Executive function and personality: The moderating role of athletic expertise

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Abstract

The relationship between personality, executive function (EF) and athletic expertise has implications for researchers and sports psychologists, alike. The current study examined the relationship between the five-factor model of personality, the lower-order model of EF, and athletic expertise. A sample of 367 participants (57% male; M_{age} = 21.9) with a range of athletic expertise (super-elite = 64; elite = 65; amateur = 75, novice = 74, and non-athlete = 89) completed a personality inventory and computerised battery of EF. Individuals with more athletic expertise reported higher extroversion, openness, and conscientiousness and better EF scores, whereas those with less expertise reported higher neuroticism and agreeableness. Results of structural equation modelling indicated that EF was largely positively related to openness and conscientiousness, negatively related to neuroticism, bi-directionally related to extroversion, and unrelated to agreeableness. Additionally, athletic expertise moderated the association between personality and EF. These findings untangle the relationship between athletes' personality and EF and has theoretical and practical implications for sports performance.

Key Words: *Athletic Expertise; Executive Function; Personality*.

Introduction

Research has a longstanding interest in the individual differences associated with athletic expertise (Steca, Baretta, Greco, D'Addario & Monzani, 2018; Voss, Kramer, Basak, Prakash, & Roberts, 2010). For example, elite level athletes use a combination of cognitive and emotional abilities to anticipate and respond to changing situations (e.g., Verburgh, Scherder, van Lange, & Oosterlaan, 2014), avoid distractions and resolve interference in play (e.g., Furley & Wood, 2016), resist short-term temptations to achieve long-term goals (e.g., Zhang et al, 2019), and make more effective decisions (e.g., Vaughan, Laborde, & McConville, 2019). Whilst a growing body of work has examined personal (e.g., traits) and cognitive differences in athletes (Jacobson, & Matthaeus, 2014; Steca et al., 2018), the neurocognitive underpinnings of personality traits that may elucidate the individual differences-athletic expertise link, remains unexplored. Understanding this relationship will be important given the respective contribution of cognition and personality to sport (Zhang et al., 2019). Moreover, it is likely this relationship differs on a function of athlete's expertise levels (e.g., cognitive performance becomes more relevant at the highest level of competition, Voss et al., 2010). As such, the present study examined whether athletic expertise moderates the relationship between cognitive processes and personality.

Personality and Athletes

Recent research has advocated the importance of personality traits and their predictive utility in sporting contexts (e.g., Allen, Greenless, & Jones, 2013; Cohen, Baluch, & Duffy, 2018). The five-factor model (FFM; McCrae & Costa, 2008) consisting of extroversion (reflecting those who are sociable, outgoing, and active), neuroticism (describing individuals who are anxious, hostile, and irritable), openness (distinguishing those who are curious, creative, and imaginative), agreeableness (describing those who are good-natured, unselfish, and forgiving), and conscientiousness (defining those who are organized, punctual, and hardworking), is one of the most popular frameworks of personality. Studies have shown that athletes tend to report higher levels of extroversion (e.g., Allen, Greenless, & Jones, 2011; Goddard, Roberts, Anderson, Woodford, and Byron-Daniel, 2019), higher levels of openness (e.g., Goddard et al., 2019) and lower levels of neuroticism in comparison to non-athlete samples (Allen et al., 2011). However, further work is needed to clarify whether trait differences have meaningful implications for athletes, such as, their association with cognitive processes.

