

Perceptual-Cognitive Assessments in Football

by Adam Francis Beavan

Thesis submitted in fulfilment of the requirements for
the degree of

Doctor of Philosophy

under the supervision of Dr. Job Fransen, Dr. Andrew
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Declaration

I, Adam Francis Beavan, declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Sport and Exercise Discipline Group, Faculty of Health at the University of Technology Sydney.

This thesis is wholly my own work as the sole author unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree at any other academic institution except as fully acknowledged within the text. This thesis is the result of a Collaborative Doctoral Research Degree program with the Institute of Sport and Preventive Medicine, Saarland University.

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Production Note:

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Adam Francis Beavan

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“Grit can be defined as passion and perseverance for especially long-term goals.”

Angela Duckworth

“Anything wise in these pages you should credit to the many experts who preceded me. Anything foolish, assume it is my error.”

James Clear, Atomic Habits, Page 9

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Octoberfest with you. To Denny (Big Narsty), your laugh was infectious. You have the potential to become the best player agent, signing all 5th division Eastern European players to Leicester City. To Mat (Beers & Tears Co-founder), you're a role model for everyone to keep pursuing their passion, to stay adventurous, and to not take one's self so seriously. To Ludwig (congratulations), your passion and dedication for improving research in your topic is unchallenged. I look forward to continuing our friendship into the new era of our careers, even if you don't. To Monica (Chica), thanks for laughing at the same joke I told everyday making me feel like a real comedian... "dad the moves"! Last and certainly least, to Chris (Barnsley & Thompson), we became brothers bonded by the same unique sense of humour and outlook on life. Thanks for making my time in SB the funniest years of my life. I think I spent more time and wrote more words on WhatsApp with you than I ever did on my PhD.

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The format of this thesis is aligned with the ‘Thesis by Publication’ format as per the standards of both Saarland University and the University of Technology Sydney.

List of Publications Incorporated Into This Thesis

The below list outlines the published, in press or in preparation studies that are incorporated into this thesis. The studies listed below are presented in full in the following Chapters of this thesis.

Chapter 1:

- i. Beavan, A. (2019). Extraordinary Tools Require Extraordinary Evidence. *Science and Medicine in Football*, 3:4, 263-264, <https://doi.org/10.1080/24733938.2019.1678948>

Chapter 3:

- i. Beavan, A., Spielmann, J., Mayer, J., Skorski, S., Meyer, T., & Fransen, J. (2020). The Rise and Fall of Executive Functions in High-Level Football Players. *Psychology of Sport and Exercise*. <https://doi.org/10.1016/j.psychsport.2020.101677>

Chapter 4:

- i. Beavan, A., Fransen, J., Spielmann, J., Mayer, J., Skorski, S., & Meyer, T. (2018). The Footonaut as a new football-specific skills test: reproducibility and age-related differences in highly trained youth players. *Science and Medicine in Football*, 3(3), 177-182. <https://doi.org/10.1080/24733938.2018.1548772>

Chapter 5:

- i. Beavan, A., Chin, V., Spielmann, J., Mayer, J., Skorski, S., Meyer, T., & Fransen, J. (*in press*). A longitudinal analysis of the executive functions in high-level football players. *Journal of Sport & Exercise Psychology*.

Chapter 6:

- i. Beavan, A., Fransen, J., Hanke, L., Spielmann, J., Skorski, S., Mayer, J., & Meyer, T. Using Stroboscopic Vision to Restrict Visual Feedback in a Football Specific Skill Assessment. *In preparation*.
- ii. McGuckian, T., Beavan, A., Mayer, J., Chalkley, D., Pepping, GJ (2020). The association between visual exploration and passing performance in high-level U13 and U23 football players. *Science and Medicine in Football*.

Appendix:

- i. Beavan, A., Spielmann, J., Mayer, J., Skorski, S., Meyer, T., & Fransen, J. (2019). Age-Related Differences in Executive Functions Within High-Level Youth Soccer Players. *Brazilian Journal of Motor Behavior*, 13(2), 64-75. <https://doi.org/10.20338/bjmb.v13i2.131>
- ii. Beavan, A., Spielmann, J., Mayer. (2019). Taking the First Steps Towards Integrating Testing and Training Cognitive Abilities Within High-Performance Athletes; Insights from a Professional German Football Club. *Frontiers in Psychology*, 10, 2773. <https://doi.org/10.3389/fpsyg.2019.02773>

List of Conference Presentations

The below list outlines conference presentations at which the findings of this thesis were presented.

