THE USE OF PERFORMANCE ANALYSIS IN OLYMPIC AND PARALYMPIC SPORT: THE PERSPECTIVES OF COACHES AND ANALYSTS

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'Always get out the tent' – Scott Sears

Abstract

Performance analysis research to date has generally focused on understanding the best at the expense of how this information can be implemented within applied practice to benefit future performance (Mackenzie & Cushion, 2013). As such, the what, when, how, and why regarding the use and implementation of feedback and performance analysis within applied practice by the coach, performance analyst, athlete, or in combination, remains largely unexplored.

Therefore, this PhD aimed to address the academic and applied need for empirically based understanding regarding the delivery of performance analysis and feedback within applied elite sport settings. Interview and questionnaire-based approaches were utilised to capture the views and opinions of elite coaches and performance analysts, i.e. those working with athletes who compete internationally at the Olympic/Paralympic Games and World Championships, regarding their current and desired delivery. Within Study 1, face-to-face interviews were used to explore the what, when, how, and why of the delivery of performance analysis practice. Data were collected from 23 performance analysts across various Olympic and Paralympic sports. The experience of the coach and the constraint of time had the most significant impact upon practice, with video, profiling and reports being highlighted as the stand out deliverables. Video feedback was usually coach led, whilst data delivery was more evenly distributed between coach and analyst.

As the analysts tended to highlight the coach as the overriding feedback provider, Study 2 examined, 1) what coaches' value within performance analysis, 2) how coaches utilise performance analysis and feedback within applied practice, and 3) the difference, if any, between experienced and inexperienced performance analysis users. Data were collected via an online questionnaire, which identified training goals, discussion and

philosophy as the most prominent features influencing analysis direction. Additionally, coaches with greater experience chose to deliver significantly more feedback sessions within 1-hour of performance. Feedback sessions were primarily < 20-minutes in duration, delivered consistently according to a preferred schedule, face-to-face, within an individual format, and delivered using a balanced (experienced) or mostly positive (inexperienced) approach.

Study 3 utilised a comparative approach to identify incongruency, if any existed, between coach and analyst, whilst offering areas of potential focus to facilitate greater alignment moving forward. Agreement on the provision, importance and need for full video was confirmed. The majority of analysts provided profiling often, or all of the time, however, despite its prevalence as a taught component of post-graduate performance analysis courses, only one third of coaches felt this was the required amount. Communication, or lack of in places, was identified as a key aspect potentially requiring additional focus.

The empirical findings of this thesis have identified some of the key processes and practices delivered and desired by elite coaches or analysts operating within the applied Olympic and Paralympic environment. The various complexities within performance analysis as well as the numerous intertwining factors that impact upon practice have also been presented. The findings identified, as well as the questionnaires used within data collection should be utilised by analysts and coaches moving forward to, 1) facilitate information sharing between sports whilst offering the ability to 'check and challenge' processes, 2) offer an easily implemented and transferable method to facilitate intermittent review of practice, and 3) identify areas within practice potentially requiring development, thus ensuring continued applied impact.

Publications resulting from this thesis

Published journal articles:

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Nicholls, S., & James, N. (2016). The Use of Performance Analysis and Feedback within the Elite Olympic Sports Environment. Research paper presented at the 11th World Congress of Performance Analysis of Sport, Alicante, Spain, November.

Nicholls, S., & James, N. (2015). Feedback science within elite Olympic sports. Research paper presented at the EIS National Conference, Hinckley, England, December.

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Chapter 1: Introduction

1.1 – Background

Performance analysis in sport has received considerable interest within academic research throughout the past 30 years (e.g. Hughes & Franks, 1997) and is suggested as a key component within the coaching process (Carling, Williams & Reilly, 2005). Moreover, to support this notion, various journal sub-sections (e.g. Journal of Sports Science), separate standalone journals (e.g. International Journal of Performance Analysis in Sport), and applied positions have emerged to coincide with the rapid rise in demand and value placed upon the area of performance analysis. Academic interest has been primarily concerned with a number of main theme areas, namely; 1) key performance indicators e.g. Hughes and Bartlett (2002), 2) system design, operational definitions and reliability e.g. Cooper, Hughes, O'Donoghue and Nevill (2007), 3) key determinants of performance, performance profiling and predictive methods e.g. Hughes, Evans and Wells (2001) and 4) the measurement of work-rate profiles e.g. Cahill, Lamb, Worsfold, Headey and Murray (2013). Much of this research has attempted to identify cause-effect relationships through reductive quantitative approaches in 'an attempt to understand the functioning of the whole through an analysis of its individual parts' (Mackenzie & Cushion, 2013, p. 640). Such a process is utilised to offer insight into What It Takes To Win (WITTW) within the respective sporting demographic.

Ultimately, the focus of performance analysis research to date appears to be on understanding the best at the expense of how this information can be implemented within applied practice to achieve subsequent performance gains (Groom, 2012; Mackenzie & Cushion, 2013). Although a required building block for further research within the topic or sport of interest, the need for more impactful studies offering greater transferability

(Mackenzie & Cushion, 2013) to benefit the end user are required, and thus avoid the criticism of 'research for research sake'. Williams and Kendall (2007) further highlighted the disconnection between sports science research and the important issues within elite coaches' day-to-day applied practice. More specifically, sports science research often fails to incorporate 1) participants within a naturalistic setting or 2) elite level participants (athlete, coaches or otherwise) within data collection and as such, can be considered far removed from the 'real world' of high-performance sport. Consequently, for coaches and practitioners to purposefully and successfully implement reported information within the elite environment, research within performance analysis (and sports science more broadly) needs to be more useful to them, conducted with elite populations, and thus, better reflect the 'real world' of elite/high-performance sport.

The emergence of the forthcoming research topic(s) was primarily driven by the needs of the funding body, the English Institute of Sport (EIS), and its desire to understand the use of performance analysis and feedback in a greater depth within Olympic and Paralympic environments across their 'network'. Whilst the EIS provided a general theme, the overarching topics of focus were left open, consequently enabling myself as the researcher to identify what gaps in knowledge were evident within the literature, whilst more importantly for this project, being useful to the applied practitioner. In undertaking this project, a significant amount of time was spent: 1) reflecting on my own previous and ongoing applied experiences, and 2) observing and interacting with current practitioners working within the high-performance system in an attempt to develop a greater appreciation and understanding of their current needs, process, roles, and demands.

Specifically, the research was founded from the paucity of knowledge and understanding regarding the use of performance analysis and feedback to support practitioners within their respective applied delivery. It was observed that the majority of

research surrounding the manipulation and implementation of feedback within motor learning largely involved the performance of simple skills, lab-based assessment, and closed environments, that is arguably far removed from applied feedback practice. Furthermore, throughout the aforementioned applied exposure, whilst attempting to gain a greater understanding of what performance analysts do within practice, it became clear that the practitioners did not have time or were unable to fully investigate and understand the what, when, how and why of practice. This clear and consistent issue began to frequently raise the following issues and questions: if the performance analysts had limited time to investigate such a problem within their own environment, how could they be expected to investigate such an issue within 1) other sporting environments or 2) from the perspective of the receiver, i.e. coach or athlete?

