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1 Executive function and personality: The moderating role of athletic
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27 **Abstract**

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

42

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

44 **Introduction**

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

61 **Personality and Athletes**

62 Recent research has advocated the importance of personality traits and their predictive
63 utility in sporting contexts (e.g., Allen, Greenless, & Jones, 2013; Cohen, Baluch, & Duffy,
64 2018). The five-factor model (FFM; McCrae & Costa, 2008) consisting of extroversion
65 (reflecting those who are sociable, outgoing, and active), neuroticism (describing individuals
66 who are anxious, hostile, and irritable), openness (distinguishing those who are curious,
67 creative, and imaginative), agreeableness (describing those who are good-natured, unselfish,
68 and forgiving), and conscientiousness (defining those who are organized, punctual, and

69 hardworking), is one of the most popular frameworks of personality. Studies have shown that
70 athletes tend to report higher levels of extroversion (e.g., Allen, Greenless, & Jones, 2011;
71 Goddard, Roberts, Anderson, Woodford, and Byron-Daniel, 2019), higher levels of openness
72 (e.g., Goddard et al., 2019) and lower levels of neuroticism in comparison to non-athlete
73 samples (Allen et al., 2011). However, further work is needed to clarify whether trait
74 differences have meaningful implications for athletes, such as, their association with
75 cognitive processes.

76 **Athletes and Executive Function**

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

92 **Personality and Executive Function**

93 Research outside of sport suggests a significant association between the FFM and EF
94 (Crow, 2009; Murdock, Oddi, & Bridgett, 2013; Unsworth et al., 2009; Williams et al.,
95 2010). Surprisingly, given facets such as achievement striving, self-control and deliberation
96 for goals and their conceptual similarity to executive control, conscientiousness is rarely
97 correlated with EF (Unsworth et al., 2009). Nonetheless, neuroticism is frequently negatively
98 related to EF perhaps due to the overlap with traits negatively associated with cognitive
99 performance (e.g., Anxiety; Crow, 2009). Literature on the relationship between extroversion
100 and EF is unclear. Whilst Murdock and colleagues reported no relationship between
101 extroversion and inhibition, shifting and updating, other work has suggested a positive
102 relationship with updating and shifting (Campbell, Davalos, McCabe, & Troup, 2011), and a
103 negative relationship with inhibition (Muris et al., 2009). Similarly, research has reported a
104 positive relationship between agreeableness and EF (Williams et al., 2010), however, other
105 work reported no relationship when inhibition, updating and shifting were examined
106 separately (Murdock et al., 2013). Openness regularly demonstrates a positive relationship
107 with EF (Murdock et al., 2013). Openness shares similar neurobiological mechanisms
108 through the prefrontal cortex associated with information thresholding, a key component of
109 EF (DeYoung et al., 2010). Williams and colleagues reported a positive relationship between
110 agreeableness and a global EF measure, however, other work reported no relationship when
111 inhibition, updating and shifting were examined separately (Murdock et al., 2013).

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

117 **Personality, Athletes and Executive Function**

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

132 **The Current Study**

133 A limitation of previous work comparing athletes on individual differences is the
134 inconsistency in definition of athletic expertise. Swann, Moran and Piggott (2015) devised a
135 grouping system applicable across sport type accommodating highest level of performance,
136 success at that level, experience at that level, competitiveness of sport and global
137 representativeness of the sport, which has received support in the literature (Moran,
138 Campbell, & Toner, 2019). Additionally, work assessing the link between personality and EF
139 is difficult due to inconsistencies in EF measurement. For example, Williams et al. (2010)
140 utilised a global EF factor unrepresentative of theory. Buchanan (2016) and Zhang et al.
141 (2019) used self-report measures of EF. Additionally, Murdock et al. (2013) used composite
142 measures of inhibition, shifting and updating which blurs the respective contribution of

143 processes such as accuracy, errors and latency. According to Attentional Control Theory,
144 differentiating these processes is important for performance (Eysenck, Derakshan, Santos, &
145 Calvo, 2007). For example, Verburgh et al. (2014) reported that athletes with more expertise
146 make more effective but not necessarily more efficient decisions. We suggest that a robust
147 examination of EF requires reliable tests able to differentiate inhibition, shifting and updating
148 performance (i.e., Cambridge Neuropsychological Test Automated Battery).

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

156 Method

157 Participants

158 Three hundred and sixty-seven English-speaking volunteers aged 18-27 years ($M_{\text{age}} =$
159 $21.9 \pm SD = 2.17$; 57% male), participated. A range of interceptive (requiring coordination
160 between a participant's body, parts of, or an object in one's environment) and strategic
161 (involving simultaneous processing of large amount of sport specific information) sports
162 were sampled (Voss et al., 2010). Participants were grouped based on Swann et al.'s (2015)
163 classification which resulted in a sample of non-athlete ($n = 89$), novice ($n = 74$), amateur (n
164 $= 75$), elite ($n = 65$) and super-elite ($n = 64$)¹. Participants were recruited via sports coaches

¹ Athletic expertise is computed as: $[(A+B+C)/3] \times [(D+E)/2]$, 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'

165 and tutors in exchange for course credit. Power analysis (.80) suggested that a sample size of
166 312 would be required for moderated regression with a medium (.08) effect size (G*Power;
167 Faul, Erdfelder, Lang, & Buchner, 2007).

168 **Materials**

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

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

183 The IED measures visual discrimination and shifting. Six geometric shapes in
184 differing colours, appear on the screen. Participants match responses with target stimuli and
185 make subsequent decisions based on feedback from the previous trial. If participants chose
186 the correct match, the screen lights up green. Stimulus represent one dimension apiece (e.g.,
187 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).

