Brief Communication

Reporting Executive Dysfunctions versus Measuring Executive Functions as Predictor of Cognitive Skills in Athletes

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Abstract

Cognitive diagnostics, especially the measurement of executive functions (EFs) in the context of sports and talent diagnostics, is a popular research topic. However, research is lacking on the extent to which self-reports are sufficient to examine the EFs of athletes for performance diagnostics. Thus, the current study aims to evaluate the relationships between neuropsychological tasks (3-back task, cued GoNoGo task, flanker task, and number-letter task) and a self-report for examining EFs (BRIEF-SB). Furthermore, it should be investigatedwhether it is possible to predict the outcome of EF tasks using a self-report inventory. Therefore, 68 young professional soccer players (M_{age} = 14.26 ±1.35 years) of a national youth academy were included in the study. The weak-to-moderate correlations ($r[59] = .000$, $p = .999$ to $r[59] = -.442$, $p < .01$) and the results of sensitivity analysis (0.125 to 0.538) do not suggest using a self-report of EFs for cognitive performance diagnostics. The inventory is only suitable for identifying executive dysfunctions in athletes recovering from head injuries or concussions.

Keywords: executive functions, self-reporting, cognitive diagnostics, talent diagnostics

1 Introduction

Executive functions (EF) make it possible to act with purpose or in a goal-directed manner. According to Diamond (2013), the definition of EF includes the functions of working memory, inhibition, and cognitive flexibility. Expert performance in sports requires outstanding physical capabilities and motor control, perception, information processing, and cognitive functioning such as EFs (Voss et al., 2010). Previous studies provide evidence that experts in sports have superior EFs compared to non-athletes (for review, see Scharfen & Memmert, 2019). Furthermore, open-skill sports (i.e., nature and combat) tend to have the most significant positive influence on EFs (for review, see Heilmann et al., 2022).

The EF tests (i.e., flanker task, n-back task, and trail-making task) can describe the cognitive performance of athletes. In conclusion, the authors of some studies (Montuori et al., 2019; Sakamoto et al., 2018; Vestberg et al., 2012) suggest implementing the measurement of EFs as a cognitive part of performance diagnostic measures. Furthermore, the authors critically discuss neuropsychological diagnostics (Kilger & Blomberg, 2020). For instance, Beavan et al. (2019, 2020) described the age-dependent function of EF development. This function is oriented towards the development of general populations reported in previous research. The current study attempts to retrieve the idea of Beavan et al. (2020) to implement the threshold hypothesis in consideration of EFs in sports. The theory describes that only a critical value regarding the domain-generic cognitive functions must be reached to achieve high performance in a team sport (Beavan et al., 2020). However, knowledge is lacking whether this critical value must be examined using computerised neuropsychological tests or a self-report of EFs would be suitable.

Dysfunctions of EFs could be assessed by parents, educators, or a self-report. An example of self-reporting EF inventory is the Behaviour Rating Inventory of Executive

Function (BRIEF-SB; Roth et al., 2014). The inventory is a clinical scale to examine and interpret executive dysfunctions in a daily life setting. For example, the rating is used in previous studies to identify executive dysfunctions of athletes after a history of concussion (Rosso, 2016) or, in general, to examine the neuropsychiatric and cognitive outcomes of contact sport athletes (Alosco et al., 2017). The authors explicitly point out that the BRIEF scales are based on the circumscribed neuropsychological functions but that no conclusions can be drawn about neuroanatomical substrates (Drechsler & Steinhausen, 2013). Nevertheless, the inventory results could allow deductions about dysfunctions of EFs or their falling below a critical value to achieve high performance in the relevant sport.

Knowledge is lacking about the use of a self-reporting inventory to assess the EF of athletes. The current exploratory study aims to examine the correlations between neuropsychological tasks (3-back task, cued GoNoGo task, flanker task, and number-letter task) and scores of BRIEF-SB in athletes. The investigation should clarify the extent to which the inventory can predict dysfunction or poor EF-performance demonstrated by neuropsychological testing. It is hypothesised that the self-reported EFs correlate with the results of the neuropsychological measurements.