Similarly, academic writing unfortunately offers limited insight, with the exception of Wright and colleagues (2012; 2013; 2016) and Groom's (Groom, Cushion & Nelson, 2011) primarily football work, into; 1) what takes place within applied sessions, 2) how performance analysis is utilised within practice or 3) feedback session structure and the interactions between analyst, coach and athlete from an interpretive perspective. Consequently, there is a lack of understanding regarding the why of practice, i.e. why is performance analysis used how it is? Bertram, Marteniuk and Guadagnoli (2007) further argued that those working within elite sport, specifically coaches and performance analyst practitioners, would benefit from a framework for how and when to use video and performance analysis information in practice and, perhaps more importantly, how and when not to use it. Middlemas (2014) suggested that researchers should begin to move away from research focusing upon the capture and analysis of video and data, towards a greater emphasis on the human element, more specifically, how it is delivered and received. Indeed, research exploring and interpreting the activities and processes of a wide

variety of participants within applied elite environments appears crucial within the development and understanding of current practice to facilitate the progression of future practice. The research presented within this thesis therefore attempts to uncover these unknowns, add to, and ultimately build upon the limited knowledge regarding the use of performance analysis and feedback within the Olympic and Paralympic sports environment. Furthermore, the research serves to guide practitioners and coaches alike within the delivery and integration of performance analysis and feedback into their future day-to-day practice.

1.2 – Aims and objectives

1. Outline how performance analysts deliver feedback and performance analysis information within practice.

   Related objectives:

   - Understand how, when, what do analysts currently feedback.
   - Understand why analysts undertake practice in the way they do.
   - Understand how, when, what do analysts desire to feedback.
   - Determine how the analyst is utilised within applied practice.

2. Understand coaches' perceptions of the use and implementation of feedback and performance analysis within applied practice.

   Related objectives:

   - What do coaches' value within the performance analysis service?
   - How do coaches utilise performance analysis?
   - Outline how can performance analysis feedback can be delivered more effectively to further benefit coaches within practice.

- Outline what affects the ability to feedback at these more effective opportunities.

3. Describe the congruency between the coach-analyst regarding practice.

   Related objectives:

   - Identify the key differences and similarities between the approaches of the coach and analyst.
   - Outline potential target areas to enable a more aligned delivery.

1.3 – Methodological and philosophical considerations

The methods and questions utilised by researchers are continually influenced, consciously or sub-consciously, by their underlying beliefs (Morgan, 2007). These beliefs, when viewed as their root commitments, can be grouped and rationally explained within a number of paradigms. A paradigm is a pattern or model, an exemplar; a typical instance of something, an example. A number of research paradigms are currently recognised, including positivism, interpretivism, critical theory and post-structuralism, all of which influence the various research decisions that are made when investigating different types of research questions. Each of these paradigms is underpinned by different views of the nature of knowledge and the relationship between researcher and what can be known, often referred to as epistemology. For example, positivism is underpinned by scientific verification, logical or mathematical proof. Whereas interpretivism or interpretivists look for meaning in a subjective experience, seeking to gain an in-depth insight into the participant's life or practice. The main assumptions, adapted from Krane and Baird (2005), of each paradigm outlined below:

1) Positivism: Observable, empirical, and quantifiable. Prediction and explanation. Unbiased and objective.
2) Interpretivism: Reality grounded in perception. Subjectively assessed.
3) Critical theory: Multiple realities, situated knowledge, which is socially and historically bound. Empowerment and emancipation.
4) Post-structuralism: No universal truth. Deconstruction.

Research studies can utilise a qualitative, quantitative or mixed method approach, generally influenced by the paradigmatic commitment made, and therefore it is important to understand the various differences, benefits and limitation of each approach so the data that is collected and presented can be placed in greater context. Quantitative techniques (generally positivism) focus on measuring or counting using predetermined categories (Skinner, Tagg & Holloway, 2000). Qualitative research (generally interpretivism) focuses on experiences and the meanings they place on such experiences, involving direct contact with people in their everyday settings, which is often collected via spoken or written response (Skinner et al., 2000). Finally, mixed method approaches are a combinational research approach whereby researchers collect and analyse both quantitative (e.g. pre-coded surveys) and qualitative (e.g. verbatim participants response) data within the same study (Shorten & Smith, 2017; Tashakkori & Creswell, 2007), often used to address research questions that neither quantitative nor qualitative methods could completely answer in isolation (Shorten & Smith, 2017). A key step within this type of approach is 'data linkage' or the integration of each data source at an appropriate stage in the research process. Furthermore, considerations regarding whether each method is given equal priority or not is another key decision that needs to be made. For example, gaining an understanding when a performance analyst delivers feedback, e.g. immediately or delayed,

could be obtained from a quantitative approach using pre-coded responses. However, 'the why' or reasons associated with these choices would be best collected through participant spoken responses that allow the participant to provide as much detail and information as necessary all within their own words.

The concise overview of the potential paradigmatic stances above demonstrate that the thesis is underpinned by positivism, in that addressing the research questions posed in the thesis is primarily concerned with knowledge that is quantifiable and observable, i.e. how often analysts or coaches use a specific method of analysis (epistemology position), with the aim of explaining why participant's use what they use within their practice environment (ontology position). Given the objectives and research questions posed within the thesis, as well as the need to quantify how and what is delivered, whilst beginning to understand why difference may occur within practice, a mixed method approach within the form of surveys were selected as an appropriate methodological choice.

A survey approach was used to most appropriately combine quantitative (frequency and distribution) and qualitative (verbatim responses) participant responses from a vast number of sports environments, coaches, and analysts throughout the UK. Surveys enable direct comparison through the use of pre-coded response categories, whilst offering each participant opportunity to provide 'the why' behind their approach to practice within spoken or written text. Key advantages of this approach, and an overriding reason why mixed methods surveys were chosen within this thesis, include; 1) complementarity, or the enhancement of findings from one method by the use of another and 2) initiation, or the capacity to access new insight into a particular phenomenon (Moran, Matthews & Kirby, 2011).

Surveys and questionnaires are the most utilised method of collecting data within mixed method designs where participant responses are key to understanding the

phenomenon or answering the research question of interest. Many researchers use these terms interchangeably, however an important distinction exists between the two. A questionnaire is any set of written questions, while a survey is the set of questions as well as the process of collecting, aggregating and analysing the responses provided to those questions. Simply put, questionnaire describes the content, while survey is a broader term describing content, method and analysis. Among the various methods of data gathering for research, the survey method is often preferred due to its strengths, namely: 1) high representativeness, 2) low cost, and 3) convenient data gathering. However, as with all research techniques, surveys are sometimes negatively affected by 1) design inflexibility, and 2) the inappropriateness of questions by virtue of the need to generalise the questions for the desired audience, i.e. not specific to an individual's environment or experience. In order to limit these potential negative effects, the survey design stage involved considerable pilot testing to ensure questions could be effectively answered by the desired demographic.

