfen & Memmert, 2019).

To date, much research examining working memory in sport has examined the ability and capacity components separately (Furley & Wood, 2016). This separation may have resulted in a reduced understanding of how these two complimentary processes function together (Baddeley, 2003). For example, dual-process theories used to examine working

memory suggest that attention is regulated by automatic and controlled thinking (Evans & Stanovich, 2013). Automatic processes require little working memory whereas controlled thinking relies on both working memory-capacity and working memory-ability. Whilst elite performance relies on a combination of both automatic and controlled thinking, better working memory is associated with improved sport performance (Buszard & Masters, 2018). The higher scores of elite athletes on working memory-ability and working memory-capacity suggest that these processes increase in parallel with athletic expertise. This aligns with Baddeley's (2003) working memory model describing the ability (i.e., the central executive responsible for processing incoming information considering existing information) and capacity (i.e., the episodic buffer responsible for number of information held short-term) functions of working memory.

The significant relationship between the variables highlight the relevance of hot and cold cognitive processes for TEI. Working memory-emotional and working memory-capacity were both positively associated with TEI, whereas working memory-ability was negatively correlated. Note, that the negative association is in line with expectations indicating a link between more efficient working memory-ability and higher TEI. Previous research suggests that high TEI individuals only perform better on emotionally-laden cognitive tasks (Checa & Fernández-Berrocal, 2019; Gutiérrez-Cobo et al., 2017) which was not supported in the present sample of athletes. Our findings align with previous research highlighting the importance of TEI for information processing (Austin, 2005; Petrides & Furnham, 2003). Our findings, specified to working memory, indicate that recall and discrimination of both hot and cold stimuli is important for performance. It is likely that an emotionally intelligent individual can process and encode emotional information for recall equally across both positive and negative stimuli. Opposed to previous research, which reported that those high in emotional intelligence have better recall of negative stimuli in stressful situations only

(Mikolajczak et al., 2009), perhaps this distinction is less important to elite athletes who may prioritise other cues (e.g., stimuli most important to sport performance; Vaughan et al., 2019). For example, elite athletes regularly experience positive and negative emotions therefore must focus on the most salient performance-related information regardless of valence in order to be successful (Laborde et al., 2016). Thus, increased levels of TEI are likely to help athletes process emotional stimuli, in turn facilitating working memory as highlighted in the current work with higher TEI scores associated with better recall on the ERT.

The present findings, while providing evidence of a cognitive basis of TEI using a valid operationalisation for the sport context (Laborde et al., 2016; Petrides, 2009; Vaughan et al., 2019), also support the notion that a balance between emotion and cognition may result in better performance (Gutiérrez-Cobo et al., 2017). This may be particularly beneficial in the sport environment which is replete with situation-specific, emotionally-laden stimuli which require real-time processing under physical and cognitive pressure. Indeed, increased proficiency in cognitive reappraisal (i.e., manipulating emotional stimuli to facilitate performance; Heilman, Crisan, Houser, Miclea, & Miu, 2010) may result in better performance, and increased TEI may further enhance an individual's ability to reinterpret the emotion-laden situation with greater aptitudes in abilities such as impulse control shown to effect performance (Krenn et al., 2018). The present findings are especially relevant for coaches. For example, training emotional intelligence has shown some promise for sport performance improvements (Campo et al., 2019) and in combination with working memory training (i.e., cognitive training) may be particularly beneficial for athletes (e.g., reducing the negative impact of anxiety on performance; see Ducrocq, Wilson, Smith, & Derakshan, 2017, for an example of working memory training). Adopting an applied perspective, and considering the current findings, coaches could provide training packages aimed at improving

emotional intelligence, working memory, and/or a combination of both, to further improve performance.

The moderating effect of athletic expertise was in line with our expectations. The multigroup analyses suggested that those with more expertise performed better on measures of TEI, working memory-emotional, working memory-capacity, and working memory-ability compared to those with less expertise. Whilst, the current study is the first to examine the interplay between these constructs, there may be some candidate reasons for these findings. First, Baddeley's (2003) conceptualisation of working memory includes multiple components as do other conceptualisations. For example, Logie (2011) specified the importance of different sensory processes (e.g., episodic visual memories) for working memory performance, which may involve emotional competencies. Second, research attests to the importance of emotion for long-term coding (i.e., memory; Kensinger & Corkin, 2003). It is possible that emotion and memory ability interact and facilitate performance via processes such as pattern recognition, which are important for elite athletes (Furley & Wood, 2016; Scharfen & Memmert, 2019; Vetberg et al., 2017). Beyond the scope of the current work, we suggest that future research should test these hypotheses.