2 Methods

Participants

Sixty-eight young players of a national youth soccer academy (highest German youth league) were included in the study (M_{age} = 14.26 years, SD = 1.35 years). The average training age was M_{tage} = 9.12 years (SD = 2.51 years).

All procedures performed in the studies involving human participants adhered to the ethical standards of the institutional research committee and the 1964 Helsinki Declaration and its later amendments or to comparable ethical standards. Informed consent was obtained from all participants or legal representatives included in the study.

Measurements

Neuropsychological EF Tasks. Computerised neuropsychological tests with Inquisit Lab 6 (Millisecond Software LLC, Seattle, WA, USA) were performed to describe executive functions on a 17-inch screen and a QWERTZ keyboard. An Eriksen-flanker task (Eriksen & Eriksen, 1974) and cued Go/No go task (Verbruggen & Logan, 2008) were utilised to assess participants' inhibition. Furthermore, a 3-back task (Kirchner, 1958) was used to examine participants' working memory. To evaluate cognitive flexibility, a number-letter task was carried out modified from the Alternating-Runs-Switch task by Rogers and Monsell (1995). For further description of EF tasks, see Heilmann et al. (2022).

Self-Reporting of EF. The German version of the BRIEF-SB scale was used for the self-reporting of EF (Drechsler & Steinhausen, 2013; Gioia et al., 2000). The scale is an inventory of 80 items representing eight index scales (Inhibit, Shift, Emotional Control, Monitor, Working Memory, Plan/Organise, Organisation of Materials, and Initiate) and two validity scales (Inconsistency and Negativity). Items such as "If I'm given three orders at once, I can only remember the first or third" have to be answered with a three-point Likert scale: "never / very rarely" (1), "sometimes" (2), or "often" (3). Total scores of "behaviour regulation index" (BRI), "cognitive regulation index" (CRI), and an overall score (TS) of the eight index scores were calculated (Drechsler & Steinhausen, 2013). The scale has a well-established construct and predictive validity and internal consistency of Cronbach's α between 0.73–0.85 for index items and 0.96 for total score (Drechsler & Steinhausen, 2013).

Procedures

The soccer players were tested at their training facilities from September 2021 to November 2021. First, players arrived at the facilities and were greeted by the experimenter (author). Next, they were educated about the procedures and requested to sign the informed consent. After that, the players completed the BRIEF-SB inventory and performed the cognitive tasks, which lasted approximately 45 min. The order of neuropsychological tasks switched in randomised order to control for sequence effects. The players were tested in a quiet room one hour before training to avoid physical exercise effects, between 10:00 am and 4:00 pm.

Statistical Analysis

The Bravais-Pearson correlation was calculated between neuropsychological EF tasks' parameters and BRIEF-SB items. The fulfilment of requirements for parametric correlation analysis was checked. Correlations of ±1 are specified as perfect, ±.70-.99 as strong, .40-.69 as moderate, and .01-.39 as weak (Dancey & Reidy, 2007). Discriminatory power, respectively sensitivity was calculated with 2 x 2 contingency table for the total score of BRIEF-SB. The value specifies the ability to identify the 20 worst values of neuropsychological tasks by using the BRIEF-SB inventory (sensitivity = number of true positives / number of true positives + number of false negatives). The number of 20 worst scores was set because it would be interesting for practitioners to identify the worst 20 players in terms of EF from a sample of 68 players. A sensitivity of 0.75 is acceptable in this study. Statistical analyses were performed using SPSS 28 (SPSS, Chicago, IL, United States). A significance level of 0.05 was chosen.

3 Results

Correlational Analysis

The results of correlational analysis show significant negative correlations between the accuracy of 3-back task for evaluating working memory and the index "shift" ($r[63] = -.251$, $p = .045$) and "plan / organise" ($r[63] = -.276$, $p = .028$).

Furthermore, significant correlations could be identified between the indexes "monitor", "working memory" and "plan / organise" and the parameters of response time in the cued GoNoGo task (mean, vertical, and horizontal cue; $r[67] = .253$, $p =$

.037 to *r*[67] = .371, *p* = .002), representing inhibition of participants. There were positive, significant relationships between total scores (BRI, CRI, and TS) and response times in the cued GoNoGo task (*r*[67] = .251, *p* = .039 to *r*[67] = .288, *p* = .017).