Statistical inferencing within research is another key aspect to consider within research practice as the ability to collect data on the entire population of interest is often impossible. As a consequence, statistical inferencing is the process of using data analysis to deduce properties of a wider population from an observed data set. Although statistical inferencing attempts to provide insight into the wider population, this method has two main limitations which need to be acknowledged. Firstly, the method attempts to provide data about a population that has not been fully measured, thus the insights that are calculated carry a degree of uncertainty as to whether they are a correct representation. Secondly, a number of inferential tests require the user to make educated guesses based upon theory. Linked to this, the confidence we can have in statistical testing is also impacted by the sample size of the wider population which the data has been collected to

represent. Within this thesis smaller sample sizes were arguably present, but to overcome this potential weakness, the sample population were all from the elite level, which should be considered a clear strength. General access to elite populations is difficult and often very challenging to achieve. Elite sports are generally secretive in nature and do not wish to potentially divulge specific information which may be perceived as their coaching or team's 'competitive edge' in fear of benefitting their future opponents. Obtaining information from these elite populations is a clear strength of the thesis and helps to address this knowledge gap, thus providing the academic researcher and applied practitioner with real world information to ultimately benefit applied practice.

1.4 – Organisation of thesis

Chapter 1 is an Introduction to the topic and provides background information and the important research questions that will be addressed within the thesis. Following this, Chapter 2 the Literature Review, presents, evaluates and considers the recent and key developments within the fields of feedback, sports motor learning and performance analysis. This chapter highlights the wide variety of research, and in turn, the difficulties of interpreting and subsequently implementing such findings into the 'real world' of applied practice. To answer the aims presented in this thesis, three studies were conducted. In the third chapter, aim 1 is addressed through the use of structured interviews. Here, the current and desired methods of feedback practice by performance analysts within the applied environment are explored. In the fourth chapter, aim 2 is addressed utilising a questionnaire approach to examine coaches' perceptions, use and implementation of feedback and performance analysis practice, including developing an understanding of what coaches' value from the performance analysis service. The fifth chapter addresses aim 3, examining the congruency between coach and analyst regarding their use of

performance analysis and feedback. The sixth and final chapter, Discussion and Conclusions, considers the implications of the thesis through a reflective analysis of the research, the limitations of the thesis, where the thesis sits within the literature, the implications for educator and applied practitioner and finally, future research directions.

Chapter 2: Literature Review

2.1.1 – Introduction

As theory and evidence is essential to scientific progress and informed professional practice, the purpose of this narrative review is to evaluate, compare, and contrast the literature justifying the target aims and objectives. Therefore, the following review outlines recent and key developments within the fields of feedback, sports motor learning and performance analysis from the English literature. The review will illustrate the strengths, weaknesses, and inconsistencies within findings, thereby facilitating future understanding. A citation-based methodology was applied to search for English language literature which evaluated the use of feedback, sports motor learning, and performance analysis within applied practice. This method has been demonstrated by Janssens and Gwinn (2015) as an efficient and effective method of identifying publications of similar interest and topic for reviews. Peer-reviewed journal publications were used as the primary source, but various textbooks were also utilised where appropriate. The search strategy was not limited to a systematic search strategy, i.e. only specific keywords used, however, the initial direction of the review did begin with a broad search using terms such as: 1) feedback within sport, 2) performance analysis within sport, and 3) video feedback. From here the reference lists of relevant papers were used to identify further papers linking to the topic area of interest in a timely and efficient manner. In addition, the review was not limited to a specific and set period during the initial onset of the thesis, but was however, continually updated throughout the duration of the project when newer research was published.

The review is structured into a number of key areas; firstly, the review provides a brief overview of the key research trends and current interests within performance analysis research thus far. Secondly, it considers where and why performance analysis came about

in sport, and the importance of accurate and reliable information within the provision of feedback for performance improvement. Thirdly, the use, manipulation and implementation of feedback within sports motor learning research to date is presented. Thereafter, the effectiveness of performance analysis and the importance of empirical 'real world' data within research studies is offered. The review and analysis presented is key to demonstrate recent and important developments within performance analysis and feedback literature. Furthermore, the review enables the identification of a number of research gaps within our current knowledge and understanding regarding the use and implementation of performance analysis and feedback within applied practice. The review concludes by outlining the current research problem, and in turn, the key areas of investigation that will be addressed by this thesis.

2.1.2 – What is performance analysis?

Performance analysis is a sub-discipline of sport science, utilised as a means of comprehensively and objectively quantifying critical events within a sports performance in both, a reliable and consistent manner (Hughes & Bartlett, 2008; Hughes & Franks, 2004). The primary goal of performance analysis is to provide athletes and coaches with appropriate information, via qualitative and quantitative feedback, facilitating behaviour and performance improvements. Consequently, performance analysis has become a widely accepted and important tool within the coaching process by virtue of the ever-growing significance of objective and accurate analysis, feedback, and appropriate intervention within the development of performance (Hodges & Franks, 2004; Lyle, 2002; Mayes, O'Donoghue, Garland & Davidson, 2009). To achieve this, importance is placed upon what has now developed into a standalone member of the coaching and sports science team, i.e. the performance analyst. The role of the performance analyst is to identify and

provide information related to critical aspects of a sports performance, in turn, enhancing athlete development and the coach decision-making process (Groom et al., 2011; O'Donoghue, 2006).

Performance analysts are becoming an ever more important member of the 'team behind the team' within professional clubs (e.g. Rugby Union – the evident match support alongside their respective coaches) and sporting organisations (e.g. the English Institute of Sport [EIS]). As a consequence, a number of universities offer standalone under-graduate or post-graduate courses (e.g. Middlesex University, University of Chester, Cardiff Metropolitan University) or modules within a broader undergraduate programme specialising in performance analysis. The ever-expanding International Journal of Performance Analysis in Sport (IJPAS), and the sub-section of the Journal of Sport Sciences (JSS) demonstrates the ever-growing importance and interest within the area from a research perspective.

2.1.3 – General research themes within the performance analysis literature

Research within performance analysis has tended to focus upon four main areas, including: 1) key performance indicators (e.g. Choi, O'Donoghue & Hughes, 2008; Csataljay, O'Donoghue, Hughes & Dancs, 2008; Hughes & Bartlett, 2002; James, Mellalieu & Jones, 2005; Lames & McGarry, 2007; O'Donoghue, 2008), 2) system design, operational definitions and reliability (e.g. Cooper et al., 2007; Thomson, Lamb & Nicholas, 2013), 3) key determinants of performance, performance profiling and predictive methods (e.g. Hughes et al., 2001; James et al., 2005; O'Donoghue, 2005) and 4) the measurement of work-rate profiles (e.g. Cahill et al., 2013; Petersen, Pyne, Dawson, Kellett & Portus, 2011; Reilly & Thomas, 1976; Waldron, Twist, Highton, Worsfold & Daniels, 2011).