### **Limitations and Future Directions**

The present study has several strengths, such as the use of SEM to model executive function data, multiple indexes of working memory, and the novel use of the ERT with athletes. However, findings should be considered in light of some limitation. First, the cross-sectional design does not allow for examination of causality and direction. Similarly, self-report measures may be subject to biases (e.g., social-desirability). Future work should seek to replicate and extend these findings in longitudinal designs with ability measures of emotional intelligence (e.g., Mayer-Salovey-Caruso Emotional Intelligence Test; Mayer et al., 2008). Moreover, including multiple indices of emotional intelligence, such as the Profile

of Emotional Competence (Brasseur et al., 2013) along with the Mayer-Salovey-Caruso Emotional Intelligence Test, would also enable researchers to examine the tripartite model of emotional intelligence (Mikolajczak, 2009) per literary recommendations (Laborde et al., 2016). The tripartite model integrates work on both trait and ability emotional intelligence specifying three levels enabling researchers to examine global or separate elements of emotional intelligence. First, knowledge (i.e., the breadth of knowledge an individual has regarding emotions), second, ability (i.e., an individual's ability to implement a given strategy across emotional situations), and third, dispositions (i.e., enduring patterns of behaviour across emotional situations). Thus, providing a more complete estimation of emotional intelligence in sport (Laborde et al., 2016).

While multiple measures of working memory were used, it is likely that other executive functions are related to athletes' TEI. That is, the lower-order model of executive function suggests that attentional processes of shifting and inhibition work in tandem with working memory (Miyake et al., 2000). Future research should include multiple measures of hot and cold shifting and inhibition in order to further examine the association between affect, cognition, and athletic expertise. Finally, despite demonstrating cognitive transference (i.e., from the sport to general domain), the working memory measures provide downstream estimation of cognitive ability only (i.e., domain general as opposed to sport-specific). In order to examine application and increase ecological validity, future work should examine the model's relationship with important outcome variables such as performance and develop sport-specific measures of cognition.

## **Conclusion**

The current study is the first to examine working memory-emotional in athletes and offers potential insight into TEI's cognitive underpinnings. Results indicated that TEI was related to both hot (i.e., working memory-emotional) and cold (i.e., working memory-

capacity and working memory-ability) measures of working memory. The ability to detect affective information is important to elite athletes and likely aids important cognitive processes such as anticipation for performance (Shih & Lin, 2016). Elite athletes may balance emotional and cognitive abilities more effectively enabling them to achieve relevant goals (Vaughan et al., 2019). The neurological link between executive function and emotion, and the superior scores of elite athletes on TEIQue-SF, ERT, SSP, and SWM, highlight the importance of these constructs for athletic expertise. It is possible that the dynamic and emotionally laden sports environment requires manipulation and regulation of a range of valanced stimuli (Vaughan et al., 2019). Future research could apply these findings by examining these processes in youth athletes to determine their malleability and whether it is possible to train these specific abilities in order to facilitate athletic expertise development or improve talent identification methods.

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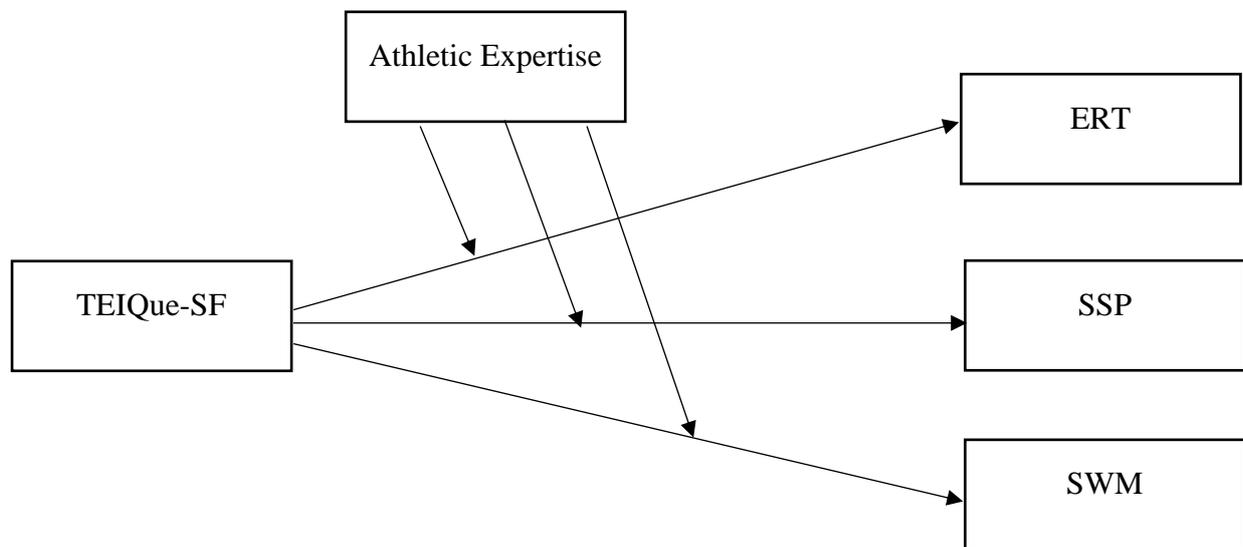