Athletes and Executive Function

Executive functions (EFs) play a critical role in an athlete's ability to plan, organize, and regulate goal-directed behaviour (Verburgh et al., 2014). Specifically, EFs consist of interrelated yet distinct lower-order cognitive processes such as shifting (i.e., ability to move attention between multiple tasks or stimuli), inhibition (i.e., ability to withhold a dominant response), and updating (i.e., ability to store and mentally manipulate information; Miyake et al., 2000). Interest in athletes EF is growing, however, investigations are producing inconsistent results (e.g., Furley & Wood, 2016; Jacobson & Matthaeus, 2014; Verburgh et al., 2014). Reconciliation of findings is challenging given methodological differences such as classification of athletic expertise, and variations in tasks used to measure EF. Nonetheless, research has generally suggested a positive association between expertise and EF performance. For example, elite athletes demonstrated better inhibitory control compared to age-matched amateur soccer players (Verburgh et al., 2014), athletes outperformed non-athletes on problem-solving and inhibition (Jacobson & Matthaeus, 2014), and shifting and updating was positively correlated with sports performance in elite soccer players (Vestberg, Reinebo, Maurex, Ingvar, & Petrovic, 2017).

Personality and Executive Function

Research outside of sport suggests a significant association between the FFM and EF (Crow, 2009; Murdock, Oddi, & Bridgett, 2013; Unsworth et al., 2009; Williams et al., 2010). Surprisingly, given facets such as achievement striving, self-control and deliberation for goals and their conceptual similarity to executive control, conscientiousness is rarely correlated with EF (Unsworth et al., 2009). Nonetheless, neuroticism is frequently negatively related to EF perhaps due to the overlap with traits negatively associated with cognitive performance (e.g., Anxiety; Crow, 2009). Literature on the relationship between extroversion and EF is unclear. Whilst Murdock and colleagues reported no relationship between extroversion and inhibition, shifting and updating, other work has suggested a positive relationship with updating and shifting (Campbell, Davalos, McCabe, & Troup, 2011), and a negative relationship with inhibition (Muris et al., 2009). Similarly, research has reported a positive relationship between agreeableness and EF (Williams et al., 2010), however, other work reported no relationship when inhibition, updating and shifting were examined separately (Murdock et al., 2013). Openness regularly demonstrates a positive relationship with EF (Murdock et al., 2013). Openness shares similar neurobiological mechanisms through the prefrontal cortex associated with information thresholding, a key component of EF (DeYoung et al., 2010). Williams and colleagues reported a positive relationship between agreeableness and a global EF measure, however, other work reported no relationship when inhibition, updating and shifting were examined separately (Murdock et al., 2013).

Buchanan (2016) found that high neuroticism and low conscientiousness were related to poorer self-report EF. However, these finding should be treated with caution given Buchanan reported no relationship between the self-report and objective measures of EF (e.g., trail-making, phonemic-awareness, semantic-fluency and digit-span). Nonetheless, Buchanan's work reiterates the importance of measurement when examining EF.

Personality, Athletes and Executive Function

Research utilising a neurocognitive framework of personality in sport is scarce. Outside of the FFM, Rincon-Campos, Sanchez-Lopez, Lopez-Walle and Oritz-Jimenz (2019) reported a negative relationship between impulsivity with inhibition, planning and shifting in American football players. Zhang and colleagues (2019) examined the relationship between the FFM and self-report self-control (i.e., a proxy of EF) among national boxers. They reported a positive relationship between competition-level and self-control. In line with others (e.g., Williams et al., 2010), they found neuroticism was negatively related to self-control, whereas extroversion, and agreeableness were positively correlated with self-control. In contrast to other findings they reported higher conscientiousness was linked to better self-control (Unsworth et al., 2009). Zhang et al.'s findings provide a good foundation for extension. That is, the use of overt measures of EF, rather than self-report, the examination of athletic expertise using an accepted sporting classification, and the exploration of the combined contributions of personality traits and expertise on EF, would broaden the scope of future work.

The Current Study

A limitation of previous work comparing athletes on individual differences is the inconsistency in definition of athletic expertise. Swann, Moran and Piggott (2015) devised a grouping system applicable across sport type accommodating highest level of performance, success at that level, experience at that level, competitiveness of sport and global representativeness of the sport, which has received support in the literature (Moran, Campbell, & Toner, 2019). Additionally, work assessing the link between personality and EF is difficult due to inconsistencies in EF measurement. For example, Williams et al. (2010) utilised a global EF factor unrepresentative of theory. Buchanan (2016) and Zhang et al. (2019) used self-report measures of EF. Additionally, Murdock et al. (2013) used composite measures of inhibition, shifting and updating which blurs the respective contribution of processes such as accuracy, errors and latency. According to Attentional Control Theory, differentiating these processes is important for performance (Eysenck, Derakshan, Santos, & Calvo, 2007). For example, Verburgh et al. (2014) reported that athletes with more expertise make more effective but not necessarily more efficient decisions. We suggest that a robust examination of EF requires reliable tests able to differentiate inhibition, shifting and updating performance (i.e., Cambridge Neuropsychological Test Automated Battery).