2.1.4 – Key performance indicators

A key performance indicator (KPI), as defined by Hughes and Bartlett (2015), is 'a selection, or combination, of action variables that aims to define some or all aspects of a performance'. A variety of methods have been proposed for the identification of KPIs, including: expert coach opinion, regression-based analysis and inferential statistics that distinguish between winning and losing performance, among others (O'Donoghue, 2008). Performance analysts have generally focused upon match, tactical and technical indicators, in turn, contributing to our understanding of the physiological, psychological, technical and tactical demands of a variety of team and individual sports (Hughes & Bartlett, 2015). KPIs can be broadly categorised into scoring (e.g. tries) or quality indicators (e.g. strike-rate) utilised as a means of demonstrating positive and negative aspects of performance. The use of KPIs within sport enables coaches and practitioners to isolate and focus upon areas of performance strengths and weaknesses related to previous performance(s) or forthcoming opposition, in turn, enabling specific strategies and training regimes to be developed (Jones, James & Mellalieu, 2008; Lames & McGarry, 2007). Subsequently, quantifiable KPIs allow observers to monitor the impact and effectiveness of interventions (James et al., 2005). Moreover, the utilisation of KPIs is a highly adaptable process, modifiable to incorporate various combinations related to team and individual performance, thus enabling specific and individualised feedback to be developed (Jones et al., 2008).

However, presenting KPI data in isolation, devoid of appropriate contextual information, can offer a distorted and unrepresentative reflection of performance (positively or negatively; Hughes & Bartlett, 2015). For example, if the number of goals scored by two football players throughout a league season was identical (e.g. 20), it could easily be construed that both players had similarly effective seasons. However, when the

total shots attempted is considered (i.e. Player A = 40 and Player B = 80), the results present a different performance overview altogether. Specifically, when the goals to shots ratios are calculated, it can be observed that player A scores 1 goal every 2 shots (1:2), whereas player B scores 1 goal every 4 shots (1:4). Therefore, based upon the additional contextual information, it could be argued that player A was more effective with their respective shooting attempts, owing to having scored the same absolute number of goals in half as many shots.

The development of appropriate KPIs forms the basis of more complex analysis, such as performance profiles and the identification of key determinants of success. This initial identification process aims to reduce the complexities inherent within a sports performance into key, quantifiable aspects, that significantly influence sporting performance. Success or failure of any performance is relative to either, 1) the opposition or 2) the team/athlete's previous performance(s). As such, to enable a comprehensive assessment of data collated using KPIs, it is necessary to compare against teams/athletes whom compete at a similar relative standard. Additional consideration should be made in respect of data normalisation, whereby raw values, devoid of appropriate context, can affect statistical interpretation and obscure meaningful performance differences (Hughes & Bartlett, 2004).

2.1.5 – System design, operational definitions and reliability

Following the identification of appropriate KPIs, a sequential data collection system is required to assess such indicators. From the football example, the performance indicator in question may be a player's shots to goals ratio; but in order for this performance indicator to be computed, it is necessary for each attempted shot and related success i.e. goal or no goal to be recorded. Data collection systems can be either hand or computer based, and

although different recording systems, both are governed by the same underlying principles (Hughes & Franks, 2004). These principles can be represented in four ways: the, 1) what or action, e.g. successful shot, 2) when or time, e.g. 20th minute, 3) where or position, e.g. 18-yard box and 4) who or player, e.g. number 9. When designing a system, the user should always: 1) maintain a clear idea of what data they wish to collect, 2) make the system as simple as possible and 3) test the system thoroughly before full implementation.

Once the system has been outlined, all variables within the system require clear, unambiguous and appropriate operational definitions (Hughes, 2015a). The development of these definitions enables the users (analyst, athletes, coaches etc.) to interpret events consistently through a shared understanding. Williams (2012) stated 'definitions are required in the notation of sport either by an individual or by a group of analyst[s] to ensure that the gathered data is both valid and reliable' (p.52). However, O'Donoghue (2007) conversely suggested, 'the presence of precise operational definitions does not guarantee good reliability nor does their absence guarantee poor reliability' (p.35). O'Donoghue (2007) further suggested that an analyst's sports specific knowledge was more important. One could argue however; the presence of clear operational definitions removes ambiguity within the process. Coaches might consider a certain indicator to represent something slightly different to that of the analyst, even if sporting background is identical, thus data interpretation may be affected, i.e. erroneous performance conclusions are offered. For example, a simple 'one-two' in football, to the majority of football observers, is a pass made from Player A to Player B, and back to Player A. However, United (pseudonym) considered a one-two, in the context of their club and analysis, as a pass under the same conditions but it must be made in a forward manner, thus gaining field progression. Furthermore, despite possessing identical labels/names, many of the indicators utilised within same sport studies may actually be defined slightly differently

(Williams, 2012). When definitions differ or are not clear and provided, it becomes more difficult to infer meaningful comparison of results (Williams, 2012). Issues regarding definition consensus can also be observed within media presented statistics as demonstrated by Worsfold and Macbeth (2009). Considerable differences were identified between four well-known broadcasters (BBC, ESPN, Sky and Eurosport) for a number of, on the surface, simplistic performance measures, e.g. corners, fouls, offsides. Until greater attempts are made to present and standardise definitions, to the benefit of all, studies aiming to continue research themes or build upon previously reported findings is more difficult.

The key factor within the implementation of a new or novel performance analysis notation system is its repeatability and reliability, and without a repeatable system, any inferences made about the information can be considered rather spurious. Reliability assessment should be carried out on an intra- and inter-observer basis. Simply put, the system should output identical data irrespective of whether the same (intra) or a different user (inter) repeats the analysis for any given performance. A wide variety of methods exist to establish system reliability, including: the percentage difference or %Error calculation (Hughes, Cooper & Nevill, 2004; Hughes, 2015b) and that proposed by Cooper et al. (2007). Both represent simplistic and easily implemented methods, which have been effectively utilised within published performance analysis research (e.g. Worsfold & Macbeth, 2009; Thomson et al., 2013). Establishing suitably reliable data is important within not only academic research, but perhaps more importantly the applied environment, whereby the information is being utilised in important coach decision-making processes (O'Donoghue, 2007).

Notwithstanding, even with carefully considered, validated, reliable operational definitions and systems, some bias is inevitable (James et al., 2005). For example, James et

al. (2005) alluded to the difficulties of identifying who is at fault within an unsuccessful lineout, i.e. was it the jumper's or the thrower's fault? Similarly, problems may occur when attempting to interpret a player's intention within certain skill performance, e.g. was a player attempting to cross the ball or shoot? These issues unfortunately contribute to the error identified within performance analysis research; reinforcing the need for clear operational definitions, combined with adequate reliability measures, to ensure all data collated is truly representative of observed performance. O'Donoghue (2007), although not thoroughly discussed, made seven very useful recommendations for consideration during the development and operation of a performance analysis notation system (see p. 46). See also Thomson et al. (2013) for an example of a successfully and appropriately designed system, set of operational definitions and accompanying reliability for amateur boxing performance.