188 the stages. Rule changes occur after six or eight correct responses. The task terminates after
189 50 trials if a participant fails to learn a rule, thus, not all participants will complete all stages.
190 Outcome measures included: IED-error (i.e., number of errors made) and IED-stages (i.e.,
191 number of stages successfully completed).

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

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

211 **Procedure**

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

220 **Design and data analysis**

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

228 Structural equation modelling with MPlus (Muthen & Muthen, 2017) was used to
229 examine the relationship between the variables as recommended by Miyake et al. (2000)
230 when analysing EFs. Goodness of fit using the maximum likelihood with robust standard
231 errors estimation (to control for the categorical nature of the moderator) was assessed with
232 the Comparative Fit Index (CFI), the Tucker Lewis Index (TLI), the standardized root mean
233 square residual (SRMR), and the root mean square error of approximation (RMSEA).
234 Following recommendations, values below .08 for the SRMR, below .06 for the RMSEA, and
235 above .90 for the CFI and TLI indicate acceptable model fit (Hu & Bentler, 1999). Six
236 models were tested; one for each EF outcome, to avoid issues with multi-collinearity and to

237 ease interpretation with increased interactions (Akinwande, Dikko, & Samson, 2015).

238 Moderation predictors were mean-centered before interaction terms were calculated.

239 **Results**

240 **Preliminary analyses**

241 Measures of central tendency for all variables and internal consistency for the
242 personality variables are displayed in Table 1. Data were screened for multivariate outliers
243 via Mahalanobis distance which revealed no outliers larger than the critical value ($\chi^2(6) =$
244 4.12, $p < .01$; Tabachnick & Fidell, 2007). Box's M was non-significant ($p > .05$) therefore
245 subsequent analyses were collapsed across gender. Age was not significantly correlated with
246 any of the test variables therefore it was not added as a covariate ($p > .05$). Results of
247 ANOVA modelling indicated that those with less expertise reported higher neuroticism and
248 agreeableness scores, and those with more expertise reported higher extroversion, openness,
249 and conscientiousness scores, and performed better on the EF measures (see Table 1).

250 **Table 1**

251 **Structural Equation Modelling**

252 As MPlus provides limited information of model fit for moderation analyses we tested
253 main effects before adding interactions (Maslowsky, Jager, & Hemken, 2015). We tested six
254 models for each EF outcome using the FFM as predictors. Results indicated acceptable fit
255 (RMSEA = .048-.059; SRMR = .057-.077; CFI = .905-.942; TLI = .911-.958), therefore we
256 proceeded by adding interaction terms (see Table 2). Again, model fit was acceptable across
257 all models and in most cases demonstrated modest improvements explaining 13–27% ($R^2 =$
258 .13–.27) of the variance between EF with athletic expertise and personality.

259 Athletic expertise yielded a positive association with all measures of EF, specifically,
260 higher expertise was related to greater shifting (i.e., fewer IED-Error and more IED-Stages),

261 greater inhibition (i.e., more SST-Stops and shorter SST-Correct latencies), and greater
262 updating (i.e., fewer SWM-Error and fewer SWM-Strategy) performance.

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

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

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

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

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

294 Table 2

295 Discussion

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

306 Despite the difficulties with reconciling findings using different methodologies, tasks
307 and outcome variables, our data provided partial support for studies using non-sport-specific
308 samples. In accord with Crow (2009) who used a test of general EF, we found a negative
309 relationship between neuroticism and EF when using separate indices of shifting, inhibition

310 and updating (i.e., greater neuroticism linked with poorer accuracy on measures of shifting,
311 inhibition and updating, and longer latencies on the inhibition task). This supports the
312 negative association between neuroticism and the error monitoring component of EF (Crow,
313 2009).

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

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

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

332 Our findings of no relationship between agreeableness and EF supports previous
333 research that examined shifting, inhibition and updating separately (Murdock et al., 2013).
334 However, our results conflict with other studies who have reported a positive relationship

335 (e.g., Williams et al., 2010). It is plausible that discrepancies between Williams et al. and our
336 data could be attributed to sampling (i.e., they tested 60-85 year olds and we tested 18-27
337 year olds) and task output differences (i.e., composite scores may blur the unique contribution
338 of individual outcomes measures).

339 Our findings concurred with other athlete data regarding neuroticism, extroversion,
340 and conscientiousness, yet contrasted the pattern of results for agreeableness (Zhang et al.,
341 2019). The most likely explanation for differences between Zhang et al.'s data and our own,
342 is their use of questionnaire scores to measure self-control, whereas we used behavioural EF
343 tasks.

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

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

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

380 **Limitations and Future Directions**

381 The present study has numerous strengths, such as the novel inclusion of athletic
382 expertise, large sample size, and use of reliable behavioural measures of EF. However,
383 several limitations need mention. For example, the cross-sectional design limits causality and

384 direction, and using single measures of EF provides a snapshot of ability. Future work should
385 endeavour to include multiple measures of EF to examine consistency across tasks and
386 attempt to model the facet levels of the FFM (e.g., using the longer NEO PI-R; McCrae &
387 Costa, 2008). Just as the current work deconstructs EF, similar procedures may reveal more
388 intricate associations between the constructs at the facet level (Williams et al., 2010). We call
389 for designs that build on our work to determine causality and direction. We also recommend
390 that new work integrates Attentional Control Theory (e.g., including measures of anxiety;
391 Eysenck et al., 2007) to reveal important individual differences which may influence
392 performance and be highly relevant in a dynamic and stimuli driven context such as sport.

393 **Conclusion**

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

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Table 1

Descriptive statistics, internal consistencies and zero-order correlations

Measure	M (SD)						ηp^2	α	Correlations											
	Total	Super-elite	Elite	Amateur	Novice	Non			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.

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

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.

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