The current study aimed to clarify the relationship between personality and EF in athletes using separate indices of inhibition, shifting, and updating, and explore the moderating effect of athletic expertise. We hypothesized that neuroticism would be negatively correlated inhibition, shifting and updating, while agreeableness, conscientiousness, and extroversion would be positively correlated with inhibition, shifting and updating. Further, we predicted athletic expertise to positively moderate these relationships.

Method

Participants

Three hundred and sixty-seven English-speaking volunteers aged 18-27 years (M_{age} = 21.9 ± *SD* = 2.17; 57% male), participated. A range of interceptive (requiring coordination between a participant's body, parts of, or an object in one's environment) and strategic (involving simultaneous processing of large amount of sport specific information) sports were sampled (Voss et al., 2010). Participants were grouped based on Swann et al.'s (2015) classification which resulted in a sample of non-athlete (*n* = 89), novice (*n* = 74), amateur (*n* = 75), elite (*n* = 65) and super-elite (*n* = 64)[1]. Participants were recruited via sports coaches

[1] Athletic expertise is computed as: [(A+B+C/2)/3] x [(D+E)/2], where A is the athlete's highest standard of performance, B is success at the athlete's highest level, C is experience at the athlete's highest level, D is competitiveness of sport in athlete's country, and E is global competitiveness of sport. Samples are coded as semi elite (novice; a score of 1-4), competitive elite (amateur; a score of 4-8), successful elite (elite; a score of 8-12) or world-class elite (super-elite; a score of 12-16). Those who failed to score on Swann and colleagues'

and tutors in exchange for course credit. Power analysis (.80) suggested that a sample size of 312 would be required for moderated regression with a medium (.08) effect size (G*Power; Faul, Erdfelder, Lang, & Buchner, 2007).

Materials

NEO Five-Factor Inventory (NEO-FFI; Costa & McCrae, 1992). The 60-item NEO-FFI was used to index neuroticism (e.g., I am not a worrier), extroversion (e.g., I like to have a lot of people around me), openness (e.g., I often enjoy playing with theories or abstract ideas), agreeableness (e.g., I believe that most people will take advantage of you if you let them), and conscientiousness (e.g., I keep my belongings neat and clean), on a five-point Likert scale ranging from strongly disagree to strongly agree. Higher scores represent higher characteristics of the trait. Satisfactory internal consistency has been reported with athlete samples (Allen et al., 2011).

Cambridge Neuropsychological Test Automated Battery (CANTAB®). Three subtests from CANTAB (http://www.camcog.com) were administered measuring: shifting through the Intra-Extra Dimensional Set Shift Test (IED); inhibition using the Stop Signal Task (SST); and updating with the Spatial Working-Memory Test (SWM). CANTAB has been reported as a robust measure of cognition in clinical and non-clinical populations (Syvaoja et al., 2015).

The IED measures visual discrimination and shifting. Six geometric shapes in differing colours, appear on the screen. Participants match responses with target stimuli and make subsequent decisions based on feedback from the previous trial. If participants chose the correct match, the screen lights up green. Stimulus represent one dimension apiece (e.g., shape) and then two dimensions apiece (e.g., line and shape) as participants progress through

criteria were non-athletes (a score of 0). We used the tags, non-athlete - super-elite in line with previous work e.g., Vaughan et al., 2019).

the stages. Rule changes occur after six or eight correct responses. The task terminates after 50 trials if a participant fails to learn a rule, thus, not all participants will complete all stages. Outcome measures included: IED-error (i.e., number of errors made) and IED-stages (i.e., number of stages successfully completed).