- i. Beavan, A., Fransen, J., Spielmann, J., Skorski, S., Mayer, J., Hauser, T., Meyer, T. (2019). 'The Rise and Fall of Executive Functions in Athletes', paper presented at the German Olympic Sports Federation's (DOSB) Annual Conference for Sports Psychology, Hoffenheim, 25th October.
- ii. Beavan, A., Fransen, J., Spielmann, J., Skorski, S., Mayer, J., Hauser, T., Meyer, T. (2019). 'The Rise and Fall of Executive Functions in Athletes', paper presented at the 15th European Congress of Sport & Exercise Psychology, Münster, 15-20 July.
- iii. Beavan, A., Fransen, J., Hanke, L., Spielmann, J., Skorski, S., Mayer, J., Hauser, T., Meyer, T. (2019). 'High Level Football Players' Ability to Use Implicit Information as Affordances for Action', paper presented at the European College of Sport Science, Prague, 2-7 July.
- iv. Beavan, A., Fransen, J., Hanke, L., Spielmann, J., Skorski, S., Mayer, J., Hauser, T., Meyer, T. (2019). 'Executive functions in elite level football players', paper presented at the World Congress of Science and Football, Melbourne, 3-7 June.
- v. Beavan, A., Fransen, J., Hanke, L., Spielmann, J., Skorski, S., Mayer, J., Hauser, T., Meyer, T. (2018). 'Using stroboscopic vision to restrict visual feedback in a football specific skill assessment', paper presented at the Australasian Skill Acquisition Network conference, Sydney, 15-16 November.
- vi. Beavan, A., Fransen, J., Hanke, L., Spielmann, J., Skorski, S., Mayer, J., Hauser, T., Meyer, T. (2018). 'Using stroboscopic vision to restrict visual feedback in a football specific skill assessment', paper presented at the European College of Sport Science, Dublin, 4-7 July.

Preface

This dissertation is a synthesis of the research that dates back almost a hundred years as well as the most recent findings that scientists have made, and everything in between. My contribution, I hope, is to connect the ideas of various research domains both within and external to sport, and incorporate the philosophies shared by the practitioners that have been implementing such ideas into practice for many years. Together, this dissertation should present a clear fusion of the research and presents the findings in a way that is highly actionable for both researchers and practitioners.

I wrote this thesis and all the manuscripts included within in many countries from Europe to Australia, in cafés and hospital rooms, in houses and hotels, in universities and football club offices, at work and on holiday, from morning to night, and while travelling in trains, planes and cars. I believe that I was always influenced by my environment, and I offer the reader a choice to imagine which environment I was immersed in when writing various sections of this thesis.

Last, external books that inspired me to finish my PhD me were many, but notable mentions were *Atomic Habits* by James Clear, *Thinking Fast and Slow* by Daniel Kahneman, and *The Big Five For Life* by John P. Strelecky.

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List of Symbols and Standard Abbreviations

AIC	Akaike's Information Criterion
ACL	Anterior Cruciate Ligament
ANOVA	Analysis of Variance
Au	Arbitrary Units
Bundesliga	Germany's 1st division in football
C	Congruent
cEV	Conditional Explained Variance
CI	Confidence Intervals
CV	Coefficient of Variation
DMGT	Differentiated Model of Giftedness & Talent
DT	Determination Test
EFs	Executive Functions
ES	Effect Size
Exp	Years of experience playing football
F	F-Value
Football	Association Soccer
Hz	Hertz
IC	Incongruent
IMU's	Inertial Measurement Units
IQ	Intelligence Quotient
IQR	Interquartile Range
Km/hr	Kilometres per hour
LCD	Liquid Crystal Display
LEDs	Light Emitting Diodes
LS	Less Skilled
LSPT	Loughborough Soccer Passing Test
m	Meters
MANVOA	Multivariate Analysis of Variance
mEV	Marginal Explained Variance
ms	milliseconds
n	Number of participants

NFL	National Football League (American Football)
P	P-Value
PCRTT	Precued Choice Response Time Task
PT-Test	Physical and Technical Test
r	Pearson's Correlation
RM-MANOVA	Repeated Measures Multivariate Analysis of Variance
S	Skilled
s	Seconds
SD	Standard Deviation
SSRT	Stop Signal Response Time
USD	US Dollars
VEA	Visual Exploratory Actions
VTS	Vienna Test System
y	Years
2D	Two-Dimensional
3D	Three Dimensional
%	Percentage
o	Angle
Δ	Delta (Change)