No significant correlation could be identified between the BRIEF-SB scores and the parameters of the flanker task (inhibition).

The correlations between index scales of BRIEF-SB and parameters of number-letter task could be quantified between *r*(59) = -.254, *p* = .050 and *r*(59) = -.442, *p* < .01 and *r*(59) = -.260, *p* = .045 and *r*(59) = -.359, *p* = .005 for total scores (mainly between the indices "Emotional Control", "Monitor" and accuracy parameters of number-letter task). The entire results could be accessed in Appendix (Table A1).

Sensitivity Analysis

Sensitivity analysis could be quantified with a value between 0.125 and 0.538 to identify low performance in neuropsychological tasks by the total score of self-reported EFs (BRIEF-SB inventory).

4 Discussion

This study aimed to examine the correlations between self-reported EFs and results of computerised neuropsychological tests. Furthermore, the findings attempted to outline whether the results of the BRIEF-SB inventory allow predicting the outcomes of the EF tests, respectively identifying the participants with bad EF performance.

The results of the exploratory study show only weak-to-moderate correlations between the parameters of EF tests and the self-reporting (*r*[59] = .000, *p* = .999 and *r*[59] = -.442, *p* < .01). The findings could not be compared with other studies, because, to our knowledge, no investigations relate the two instruments of evaluating EFs. However, there has been criticism about the usage of domain-generic EF tasks to evaluate the cognitive functions of athletes (Kilger & Blomberg, 2020). Expanding this statement, the current findings do not suggest the use of self-reports of EFs to assess the cognitive functions of athletes. However, using a self-report is conceivable when dysfunctions from trauma or lesions of certain brain structures are expected and when one wants to obtain information about the cognitive functions of an athlete (Alosco et al., 2017; Rosso, 2016).

Furthermore, the sensitivity analysis results do not reveal sensitivity values above a critical level of 0.75. The low scores signify that the self-report inventory of EF could not assess domain-generic cognitive skills or predict bad results in neuropsychological EF tasks. Nevertheless, neuropsychological tasks are suggested to determine EFs in athletes because practitioners can identify dysfunctions using these measurements, allowing discrimination between superior and poor EF performance.

Two limitations inherent in the current study must be considered when interpreting the results. First, the items of the BRIEF-SB inventory are often referred to in a school setting. When assessing the EFs of athletes', an inventory referring to a sports context would be more appropriate. Secondly, a response scheme that follows socially desirable responses cannot be ruled out for the athletes. A two-sided approach of a self-report and possibly a parental report is suggested for future studies.

Despite the current study's limitations, one could conclude that a self-report of EFs is unsuitable for evaluating the EF performance for talent diagnostics or similar intentions. Instead, it is applicable only for identifying conspicuous issues in the cognitive function of athletes or athletes with known head injuries.