The SST assesses response inhibition. Participants are instructed to use a two-button press pad to record their responses to an on-screen arrow stimulus pointing either left or right. The buttons on the press pad corresponded to a direction of the arrow (‘go’ stimulus). In 25% of the trials, an auditory ‘stop’ signal is presented. Participants are instructed to withhold their motor response on presentation of the ‘stop’ signal. Five blocks of 64 test trials were separated by short rest breaks. Outcome measures included: SST-Correct (i.e. the mean RT on correct trials), and SST-Stops (i.e. the percentage of correct trials requiring inhibition of the dominant response).

The SWM assesses spatial working-memory and indexes updating. Participants are presented with coloured boxes across the screen in a random pattern and instructed to search behind each box for the location of a blue token (i.e., using a process of elimination). Points are awarded for locating tokens. Tokens are hidden behind a different box within the same trial and had to be relocated. Therefore, participants must recall where the token was previously found and remember *not* to revisit those coloured boxes. The colour and position of the boxes changed with each trial to prevent the use of a set search strategy. Outcome measures included: SWM-Strategy (i.e., the number boxes used for each new search) and SWM-Errors (i.e., where participant selects a box where the token had previously been located). Lower SWM-Strategy and SWM-Error scores represent better updating performance.

Procedure

Testing was conducted individually, in designated laboratories in the University Sport or Psychology Departments and took approximately 45 minutes. The study was approved by the University's ethics committee and volunteers provided written informed consent prior to participation. Participants completed the NEO-FFI, followed by the IED, SST, and SWM. Testing was completed on a GIGABYTE 7260HMW BN touchscreen computer running a Pro Windows 8 operating system with a high resolution 13-inch display. Following testing, participants were thanked and released. Data was collated and retrieved from the CANTAB and entered onto the SPSSv24®.

Design and data analysis

A quasi-experimental design was used. Data was screened for outliers, missing data, and checked for normality to ensure all variables met the assumptions of parametric statistical analysis. Descriptive statistics and Cronbach Alpha's (α) were extracted for all necessary variables with a .70 cut-off required for stability (Tabachnick & Fidell, 2007). Analysis of variance was used to determine differences between athletic expertise groups. This was followed by zero-order correlations to examine relationships between variables. All preliminary analyses were completed on SPSSv24 ®.

Structural equation modelling with MPlus (Muthen & Muthen, 2017) was used to examine the relationship between the variables as recommended by Miyake et al. (2000) when analysing EFs. Goodness of fit using the maximum likelihood with robust standard errors estimation (to control for the categorical nature of the moderator) was assessed with the Comparative Fit Index (CFI), the Tucker Lewis Index (TLI), the standardized root mean square residual (SRMR), and the root mean square error of approximation (RMSEA). Following recommendations, values below .08 for the SRMR, below .06 for the RMSEA, and above .90 for the CFI and TLI indicate acceptable model fit (Hu & Bentler, 1999). Six models were tested; one for each EF outcome, to avoid issues with multi-collinearity and to ease interpretation with increased interactions (Akinwande, Dikko, & Samson, 2015). Moderation predictors were mean-centered before interaction terms were calculated.

Results

Preliminary analyses

Measures of central tendency for all variables and internal consistency for the personality variables are displayed in Table 1. Data were screened for multivariate outliers via Mahalanobis distance which revealed no outliers larger than the critical value ($\chi^2(6)$ = 4.12, p < .01; Tabachnick & Fidell, 2007). Box's M was non-significant (p > .05) therefore subsequent analyses were collapsed across gender. Age was not significantly correlated with any of the test variables therefore it was not added as a covariate (p > .05). Results of ANOVA modelling indicated that those with less expertise reported higher neuroticism and agreeableness scores, and those with more expertise reported higher extroversion, openness, and conscientiousness scores, and performed better on the EF measures (see Table 1).