2.1.6 – Key determinants of performance and performance profiling

Performance profiling, a methodology analysing potential performance patterns, is a collection of indicators that aims to represent typical performance, ostensibly offering some degree of prediction for future performance (Butterworth, O'Donoghue & Cropley, 2013; Hughes, 2004; O'Donoghue, 2013; Waldron & Worsfold, 2010). Each indicator selected within a profile should be of high value to the coach/athlete as to maintain focus upon key aspects of performance (James et al., 2005). Such profiles are generally established across multiple performances in an attempt to consider performance variability, however, the appropriate number of performances required to produce a representative profile is largely questioned (Butterworth et al., 2013; Hughes et al., 2001). Even between indicators, the number of performances can vary significantly (see Hughes et al., 2001). Furthermore, a 'stable' performance profile may never materialise for various performance

indicators. A clear and obvious use of performance profiling is the ability of multiple athletes/teams to be easily compared against one another using objective data (O'Donoghue, 2005). Furthermore, if performance 'norms' are available, comparisons can be made against a wider population (O'Donoghue, 2005), thus enabling performances to be placed in greater context. Predictive-profiles and key determinants of success have been investigated within sports such as American football (Boulier & Stekler, 2003), basketball (Sampaio & Janeira, 2003), cricket (Najdan, Robins & Glazier, 2014), rugby (Jones, Mellalieu & James, 2004a; Jones et al., 2008), squash (McGarry & Franks, 1994), and tennis (O'Donoghue & Cullinane, 2011), to name a few.

Principally, three main sports profiling techniques are proposed within the literature, including: Hughes et al. (2001), James et al. (2005) and O'Donoghue (2005). Further studies have also attempted to apply regression-based approaches, accounting for oppositional quality and athlete ranking, to profile and predict sports performance, e.g. O'Donoghue and Cullinane (2011). Hughes et al. (2001), although offering a methodology determining the required number of performances to produce a stable profile, is subject to a number of criticisms. For example, data collected for the first time has limited use within such a methodology; furthermore, fluctuations in team changes, maturation and the fact some performances never stabilise limits overall applicability (O'Donoghue, 2005). In addition, as the number of performances (utilised within the profile) increases, the sensitivity of the cumulative mean to change decreases, and as such, the methodology presents an erroneously 'stable' profile. Moreover, despite being termed 'normative profiles', the methodology failed to adequately consider the variability of performance data or include appropriate contextual information to facilitate this process. Vučković et al. (2013) considered this criticism and incorporated the available time to play a shot (a proxy of pressure), the area of court the shot was played from and match situation (winning or

losing) into their analysis of elite squash. They found that variability in performance was related to the availability of time where less time to play a shot meant that less variation in shots played was evident.

James et al. (2005) presented position specific behaviours, attempting to account for positional variability, with the aim of allowing a coach to better evaluate individual positional performance. One criticism however, acknowledged by James et al. (2005) and reiterated by Butterworth et al. (2013), is the use of key, commonly occurring performance indicators. Within an elite environment, a number of players are likely to demonstrate similar levels of key skills, hence the discriminatory power of these variables is questionable when combined over a number of matches.

The final technique, proposed by O'Donoghue (2005), compared player performances to peer 'norms' using percentile data. The technique places performance into some context, however, coaches may understand or 'better' interpret the raw data. This issue is exacerbated when focusing upon indicators with a small normative data range. For example, a range of team passes within a database of football matches may be 340-360. An absolute reduction of 3 passes between matches (i.e. 358 to 355), although perhaps practically considered infinitesimal, demonstrates performance dropping from the 80th to the 65th percentile, and without a knowledge of the raw values, such a finding could be interpreted as a significant reduction in performance. Furthermore, when a performer (e.g. Brazil – football, ranked 5th FIFA world rankings, May 2015) competes against lower ranked opposition (e.g. Japan, ranked 50th) the results are likely to demonstrate high-level performance (i.e. a high percentile), however, when the same performer competes against an equally skilled or better opponent (e.g. Germany, ranked 1st), the indicator values will arguably be significantly lower. Thus, the method fails to account for a number of confounding influences upon performance, such as; opposition quality, match location and

score line (Lago, 2009; Taylor, Mellalieu, James & Shearer, 2008; Tucker, Mellalieu, James & Taylor, 2005). A subsequent attempt to address these influences was presented by O'Donoghue and Cullinane (2011) who developed expected performance indicator values based on a player's world ranking. Residual values determined how much 'better' or 'worse' a player did than expected. The player's profile could then be presented as an absolute comparison against raw values but also as an expected performance based on the quality of opponent faced.

Although the methodologies briefly discussed have their limitations, the methodologies present viable and relatively easily implemented techniques for the majority of practical situations. The methodologies allow users to assess and investigate differences between winners and losers, tournament stages etc., and in turn, identify the key statistics related to successful performance within their respective sport(s). However, users must strive to account for the various confounding variables identified above if achieving a more appropriate representation or comparison of performance is to be achieved.

2.1.7 – The measurement of work-rate profiles

The measurement of the physical demands of sport is a significant research area utilising performance analysis support alongside physiological testing. A method termed 'Time Motion Analysis (TMA)' was initially utilised to quantify the demands associated with football (see Reilly & Thomas, 1976) according to the intensity of player movement. TMA can be employed within training and competition through the use of video providing coaches with a means of structuring conditioning programs to optimise match preparation (Carling & Bloomfield, 2013). TMA has become increasingly popular, especially within the elite domain, whereby advances in computer technology have enabled such measurements to become considerably more accurate and self-performing (via technology

such as the Global Positioning System [GPS]). A player's work-rate can be globally quantified as total distance covered, or broken down into discrete performance actions, such as; type, intensity, duration and frequency (Reilly, 2003). Moreover, when considered in relation to time, work to rest ratios can be computed offering a measure of comparison with developed conditioning programmes aiming to reflect the demands of competitive performance (Reilly, 2007). Considerable research employing TMA (manual, semi-automated and automated) have been undertaken, including and not exclusive to; Australian football (Wisbey, Montgomery, Pyne & Rattray, 2010), basketball (Abdelkrim, Fazaa & Ati, 2007), cricket (Petersen et al., 2011), football (Bloomfield, Polman & O'Donoghue, 2004; Gabbett & Mulvey, 2008; Reilly & Thomas, 1976), hockey (Gabbet, 2008; Spencer et al., 2004), rugby league (King, Jenkins & Gabbett, 2009; McLellan, Lovell & Gass, 2011; Waldron et al., 2011), and rugby union (Cahill et al., 2013; Deutsch, Kearney & Rehrer, 2007; Duthie, Pyne & Hooper, 2005).

The early use of TMA (e.g. Reilly & Thomas, 1976) classified the players' movements into a number of categories, including: walking, jogging, striding, sprinting, sideways and backwards motion. Once collated, work rate profiles in relation to the (1) sports' overall movement demands, (2) elite versus sub-elite performer, and (3) differences in positional play could be quantified. Reilly and Thomas' (1976) early work within football identified up to 1000 different movement activities for a single player within a single game, which equated to a change in movement every 6 seconds. The overall distance covered by outfield players was reported to range 8 – 12 km, consisting of walking (24%), jogging (36%), cruising (20%), sprinting (11%), backwards motion (7%) and moving within the ball (2%; Reilly & Thomas, 1976). Furthermore, the majority of movement within team sports (e.g. football, Reilly & Thomas, 1976 and rugby, Cahill et al., 2013) in particular, is covered at low intensity.