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Abstract

Introduction:

Assessments with varying levels of perceptual information or action fidelity are commonly used in the detection and identification of talent in football. Common performance assessments can range from either highly sport-specific environments with players being immersed in a realistic environment and interacting with a football (i.e. domain-specific, high ecological validity), to players sitting in front of a computer responding to various shapes and colours with no sport-specific information presented (i.e. domain-generic, low ecological validity). Many testing batteries measure athletes with a multitude of different tests that are placed along various points on ecological validity continuum. However, very few of these assessments are sufficiently validated. For the assessments that attempt to closely replicate the perception-action coupling demands experienced in football game play, there are many conditions that must be met before it can be used in future research and practice. On the other side of the spectrum, it remains contentious whether using assessments that intentionally remove ecological validity from their environments has merit. These non-sport specific assessments attempt to measure the general cognitive abilities of athletes, and many researchers have advocated their usefulness in talent identification programs. Therefore, the collection of aims within this dissertation was three-fold: i) to investigate both the domain-generic and domain-specific perceptual-cognitive abilities of all athletes (i.e. academy to senior players) in order to understand what perceptual-cognitive abilities athletes exhibit, and what factors (i.e. environment and heritable) contributed towards their cognitive profile, ii) to track both domain-specific and domain-generic abilities longitudinally in order to understand their relationships with increased exposure to football training, and iii) to learn from the limitations of the domain-specific skills assessment and incorporate new technologies in order to gain a further insight to investigate how emerging technologies could help to develop more representative assessments.

Methods:

To understand the between-group differences of domain-generic and domain-specific abilities across the youth developmental period of athletes, a variety of independent studies were undertaken. First, 343 male players (age: 10.34 – 34.72 years; playing

experience: 5 – 22 years) from the U12-Senior age groups of a professional German football club were recruited. Age, experience and playing position were recorded to examine which factors contributed more to the development of domain-generic abilities (Chapter 3). Players participated in four generic cognitive tasks aimed at measuring higher-level cognitive functioning: a precued choice response-time task, a stop-signal reaction-time task, a sustained attention task, and a multiple-object tracking task. Second, a new football-specific skills test was used to measure the domain-specific abilities of the athletes throughout adolescence, and the reliability and age-discriminant validity of this new domain-specific skills test was investigated (Chapter 4). Third, 304 players from the same cohort as Chapter 3 had their data analysed longitudinally to track the longitudinal development of both domain-generic (assessments from Chapter 3) and domain-specific (assessment from Chapter 4) abilities across three seasons (Chapter 5). Lastly, the final investigation of the dissertation was divided in two parts to explore how to develop more representative task designs within the football specific skills assessment used in the previous chapters. Accordingly, Chapter 6a) 85 amateur male participants (19.5 ± 5.4 years old; 13.1 ± 6.0 years playing football) completed two sessions in the skills assessment task under two different visual conditions: stroboscopic and full vision. Participants were subdivided into skilled (S: top 50%) and less-skilled (LS: bottom 50%) groups using their point score from the full vision condition. Chapter 6b) Exploratory head movements of fourteen U13 and thirteen U23 high-level football players were recorded with a head worn inertial sensor in the skills assessment task, from which the count, frequency and excursion of head movements were extracted before and during ball possession investigate whether visual exploratory action is associated with passing performance.

Results:

Chapter 3 first demonstrated that a negatively accelerated curve generally best described the relationship between age, experience and domain-generic abilities. Age and experience only explained a very low to moderate proportion of the variance in EFs (marginal explained variance ranged between 2 and 57%). Furthermore, although Chapter 4 revealed that the new domain-specific skills test yielded acceptable test-retest reliability for the correct number of passes to a target ($CV = 7.5-11.1$; $r = 0.48$; $p < 0.001$) and the speed at which they completed each trial ($CV = 2.6-5.1$; $r = 0.70$; $p < 0.001$), the assessment was not able to differentiate between athletes over the age of 15. This plateau