Table 1

Structural Equation Modelling

As MPlus provides limited information of model fit for moderation analyses we tested main effects before adding interactions (Maslowsky, Jager, & Hemken, 2015). We tested six models for each EF outcome using the FFM as predictors. Results indicated acceptable fit (RMSEA = .048-.059; SRMR = .057-.077; CFI = .905-.942; TLI = .911-.958), therefore we proceeded by adding interaction terms (see Table 2). Again, model fit was acceptable across all models and in most cases demonstrated modest improvements explaining 13–27% (R^2 = .13–.27) of the variance between EF with athletic expertise and personality.

Athletic expertise yielded a positive association with all measures of EF, specifically, higher expertise was related to greater shifting (i.e., fewer IED-Error and more IED-Stages), greater inhibition (i.e., more SST-Stops and shorter SST-Correct latencies), and greater updating (i.e., fewer SWM-Error and fewer SWM-Strategy) performance.

Higher neuroticism was associated with poorer shifting (i.e., greater IED-Error) and poorer updating (i.e., greater SWM-Strategy and greater SWM-Error), poorer inhibition (i.e., fewer SST-Stops), and poorer inhibitory efficiency (i.e., longer SST-Correct). However, neuroticism was unrelated to IED-Stages. The neuroticism x expertise interaction revealed that higher neuroticism and higher expertise was linked to better shifting (i.e., fewer IED-Error), better updating (i.e., fewer SWM-Strategy and fewer SWM-Error), and better inhibition (i.e., greater correct SST-Stops and shorter SST-Correct). The interaction was not related to IED-Stages.

Higher extroversion was associated with better shifting (i.e., more IED-Stages), better inhibition (i.e., greater correct SST-Stops and shorter SST-Correct latencies), and better updating (i.e., fewer SWM-Strategy). Nonetheless, extroversion was unrelated to IED-Error and SWM-Error. The extroversion x expertise interaction followed a similar pattern, such that, higher expertise and higher expertise was associated with better shifting performance (i.e., more IED-Stages), better inhibitory performance (i.e., more SST-Stops and faster SST-Correct latencies), and better updating (i.e., fewer SWM-Strategy).

Greater openness was linked to better shifting (i.e., fewer IED-Error and more IED-Stages), greater inhibitory control (i.e., more SST-Stops and faster SST-Correct) and better updating (i.e., fewer SWM-Error and fewer SWM-Strategy). In accord, the openness x expertise interaction revealed higher openness and higher expertise was associated with better shifting (i.e., fewer IED-Error and more IED-Stages), better inhibition (i.e., more SST-Stops and shorter SST-Correct), and better updating (i.e., fewer SWM-error and fewer SWM-Strategy).

Higher conscientiousness was associated with better shifting (i.e., less IED-Error and more IED-Stages), better inhibition (i.e., more SST-Stops and shorter SST-Correct), and better updating (i.e., fewer SWM-Error and fewer SWM-Strategy). The inclusion of expertise (i.e., conscientiousness x expertise) showed analogous results, that is, higher conscientiousness and higher expertise was related to better shifting (i.e., fewer IED-Error and more IED-Stages), better inhibition (i.e., more SST-Stops and faster SST-Correct), and better updating (i.e., fewer SWM-Error and fewer SWM-Strategy).

Agreeableness did not predict any of the EF outcomes and adding athletic expertise did not moderate effects (see Table 2).

Table 2

Discussion

The aim of this research was to disentangle the relationship between personality and EF and determine whether these relationships were moderated by athletic expertise. Preliminary analyses supported previous work indicating that those with greater expertise performed better on tasks of inhibition, shifting and updating, compared to those with less expertise (Jacobson, & Matthaeus, 2014; Verburgh et al., 2014; Vestberg et al., 2017). Personality differences aligned with previous work suggesting athletes score higher on extroversion, openness, and conscientiousness and non-athletes score higher on neuroticism and agreeableness (Allen et al., 2011; 2013; Steca et al., 2018). Furthermore, results supported predictions that athletic expertise moderated the relationship between personality and EF.