Developing upon the global movement demands of sport, more recent studies have started to report differences between playing positions or positional clusters (rugby union – Cahill et al., 2013; Quarrie, Hopkins, Anthony & Gill, 2013 or football – Bloomfield, Polman & O'Donoghue, 2007). Authors (Cahill et al., 2013; Venter, Opperman & Opperman, 2011) have also began utilising individualised speed classifications in an appreciation that not all athletes are able to achieve the same locomotive speed (e.g. winger vs. prop-forward in rugby union), with further analyses investigating the relative distance (overall and within various speed zones) travelled focusing upon ball in play data (Deutsch et al., 2007; Nicholls, 2014). More specifically, does the relative distance travelled within specific speed zones (e.g. sprinting) increase or decrease when analyses focus upon only ball in play data? What are the implications of an observed increase in high intensity movement demand upon training regimes developed from 80-minute match data (i.e. when the ball is *in* and *out* of play) within rugby union (i.e. are our athletes appropriately prepared)?

Overall however, manual TMA is generally considered labour intensive, time consuming and limited to the analysis of a single player at any one moment (Carling & Bloomfield, 2013). Arguably, such methods are also subject to a number of inaccuracies, especially when positional information is being recorded; furthermore, the method considers each movement category (e.g. walking, jogging) as standalone categories, in turn, offering no transitional assessment of acceleration and deceleration. Notwithstanding, the method is simple, cheap, and easy to use with a bit of practice; enabling users at all respective levels (competition, budget etc.) to answer specific performance questions. The issues encountered with manual TMA, by virtue of technological development, have since been addressed through the creation of numerous semi- and automated player tracking systems (Carling & Bloomfield, 2013). Many of the commercially available systems have

yet to be independently and scientifically assessed; furthermore, the cross-analysis of multiple systems is yet to be comprehensively explored (presumably due to company reluctance and the implications of conflicting motion analysis results). In addition, the accuracy of GPS units is affected by a number of variables, most notably, the number and geometrical arrangement of satellites relative to one another/the receiver, and the environmental build-up, e.g. tall buildings and enclosed stadia. The cost of a GPS system can be considerably high; therefore, their use is often restricted to the elite level whereby monetary budgets are far greater.

Nevertheless, computer and digital based systems such as Prozone (validation – Di Salvo, Collins, McNeill & Cardinale, 2006 and research utilisation – Di Salvo, Gregson, Atkinson, Tordoff & Drust, 2009) track the movements of each participating player simultaneously providing technical, tactical and physical information. However, problems associated with loss of player tracking, due to player clustering (e.g. corners), can become an issue requiring numerous manual adjustments. Portable tracking devices, specifically GPS, are another means of player tracking with the additional ability of quantifying areas such as impact/collisions, accelerations/decelerations and physiological exercise intensity via synchronised heart-rate measurements. GPS devices have been developed with a sampling frequency i.e. number of data points collated per second of 1, 5, 10, 15 and 20 Hz. Numerous studies have attempted to investigate the validity and reliability of the devices for measuring sports specific movement patterns (Coutts & Duffield, 2010; Jennings, Cormack, Coutts, Boyd & Aughey, 2010; Johnston, Watsford, Kelly, Pine & Spurrs, 2014; Rampinini et al., 2015; Vickery et al., 2014). The growing use of motion analysis devices is particularly evident within rugby union, whereby the GPS receivers outline can be seen between the player's shoulders. Their use within rugby union has enabled GPS studies quantifying the competitive demands of the sport to be undertaken

(Cahill et al., 2013; Cunniffe, Proctor, Baker & Davies, 2009). Unfortunately, methods of competitive data collection within certain sports e.g. football are otherwise limited, by virtue of the rules and regulations associated with technological implementation (GPS devices are restricted within many competitive sporting environments).

2.1.8 – Section conclusion

In this section, four general research themes have been discussed, namely: 1) key performance indicators, 2) system design, operational definitions and reliability, 3) key determinants of performance, performance profiling and predictive methods and 4) the measurement of work-rate profiles. It is not the design of the above section to extensively explore, present and contrast the research within the respective areas, but offer an outline of the research and starting points for further reader enquiry. The areas arguably illustrate the approximate order of consideration within performance analysis practice. Specifically, to gain an understanding of the key determinants of performance, profiling or work-rate profiles, the users are required to appropriately develop a set of suitable performance indicators within a valid and reliable data collection system. A subsequent aim of the performance analysis domain, via the above processes, and arguably a foundation with which the area is built, is the need to receive highly accurate information to enable objectively informed decision-making regarding performance. The following section therefore aims to review the need, yet difficulties, of obtaining accurate and reliable information within the provision feedback.

2.2.1 – Accurate and reliable information in the provision of feedback

The importance of accurate information to facilitate improvements has been well established within coaching and performance analysis literature (Hughes & Franks, 2004). The discipline of performance analysis can be considered to have developed from a desire

to receive/provide accurate and reliable information to facilitate performance improvement. Traditionally however, performance feedback has involved subjective observations and conclusions based upon a coach's perceptions and experiences (Maslovat & Franks, 2015). Whilst there is a clear requirement of objective/unbiased, reliable and accurate information, this should not be construed as a suggestion that coaches, individually or as a coaching team, couldn't effectively meet these requirements without external aid or technological intervention. However, due to the importance of reliable information within a wide variety of situations, e.g. the learning process, the assessment of human observation has been studied in relation to memory recall (Neisser, 1982) and criminal identification (Wells & Olsen, 2003) with some attention to sport (Franks & Miller, 1986; Laird & Waters, 2008; Nicholls & Worsfold, 2016).

Franks and Miller (1986) assessed the observational accuracy of novice coaches (third year physical education students) during an international soccer game. A questionnaire assessed observations of ball possessions, shots, passing, set pieces, crosses, and goalkeeper information. Mean recall of 42% was identified, with certain categories being more effectively recalled than others, e.g. goalkeeper contact: 33% and set pieces: 71% respectively. The authors suggested the lack of alignment to previous research (Thornton & Zorich, 1980) related to issues regarding participant experience. More specifically, as the coaches were novices, they would potentially 'view the events without any directed system of observation' (p. 43). Therefore, the game events may have appeared random in nature and, hence, difficult to store and retrieve. Franks and Miller (1991) subsequently attempted to address the issue of random observation, through a study designed to improve observational skills. The study split 36 football coaches into an experimental and two control groups whereby: (1) undertook a specific training programme, (2) answered a questionnaire following observation, and (3) engaged within

group discussion and reflection (Franks & Miller, 1991). Following a 30-minute excerpt of an international match, coaches were questioned upon the scoring of goals, the taking of shots, and the missed opportunities to shoot with results identifying pre-test recall of 16.8%, whilst post-test increased to 21%. The experimental group appeared to benefit most from the intervention (> 10% improvement), whereas the control groups marginally, improved (control 1) and deteriorated (control 2) at post-test (Franks & Miller, 1991).