in both the developmental trajectories of domain-generic (Chapter 3) and domain-specific (Chapter 4) abilities was confirmed in the longitudinal study (Chapter 5), revealing that a performance plateau was apparent for domain-specific abilities during adolescence (i.e. 15 years old), whereas domain-generic abilities improved into young adulthood (i.e. 21 years old). Consequently, a further investigation into more representative task design had merit, where Chapter 6a) reported that restricting athletes' visual feedback in the football skills assessment impacted time of completion per trial to in both S and LS groups equally (S: 0.21s; LS: 0.18s; $p=0.543$), but S athletes' accuracy (S: 11.7%; LS: 0.4%; $p<0.001$) were significantly more affected compared to full vision conditions. Lastly, Chapter 6b) reported that the variables that best explained faster performance were a higher number of head turns before receiving the ball, and a lower number of head turns when in possession of the ball, which older athletes perform better than younger athletes.

Discussion/conclusion:

Overall, the investigation into domain-generic assessments across Chapter 3 and 5 found that athletes improve their performance during late childhood until reaching adolescent (i.e. average age of 15 years old) and was independent of how many years of experience playing football or which position they played on the field. As the developmental trajectories of high-level football players' domain-generic abilities reflected those observed in general populations' despite long-term exposure to football-specific training and gameplay, this questions the relationship between high-level experience's capacity to improve domain-generic abilities and challenges the validity of including non-sport specific assessments as a measure of football performance potential in high performing athletes. Lastly, despite the best efforts to use highly technical assessments to measure football skills in Chapter 4 and 5, the assessments may have under-represented the perceptual or action components necessary to allow athletes to demonstrate their expertise. Thus, more studies that aim to improve on the task designs of assessment tools has merit, and future studies could build off the foundations from the studies within Chapter 6 [i.e. stroboscopic glasses (6a) and head movement sensors (6b)] as methods to expand on the representativeness of assessment tasks.

Navigation of Thesis

Athletes are subjected to continuous performance assessments from the time they enter a high-performance training environment until the day they leave. Throughout their career span, athletes will be repetitively subjected to comparisons both on age and playing level grouped norms on all aspects of their performance. Interestingly, many of the performance assessments commonly used in football have yet to be supported by science; tools that are generally implemented first by practice with science proceeding with justification of the methods. Therefore, this thesis adds important findings that contribute to the debate of whether measures of cognitive abilities should be implemented in high-performance sport.

Chapter 1 provides a general introduction to the thesis, a description of the theoretical background of various performance assessments, and the applicability and proposed value of these assessments to explain expertise by reviewing the extant literature both within and external to a sporting domain. Furthermore, a probing investigation is also included to understand if there are any observable relationships between age and generic cognitive abilities in football players that could provide a rationale towards continuing the investigation of using non-sport specific assessments.

Chapter 2 provides a statement of problems and related aims of the experimental studies within this thesis.

Chapter 3 contributes to the nature vs. nurture debate in a large cohort of high-level football players by analysing the contribution that age, years of experience playing football and playing position have on explaining performance on generic measures of cognition.

Chapter 4 explores the reliability and age-discriminant validity of a new sports-specific skills assessment task and provides benchmark performance data of high-level football players performances throughout late childhood into young adulthood.

Chapter 5 is a rigorous statistical approach that examines how players develop their domain-specific and domain-generic perceptual-cognitive abilities throughout late childhood into early adulthood in a three-year longitudinal manner.

Chapter 6 contains two separate investigations that examine the perceptual abilities of how athletes receive information in the football-specific skills assessment and discusses the relevance of adapting existing equipment to better match the perception or action demands of football. Both studies implemented technology in the skills assessment task validated in Chapter 4 in attempt to improve the representative task designs of assessments in sport. The first study within this chapter uses stroboscopic glasses technology to vary the amount of visual input that athletes require to perform their football specific movements, providing a further understanding of perception-action coupling in high-level and lower-level athletes. The second study within this chapter discusses a study that used inertial measurement units placed on the head of athletes to examine the relationship between visual exploratory head movements prior to ball possession and with ball possession, and the effect on subsequent performance with the ball.

Chapter 7 provides a general discussion of the thesis, including a summary of findings from each chapter, research limitations, and an outline of future directions for this field of research.

Chapter 8 contains the appendices, which two full manuscripts can be found amongst other miscellaneous documents. The first manuscript is the preliminary study mentioned in Chapter 1, and the second manuscript is an opinion piece written about the implementation of a cognitive assessment battery within a professional football club.

Chapter 9 contains all the full citations of the references used throughout this dissertation.