Despite the difficulties with reconciling findings using different methodologies, tasks and outcome variables, our data provided partial support for studies using non-sport-specific samples. In accord with Crow (2009) who used a test of general EF, we found a negative relationship between neuroticism and EF when using separate indices of shifting, inhibition and updating (i.e., greater neuroticism linked with poorer accuracy on measures of shifting, inhibition and updating, and longer latencies on the inhibition task). This supports the negative association between neuroticism and the error monitoring component of EF (Crow, 2009).

Our results for extroversion agreed with Murdock et al., (2013) who found no relationship with EF (i.e., we also found no relationship between extroversion and accuracy of shifting or updating). Moreover, our findings for inhibitory control concurred with Campbell et al., (2011) who demonstrated a positive association between extroversion and inhibition (i.e., we found greater extroversion was related to better accuracy and shorter latencies on the inhibition task) yet our data stood in contrast with Muris et al., (2009) who reported higher extroversion was linked to poorer inhibition. Although, it is likely differences between our results and Muris et al.'s could be explained by sampling (i.e., our participants were aged 18-27 whereas theirs were aged 9-12 years), and measurement differences (i.e., SST vs self-report).

We demonstrated a positive association between openness and EF supporting claims that it shares a neurological basis with EF (Murdock et al., 2013).

The pattern of our results for conscientiousness afforded mixed support, such that, our data supported some work (e.g., Buchannan, 2016), yet contrasted with others (e.g., Murdock et al., 2013; Unsworth et al., 2009). Despite Murdock et al. and Unsworth et al. using behavioural measures of EF, neither studies deployed the same indices of shifting, inhibition and updating as we did, as such, it is possible that task differences might explain discrepancies.

Our findings of no relationship between agreeableness and EF supports previous research that examined shifting, inhibition and updating separately (Murdock et al., 2013). However, our results conflict with other studies who have reported a positive relationship (e.g., Williams et al., 2010). It is plausible that discrepancies between Williams et al. and our data could be attributed to sampling (i.e., they tested 60-85 year olds and we tested 18-27 year olds) and task output differences (i.e., composite scores may blur the unique contribution of individual outcomes measures).

Our findings concurred with other athlete data regarding neuroticism, extroversion, and conscientiousness, yet contrasted the pattern of results for agreeableness (Zhang et al., 2019). The most likely explanation for differences between Zhang et al.'s data and our own, is their use of questionnaire scores to measure self-control, whereas we used behavioural EF tasks.

Our research is the first to examine the moderating effect of athletic expertise on the personality and EF link. Several findings are particularly noteworthy. First, our analyses revealed that the inclusion of athletic expertise offset the negative association between neuroticism and EF. For example, neuroticism alone was linked to poorer inhibition accuracy and longer response times, yet higher neuroticism with higher expertise lead to greater inhibition accuracy and better response efficiency. A similar pattern continued for shifting and updating accuracy. It is possible that individuals who score higher in neuroticism may be anxious, impulsive and easily frustrated which may impede task performance (Williams et al., 2010). Nevertheless, athletes with more expertise, may use different strategies to help make decisions (e.g., greater use of heuristics; Bell, Mawn, Poynor, 2013). Attentional Control Theory may also explain the change in direction of effects (Eysenck et al., 2007). That is, neurotic athletes with more expertise may perform with faster RTs and make less errors as their cognitive processing becomes more automated due to a more stimulus (i.e., environmental) driven system as opposed to a more goal (i.e., expectations) driven system (Bell et al., 2013). This explanation is hypothetical, however, and for future research to test.