The transferability of Franks and Miller (1986; 1991) to an elite environment could be challenged, in part, by virtue of the level of participants and specificity of variables assessed. Franks and Miller (1986) incorporated novice coaches, whom were not expert football observers required to observe performance on a consistent basis. The authors highlighted this limitation, suggesting the use of experienced coaches within future research. Laird and Waters (2008) developed upon this recommendation and included 'experienced, qualified, football coaches'. The results demonstrated that coaches, with domain specific experience and greater sport familiarity, recalled critical game events accurately 59.2% of the time (17.2% greater than Franks & Miller, 1986). The results still unfortunately fall short of total recollection; however, this is arguably not a realistic expectation of human observers. Moreover, the broad range of coaching experience (2-20 years), may invite criticism (are coaches who have 20-years' experience the same as those with 2 years?). However, the omission of a measure of distribution, regarding coaching experience, prevents the reader from making such assessment. Franks (1993) interestingly reported that experienced coaches produced more false positives (detected a difference when none existed) than their novice counterparts, the experienced coaches were also very confident in decisions made, even when erroneous. Such findings contrast to the logical assumption that experienced coaches are more effective or 'better' at interpreting a sports performance. The training undertaken by coaches may predispose them to seek out errors

irrespective of them existing or not. Furthermore, the inclusion and assessment of potentially generic performance variables (e.g. set pieces; Franks & Miller, 1986; Laird & Waters, 2008) has further been criticised as being 'fairly standard game events' (Groom, 2012). The failure to incorporate 'pertinent individual player or team level technical analysis' (Groom, 2012), and/or specific player assessment criteria (e.g. dribbling, passing) demonstrates the disconnection between the research and applied need.

A more recent study investigating coaching recollection (Nicholls & Worsfold, 2016), targeted specific player assessment criteria (e.g. dribbling) deemed fundamental to successful football performance. Such additions develop upon the 'fairly standard game events' (Groom, 2012) utilised within earlier research endeavours (Franks & Miller, 1986; Laird & Waters, 2008). The recollection of eight elite coaches (> 12 years elite coaching experience) was assessed on a quantity, quality and positional basis. Overall, results were in line with previous literature, whereby recall was severely limited (38.8%), despite utilising experienced football coaches. The results however did vary considerably between variables (e.g. short passing: 35.2% and shooting: 75.6%) which was attributed to the variable frequency (passing: 247.3 and shooting: 10.3 per game). Potentially, the infrequent occurrence of the shooting variable allowed coaches to more easily organise i.e. 'chunk' (Evans, Whipp & Lay, 2012; Simon & Chase, 1973) the smaller important goal-scoring related pieces of information into larger more meaningful units, which can thus be more easily stored and retrieved. Notably, dribbling, which has been firmly concluded as a key and separating factor within the talent identification of young football players (Huijgen, Elferink-Gemser, Post & Visscher, 2009; Vaeyens et al., 2006; Waldron & Worsfold, 2010), was also severely limited (37.2%). Nicholls and Worsfold (2016) suggested this finding further reinforce 'the need for objective measures' within the player identification, assessment and review process, and failure to do so risks releasing

promising young players due to the 'difficulties of accurately and consistently appraising key aspects of performance'.

A major criticism can be made regarding the dissemination of the work by Franks & Miller's (1986), whereby they have been erroneously referred to within a number of publications (e.g. Franks, 2004; Hughes & Franks, 1997; Maslovat & Franks, 2008; O'Donoghue & Mayes, 2013). Considering Franks and Miller (1986) is widely regarded as a key study providing evidence of the limitations within coaching recollection, and arguably a basis of which performance analysis is founded, the findings appear to have been taken out of context. Examples include:

> 1). 'Franks and Miller (1986) found that international level soccer coaches recalled less than 45 per cent of critical events during a match' within O'Donoghue and Mayes (2013, p. 156)

> 2). 'Studies have shown international level soccer coaches could only recollect 30 per cent of the key factors that determined successful soccer performance....(Franks and Miller, 1986, 1991)' within Maslovat and Franks (2008, p. 3) and the subsequent version Maslovat and Franks (2015, p. 12).

> 3). 'Franks and Miller (1986) compared coaching observations to eyewitness testimony of criminal events. Using methodology gained from applied memory research, they showed that international level soccer coaches could recollect only 30 per cent of the key factors that determined successful soccer performance during one match' within Franks (2004, p. 8). An earlier version of the text (Hughes &

Franks, 1997, p. 1) also stated the same quotation as above, except the 30 per cent value was replaced with ’42 %’.

As evidenced, despite quoting the same respective paper, various errors in relation to the; level of participants (3rd year physical education novices, not international level football coaches), match footage (45, not 90 minutes) and the analysis results (42, not 30%) were made. Notwithstanding, the use of performance analysis to support coaching observations has grown significantly and since become heavily relied upon within the coaching process.

2.2.2 – Section Conclusion

The inability to accurately recall information has significant implications on the accuracy and specificity of feedback delivered to athletes/coaches. However, the studies have often failed to acknowledge that 100% recall of actions may not actually be required to formulate effective feedback. For example, coaches may have trained themselves over time or through experience to filter information, therefore only focusing upon the aspects deemed important. Anderson (2010) further suggests the traditional approach utilising subjective feedback needs to be augmented with objective, accurate and relevant sources of data. The difficulties of attaining objective and reliable information from a coach, due to limitations in an observer’s recall capabilities, presents one significant barrier to the improvement of performance. Therefore, the effective use of performance analysis to enable coaches to better interpret the complex nature of a sports performance and provide appropriate, comprehensive and objective feedback is fundamental to athlete learning and future improvement (Butterworth et al., 2013). The following section shall reflect upon and discuss the use of feedback, more specifically; what is feedback, how can feedback be

manipulated and the influence of these manipulations upon the effectiveness of feedback within motor learning and sports skill acquisition.

2.3.1 – Feedback

Feedback is an essential aspect of the coaching process if athletes are to reach their potential (Carling et al., 2005; Maslovat & Franks, 2015; Schmidt & Lee, 2014), and when presented in an appropriate manner (i.e. type, quantity and timing), improves motor skill acquisition significantly and is considered a major factor in the improvement of performance (Liebermann et al., 2002; Schmidt, 1975). Athletes continuously receive sensory feedback from experiencing the sport and the environment in which they compete, including; sight, sound, tactile and proprioceptive information (O'Donoghue & Mayes, 2013; Magill & Anderson, 2014). However, an athlete often requires external aid (from a coach) to facilitate improvements, thus requiring direction towards a desired outcome. A key skill of any coach is the ability to observe a performance, evaluate what is being observed and respond accordingly (by providing effective feedback). Launder and Pitz (2000) highlight that for a performer to be successful (short and/or long term), feedback related to significant events within performance is required. Therefore, feedback should focus upon augmenting information received through proprioception and observation (Magill & Anderson, 2014). Various authors (e.g. Mononen, 2007) have suggested, second only to practice, feedback is considered the most powerful factor that can affect the learning process. Consequently, feedback must be given significant attention to enable the information to be effectively retained, implemented and achieve a positive change in performance.

The learning process can occur through intrinsic (from oneself) or extrinsic (externally sourced) feedback, whereby intrinsic feedback is generated and processed as

the athlete monitors their task related performance (Konttinen, Mononen, Viitasalo & Mets, 2004). The athlete may identify a discrepancy between desired and current performance that forces the athlete to seek out external information to bring current performance closer to desired outcome (Konttinen et al., 2004). Although intrinsic feedback is vitally important to skill performance, Hughes and Franks (2004) suggest there to be very little a coach can do to improve this 'hardwired' system. Due to the difficulties of directly training the intrinsic feedback system (Hughes & Franks, 2004), there is a clear need for external feedback to indirectly train the same respective system via the comparison of the internal to the externally validated outcome. A coach must provide a model representation of the skill through feedback until the athlete has sufficiently developed one for him or herself (Guadagnoli, Holcomb & Davis, 2002).