Appendix

Table A1 Results of correlational analysis

		3-back task		cued GoNoGo task					flanker task			number-letter task					
		MRT	ACC	ER	MRT	MRT (vert. cue)	MRT (hor. cue)	PCR	MRT	MRT (con.)	MRT (incon.)	PCR (switch)	PCR (no switch)	ACC (switch costs)	MRT (switch)	MRT (no switch)	MRT switch cost
Inhibit	r	.107	-.170	.024	.187	.192	.150	.027	.166	.163	.171	-.212	.022	-.283*	.159	.256*	-.029
	(p-value)	(.407)	(.179)	(.845)	(.127)	(.117)	(.223)	(.830)	(.179)	(.186)	(.167)	(.103)	(.868)	(.028)	(.226)	(.048)	(.827)
Shift	r	-.073	-,251*	-.045	.175	.182	.130	-.046	.098	.112	.073	-.196	-.115	-.127	.127	.236	-.053
	(p-value)	(.572)	(.045)	(.715)	(.154)	(.137)	(.289)	(.714)	(.428)	(.365)	(.559)	(.133)	(.381)	(.335)	(.332)	(.070)	(.687)
Emotional Control	r	.002	-.136	.046	.108	.108	.095	.081	.162	.165	.138	-.347**	-.166	-.262*	.173	.170	.079
	(p-value)	(.988)	(.285)	(.709)	(.380)	(.380)	(.441)	(.514)	(.191)	(.182)	(.266)	(.007)	(.205)	(.043)	(.185)	(.193)	(.551)
Monitor	r	.014	-.116	-.048	.371**	.363**	.350**	.051	.058	.072	.031	-.442**	-.223	-.323*	-.068	-.001	-.097
	(p-value)	(.915)	(.363)	(.696)	(.002)	(.002)	(.003)	(.683)	(.644)	(.561)	(.804)	(.000)	(.087)	(.012)	(.605)	(.993)	(.462)
Working Memory	r	.008	-.148	-.026	.253*	.231	.292*	.082	.097	.115	.047	-.215	-.026	-.239	.088	.173	-.048
	(p-value)	(.950)	(.244)	(.832)	(.037)	(.058)	(.016)	(.508)	(.434)	(.355)	(.706)	(.098)	(.846)	(.065)	(.505)	(.185)	(.717)
Plan/ Organize	r	-.114	-.276*	.078	.311**	.300*	.310*	.059	.159	.162	.141	-.219	-.015	-.254*	.189	.347**	-.076
	(p-value)	(.380)	(.028)	(.526)	(.010)	(.013)	(.010)	(.633)	(.199)	(.189)	(.254)	(.093)	(.910)	(.050)	(.148)	(.007)	(.563)
Organization of Materials	r	.002	-.079	.048	.127	.146	.056	-.017	.089	.106	.040	-.109	.077	-.211	.133	.163	.028
	(p-value)	(.990)	(.536)	(.697)	(.301)	(.235)	(.651)	(.893)	(.474)	(.395)	(.748)	(.406)	(.558)	(.106)	(.309)	(.213)	(.829)
Initiate	r	.109	-.097	-.097	.141	.134	.146	.112	.029	.054	-.022	-.274*	-.060	-.277*	.267*	.257*	.126
	(p-value)	(.400)	(.447)	(.433)	(.251)	(.275)	(.236)	(.369)	(.816)	(.661)	(.860)	(.034)	(.647)	(.032)	(.039)	(.047)	(.336)
Behavior Regulation Index	r	.018	-.227	-.002	.251*	.254*	.211	.031	.166	.175	.145	-.359**	-.133	-.309*	.151	.241	-.024
	(p-value)	(.891)	(.071)	(.987)	(.039)	(.037)	(.083)	(.801)	(.178)	(.157)	(.240)	(.005)	(.309)	(.016)	(.249)	(.064)	(.854)
Cognitive Regulation Index	r	-.005	-.197	.003	.274*	.265*	.270*	.078	.122	.141	.071	-.260*	-.012	-.308*	.209	.299*	.000
	(p-value)	(.971)	(.119)	(.981)	(.024)	(.029)	(.026)	(.530)	(.325)	(.254)	(.568)	(.045)	(.927)	(.017)	(.110)	(.020)	(.999)

Total Executive Score	r (p-value)	.006 (.966)	-.228 (.070)	.001 (.994)	.288* (.017)	.284* (.019)	.267* (.028)	.063 (.612)	.154 (.212)	.170 (.169)	.113 (.363)	-.333** (.009)	-.072 (.585)	-.338** (.008)	.201 (.124)	.300* (.020)	-.012 (.930)

*Note:** = $p < 0.05$, ** = $p < 0.01$; ACC = accuracy, ER = errorrate, MRT = mean response time, PCR = proportion of correct responses

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No financial support was received for this study

Conflict of interest

The authors declare that they have no competing interests.

Ethics

All procedures performed in the studies involving human participants adhered to the ethical standards of the institutional research committee and the 1964 Helsinki Declaration and its later amendments or to comparable ethical standards. Informed consent was obtained from all participants or legal representatives included in the study. The measures are part of biannual performance diagnostics of the soccer youth academy.