Second, our results demonstrated that athletic expertise augmented the direct effects for extroversion, openness, and conscientiousness, for example, where higher extroversion was associated with more SST-Stops and shorter SST-Correct latencies, this effect increased across the expertise continuum. For extroversion, the likely reason may rest with this trait being important in determining how an individual interacts with their environment (e.g., task approach; Williams et al., 2010). For example, those high in extroversion are considered assertive, attention-seeking, and gregarious, which may result in a differentiated approach to cognitive tasks. Previous research suggests that athletes with higher levels of extroversion are associated with faster movement times, therefore may develop more efficient motor mechanisms (Parma et al., 2019). For conscientiousness, these findings may be explained by the importance of these traits to athletes in comparison to previous work with non-athletes (e.g., training behaviours; Allen et al., 2011; 2013). Openness may also be particularly relevant according to differentiation theories whereby those with higher levels of cognitive ability have more specialised skills and interests which result in a more varied personality structure (e.g., sport; Murray, Booth, & Molenaar, 2016).

Third, we found no link between agreeableness and EF, with or without the moderation of athletic expertise. Although not unexpected, individuals with lower levels of agreeableness, may be more antagonistic, linked with limited cognitive control and difficulty inhibiting impulses (Williams et al., 2010). This may be particularly evident in athletic populations which are characteristic of higher levels of trait narcissism, psychopathy, and Machiavellianism (Vaughan, Madigan, Carter, & Nichols, 2019).

Limitations and Future Directions

The present study has numerous strengths, such as the novel inclusion of athletic expertise, large sample size, and use of reliable behavioural measures of EF. However, several limitations need mention. For example, the cross-sectional design limits causality and direction, and using single measures of EF provides a snapshot of ability. Future work should endeavour to include multiple measures of EF to examine consistency across tasks and attempt to model the facet levels of the FFM (e.g., using the longer NEO PI-R; McCrae & Costa, 2008). Just as the current work deconstructs EF, similar procedures may reveal more intricate associations between the constructs at the facet level (Williams et al., 2010). We call for designs that build on our work to determine causality and direction. We also recommend that new work integrates Attentional Control Theory (e.g., including measures of anxiety; Eysenck et al., 2007) to reveal important individual differences which may influence performance and be highly relevant in a dynamic and stimuli driven context such as sport.

Conclusion

The current study took a novel approach to explore the individual differences-athletic expertise link via the neurocognitive underpinnings of athlete's personality. We found EFs to be largely positively related to openness and conscientiousness, negatively related to neuroticism, bi-directionally related to extroversion, and unrelated to agreeableness. Importantly, athletic expertise moderated the association between personality and EF. Our results extend understanding by differentiating the outcomes of EF tasks and highlighting a more complex association between variables while emphasising the need for more research examining the individual differences of athletes. The findings add to both the sport and cognitive psychology literatures, joining two previously under researched areas and heeding Cattell's (1971) call for a more unified field of individual differences. Examining significant predictors of sport performance simultaneously provides a better understanding of how athletes' personal characteristics and mental processes interact and possibly influence athlete performance.