Figure 1. Hypothesised moderation model of athletic expertise on the trait emotional intelligence (TEIQue-SF) and working memory-emotional (ERT), working memory-capacity (SSP), and working memory-ability relationship (SWM).

**Table 1**

Descriptive statistics &amp; zero-order correlations

Measure	M (SD)						Zero-order Correlations			
	Total	Super-elite	Elite	Amateur	Novice	Non-athlete	$\eta p^2$	1	2	3
1. TEIQue-SF	4.93 (.89)	5.93 (.84)	5.42 (.82)	4.87 (.81)	4.61 (.87)	4.23 (.86)	.12**			
2. ERT	72.35 (7.41)	77.38 (7.19)	73.27 (7.15)	70.31 (7.07)	68.34 (7.13)	65.86 (7.09)	.05**	.43**		
3. SSP	.65 (1.42)	.82 (1.12)	.75 (1.23)	.66 (1.39)	.59 (1.48)	.55 (1.52)	.07**	.21**	.41**	
4. SWM	25.03 (6.98)	20.07 (5.74)	22.28 (5.99)	25.71 (6.35)	26.92 (6.46)	27.65 (6.53)	.08**	-.24**	-.36**	-.34**

Note. N = 437. TEIQue-SF = Trait Emotional Intelligence Questionnaire Short Form, ERT = Emotion Recognition Task, Spatial Span Task, &

SWM = Spatial Working memory. \*  $p < .05$  \*\*  $p < .01$ .

**Table 2**

Summary of structural equation models

Path	Total	Configural	Metric	Scalar
TEIQue-SF → ERT	.187**	.164**	.157**	.151**
TEIQue-SF → SSP	.114**	.097**	.095**	.092**
TEIQue-SF → SWM	-.138**	-.121**	-.119**	-.112**
Model Fit				
RMSEA	.032	.033	.049	.066
SRMR	.031	.032	.043	.058
TLI	.947	.945	.932	.918
CFI	.935	.932	.921	.909

Note. N = 437. TEIQue-SF = Trait Emotional Intelligence Questionnaire Short Form, ERT = Emotion Recognition Task, Spatial Span Task, & SWM = Spatial Working memory. RMSEA = Root Mean Square Error of Approximation; SRMR = Standardised Root Mean Square Residual; TLI = Tucker Lewis Index; CFI = Comparative Fit Index. \* p < .05 \*\* p < .01.

**Table 3**

Parameter estimates across super-elite, elite, amateur, novice, &amp; non-athletes

Path	Super-elite		Elite		Amateur		Novice		Non-athlete	
	$\beta$	SE	$\beta$	SE	$\beta$	SE	$\beta$	SE	$\beta$	SE
TEIQue-SF $\rightarrow$ ERT	.227**	.074	.211**	.093	.182**	.082	.158**	.079	.128**	.064
TEIQue-SF $\rightarrow$ SSP	.178**	.046	.145**	.064	.114**	.044	.099**	.063	.092**	.047
TEIQue-SF $\rightarrow$ SWM	-.196**	.032	-.178**	.041	-.131**	.058	-.112**	.041	-.119**	.055

Note. N = 437. TEIQue-SF = Trait Emotional Intelligence Questionnaire Short Form, ERT = Emotion Recognition Task, Spatial Span Task, &

SWM = Spatial Working memory. \*  $p < .05$  \*\*  $p < .01$ .