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Table A1

		3-back task		cued GoNoGo task					flanker task			number-letter task					
		MRT	ACC	ER	MRT	MRT (vert. cue)	MRT (hor. cue)	PCR	MRT	MRT (con.)	MRT (incon.)	PCR (switch)	PCR (no switch)	ACC (switch costs)	MRT (switch)	MRT (no switch)	MRT switch cost
Inhibit	r (p-value)	.107 (.407)	-.170 (.179)	.024 (.845)	.187 (.127)	.192 (.117)	.150 (.223)	.027 (.830)	.166 (.179)	.163 (.186)	.171 (.167)	-.212 (.103)	.022 (.868)	-.283* (.028)	.159 (.226)	.256* (.048)	-.029 (.827)
Shift	r (p-value)	-.073 (.572)	-,251* (.045)	-.045 (.715)	.175 (.154)	.182 (.137)	.130 (.289)	-.046 (.714)	.098 (.428)	.112 (.365)	.073 (.559)	-.196 (.133)	-.115 (.381)	-.127 (.335)	.127 (.332)	.236 (.070)	-.053 (.687)
Emotional Control	r (p-value)	.002 (.988)	-.136 (.285)	.046 (.709)	.108 (.380)	.108 (.380)	.095 (.441)	.081 (.514)	.162 (.191)	.165 (.182)	.138 (.266)	-.347** (.007)	-.166 (.205)	-.262* (.043)	.173 (.185)	.170 (.193)	.079 (.551)
Monitor	r (p-value)	.014 (.915)	-.116 (.363)	-.048 (.696)	.371** (.002)	.363** (.002)	.350** (.003)	.051 (.683)	.058 (.644)	.072 (.561)	.031 (.804)	-.442** (.000)	-.223 (.087)	-.323* (.012)	-.068 (.605)	-.001 (.993)	-.097 (.462)
Working Memory	r (p-value)	.008 (.950)	-.148 (.244)	-.026 (.832)	.253* (.037)	.231 (.058)	.292* (.016)	.082 (.508)	.097 (.434)	.115 (.355)	.047 (.706)	-.215 (.098)	-.026 (.846)	-.239 (.065)	.088 (.505)	.173 (.185)	-.048 (.717)
Plan/ Organize	r (p-value)	-.114 (.380)	-.276* (.028)	.078 (.526)	.311** (.010)	.300* (.013)	.310* (.010)	.059 (.633)	.159 (.199)	.162 (.189)	.141 (.254)	-.219 (.093)	-.015 (.910)	-.254* (.050)	.189 (.148)	.347** (.007)	-.076 (.563)
Organization of Materials	r (p-value)	.002 (.990)	-.079 (.536)	.048 (.697)	.127 (.301)	.146 (.235)	.056 (.651)	-.017 (.893)	.089 (.474)	.106 (.395)	.040 (.748)	-.109 (.406)	.077 (.558)	-.211 (.106)	.133 (.309)	.163 (.213)	.028 (.829)
Initiate	r (p-value)	.109 (.400)	-.097 (.447)	-.097 (.433)	.141 (.251)	.134 (.275)	.146 (.236)	.112 (.369)	.029 (.816)	.054 (.661)	-.022 (.860)	-.274* (.034)	-.060 (.647)	-.277* (.032)	.267* (.039)	.257* (.047)	.126 (.336)
Behavior Regulation Index	r (p-value)	.018 (.891)	-.227 (.071)	-.002 (.987)	.251* (.039)	.254* (.037)	.211 (.083)	.031 (.801)	.166 (.178)	.175 (.157)	.145 (.240)	-.359** (.005)	-.133 (.309)	-.309* (.016)	.151 (.249)	.241 (.064)	-.024 (.854)
Cognitive Regulation Index	r (p-value)	-.005 (.971)	-.197 (.119)	.003 (.981)	.274* (.024)	.265* (.029)	.270* (.026)	.078 (.530)	.122 (.325)	.141 (.254)	.071 (.568)	-.260* (.045)	-.012 (.927)	-.308* (.017)	.209 (.110)	.299* (.020)	.000 (.999)
Total Executive Score	r (p-value)	.006 (.966)	-.228 (.070)	.001 (.994)	.288* (.017)	.284* (.019)	.267* (.028)	.063 (.612)	.154 (.212)	.170 (.169)	.113 (.363)	-.333** (.009)	-.072 (.585)	-.338** (.008)	.201 (.124)	.300* (.020)	-.012 (.930)