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Table 1

Descriptive statistics, internal consistencies and zero-order correlations

Measure	M (SD)								Correlations									
	Total	Super-elite	Elite	Amateur	Novice	Non	ηp^2	α	1	2	3	4	5	6	7	8	9	10
1.Neuroticism	2.29 (.87)	2.03 (.54)	2.18 (.63)	2.36 (.66)	2.51 (.58)	2.78 (.53)	.11**	.73										
2.Extroversion	3.18 (.91)	3.45 (.64)	3.36 (.69)	3.22 (.57)	3.02 (.62)	2.91(.71)	.12**	.81	-.23**									
3.Openness	3.61 (.62)	3.93 (.61)	3.75 (.56)	3.62 (.58)	3.53 (.51)	3.47 (.60)	.05*	.80	-.20**	.33**								
4.Agreeableness	3.13 (.59)	2.49 (.54)	2.88 (.57)	3.01 (.51)	3.12 (.55)	3.21 (.52)	.03*	.78	-.19**	.25**	.20**							
5.Conscientiousness	3.69 (.74)	3.89 (.61)	3.74 (.66)	3.57 (.58)	3.44 (.64)	3.32 (.69)	.09**	.80	-.22**	.13*	.17**	.16**						
6.IED-Error	15.94 (12.14)	14.10 (12.65)	14.54 (13.67)	15.16 (13.26)	16.14 (12.82)	16.80 (11.41)	.07**		.15**	.06	-.16**	-.08	-.17**					
7.IED-Stages	7.14 (.91)	8.94 (.86)	8.21 (.83)	8.03 (.91)	7.64 (.99)	7.35 (.93)	.08**		-.08	.11*	.14*	-.07	.16**	-.20*				
8.SST-Correct	521.45 (181.19)	461.42 (80.83)	489.14 (87.32)	511.31 (105.62)	560.02 (109.68)	592.59 (102.21)	.06*		.10*	-.09*	-.17**	-.06	-.10*	.11*	-.22*			
9.SST-Stops	.62 (.19)	.70 (.12)	.62 (.13)	.60 (.16)	.57 (.16)	.54 (.12)	.05*		-.12*	.12*	.13*	-.07	.13**	-.10*	.23**	-15*		
10.SWM-Strategy	24.38 (6.75)	18.38 (4.55)	20.14 (4.61)	23.51 (6.26)	26.05 (6.61)	28.28 (5.86)	.10**		.15**	-.13*	-.18**	-.04	-.14**	.12*	-.21**	.18**	-.24**	
11.SWM-Error	24.91 (16.09)	19.02 (9.95)	21.38 (10.87)	23.86 (13.22)	24.84 (14.36)	25.99 (15.42)	.09*		.13*	-.06	-.13**	-.03	-.16**	.21*	-.19**	.17**	-.21**	.15**

Note. N = 367. IED = Intra-extra dimensional shift, SST = Stop Signal Tasks, SWM = Spatial Working-Memory.

* $p < .05$ ** $p < .01$.

Table 2

Standardised main and interaction effects of personality and athletic expertise on executive function

	IED-Error			IED-Stages			SST-Correct			SST-Stops			SWM-Strategy			SWM-Error		
	ΔR^2	β	SE	ΔR^2	β	SE	ΔR^2	β	SE	ΔR^2	β	SE	ΔR^2	β	SE	ΔR^2	β	SE
Predictors	.24**			.25**			.16**			.27**			.25**			.13**		
Neuroticism		.11**	.05		-.03	.04		.09*	.05		-.11**	.04		.13**	.05		.09*	.06
Extroversion		.03	.06		.09*	.05		-.08*	.06		.10**	.05		-.11**	.05		-.03	.05
Openness		-.14**	.07		.13**	.03		-.15**	.05		.12**	.04		-.16**	.07		-.10**	.04
Agreeableness		-.02	.05		-.01	.06		-.03	.06		-.07	.06		-.03	.06		-.02	.07
Conscientiousness		-.15**	.04		.14**	.02		-.10*	.04		.11**	.03		-.12**	.04		-.14**	.03
Athletic Expertise		-.10*	.03		.10**	.05		-.09*	.07		.13**	.04		-.11**	.06		-.09*	.06
Neuroticism x Expertise		-.17**	.09		.08	.06		-.16**	.06		.17**	.05		-.18**	.07		-.18**	.08
Extroversion x Expertise		.06	.08		.16**	04		-.17**	.07		.15**	.07		-.17**	.07		-.07	.07
Openness x Expertise		-.18**	.08		.18**	05		-.23**	.09		.19**	.08		-.20**	.08		-.16**	.08
Agreeableness x Expertise		.07	.06		.05	.06		.07	.08		.09	.08		.08	.09		-.06	.09
Conscientiousness x Expertise		-.19**	07		.20**	.05		-.18**	.09		.18**	.05		-.18**	.08		-.19**	08
Model fit indices																		

RMSEA	.049	.044	.052	.041	.047	.057
SRMR	.061	.056	.066	.051	.059	.073
CFI	.924	.945	.916	.951	.937	.909
TLI	.932	.953	.925	.962	.945	.917

Note. N = 367. IED = Intra-Extra Dimensional Set Shift, SST = Stop Signal Task, SWM = Spatial Working-Memory.

* $p < .05$. ** $p < .01$.