Anderson (2010) presented a *triptych* that can be viewed as a simple summary checklist of controllable factors influencing the effectiveness of feedback. The first part of the triptych; feedback must be accurate and relevant, will for ease of explanation be broken down into 1) accurate and 2) relevant. The importance of accurate information within the provision of feedback has been discussed, so will not be discussed further. However, accurate feedback must also be relevant. For feedback to be optimally effective, it has to be relevant to the athlete and the desired performance. For example, providing feedback information related to the smash (e.g. strike the shuttle downwards) in badminton, when the performance issue is specifically related to the overhead clear, would fail to elicit the desired improvement within the overhead clear. The need for relevant and specific information is of paramount importance as not to encourage an unwanted change in performance elsewhere, i.e. the athlete implements a piece of information erroneously within a potentially already mastered aspect of performance. Furthermore, feedback will only be relevant to an athlete if, and only if, the individual knows and engages with the

performance goal, and acknowledges the need to carry out corrections relative to it (Liebermann et al., 2002).

The second aspect (feedback needs to be decipherable) can be supported by the preliminary research of Anderson and colleagues (Anderson et al., 2005; O'Leary & Anderson, 2002). The authors highlighted; 1) the acceptable nature of involving some athlete-learner processing requirement within feedback (rowing performance remained constant irrespective of verbal instruction, visual distraction or a combination task; O'Leary & Anderson, 2002) and 2) the importance of the athlete understanding the direct link between action and outcome (knowledge of projectile motion and ball rotation improved simulated rugby line out throw performance compared to a control group; Anderson et al., 2005). Anderson (2010) however suggested that coaches and practitioners must provide the athlete with sufficient and appropriate time to interpret and decipher all information provided during feedback sessions.

The final aspect of the triptych concerns the timing/type (e.g. concurrent) and delivery method (e.g. software package) of the feedback (Anderson, 2010). Arguably, this third aspect can be further expanded to include considerations for the type of task (e.g. cyclical), the content of the feedback (e.g. verbal instruction) and the induced focus of attention (e.g. external). The methods and forms feedback can be delivered to an athlete appear limitless, and only restricted by the creativity and imagination of the coaches, practitioners and software developers (Anderson, 2010). However, the optimal methods of delivery (e.g. visually or aurally, concurrent or post-performance) within the applied environment are far from understood and therefore presents the types of questions requiring significant and systematic research attention.

The most widely researched aspect of the triptych, probably due to the ease of manipulation, has been this third aspect, i.e. the timing, task type, content of feedback. As

such, research has emerged within sports including swimming (Perez, Llana, Brizuela & Encarnacion, 2009), gymnastics (Boyer, Miltenberger, Batsche & Fogel, 2009), golf (Guadagnoli et al., 2002) and tennis (Cutton & Landin, 2007), to name a few. Due to the number of studies manipulating this aspect within learning environments (sports or otherwise), it would be logical to discuss and evaluate the impact of feedback timing/type and task type upon skill learning.

2.3.2 – Feedback type

Schmidt (1975) reported that feedback presented in the correct type (i.e. concurrent) plays a significant role in the learning of new skills and the enhancement of performance. Therefore, it is not surprising that feedback type is widely manipulated within skill acquisition literature and as such, could be construed as an important aspect of sports skill learning and development. However, research findings relating to this aspect have presented a wide variety of results, therefore complicating applied application (Maslovat & Franks, 2008). Research investigating the timing/type and influence of feedback has included the use of bandwidth (Chambers & Vickers, 2006; Smith, Taylor & Withers, 1997), concurrent (Baudry, Leroy, Thouvarecq & Chollet, 2006; Eriksson, Halvorsen & Gullstrand, 2011; Fitzpatrick & Anderson, 2007; Konttinen et al., 2004; Perez et al., 2009), post-performance (Boyer et al., 2009; Cutton & Landin, 2007; Emmen, Wesseling, Bootsma, Whiting & Van Wieringen, 1985; Guadagnoli et al., 2002; Van Wieringen, Emmen, Bootsma, Hoogesteger & Whiting, 1989; Weir & Leavitt, 1990), summary (Schmidt, Lange & Young, 1990; Schmidt, Young, Swinnen & Shapiro, 1989; Thow, Naemi & Sanders, 2012; Weeks & Sherwood, 1994), self-selected (Janelle, Barba, Frehlich, Tennant & Cauraugh, 1997; Janelle, Kim & Singer, 1995) and fading schedule (Winstein & Schmidt, 1990) mechanisms.

2.3.3 – Terminal / immediate feedback

Terminal feedback, in this review is considered as the feedback solely provided following the performance of a skill that does not appropriately fit in line with a secondary feedback type. For example, feedback presented under the bandwidth conditions may be provided terminally, but is however constrained firstly by the bandwidth principles, whereby the feedback is only provided if performance falls outside of a pre-determined range. A consistent theme within the provision of feedback and consequently a key selling point of new technologies to coaches, teams and sporting organisations, is the ability to provide the users with real-time or immediate processing and feedback (Phillips, Farrow, Ball & Hemer, 2013). Coaches very often assume immediate feedback to be a valid way of improving skill performance and therefore assume that technologies and methods providing such feedback are highly beneficial for skill acquisition (Liebermann & Franks, 2015; Liebermann et al., 2002).

A number of motor learning and sport skill acquisition crossover studies exist regarding terminal feedback (e.g. Weir & Leavitt, 1990; Nunez Sanchez & Galvez Gonzalez, 2010). These studies take a simple movement task (e.g. throwing) and *more closely align* the movement with a sports situation (e.g. dart throwing). Although *more closely aligned*, the studies arguably fail to fully represent a sporting situation and can be questioned for their ecological validity. For example, participants within Weir and Leavitt (1990) threw darts towards a dartboard within a dimmed room, whereby only the board centre i.e. 'the bulls eye' was illuminated. As the throwing arm-initiated movement, the centre light turned off to prevent the participant receiving visual feedback on performance. Visual feedback is generally commonplace within most competitive sporting situations. However, despite arguably lacking ecological validity, the aim of these types of studies is to specifically assess the influence and impact of the feedback provided. Weir and Leavitt

(1990) combined two levels of athlete models (skilled and unskilled) and two levels of knowledge of results, creating four participant groups. The inclusion of athlete models is likely due to the notion that observing a model is considered more beneficial within the earlier stages of learning than not observing one, i.e. model representation accelerates initial learning. Weir and Leavitt (1990) failed to support this with their assessment of either, performance accuracy or consistency, suggesting the task type or number of observational trials to likely account for the contrasting findings.

Early investigation by Emmen et al. (1985) evaluated the effect of video modelling/feedback on learning the tennis service. Participants were assigned to one of five groups; Traditional 1 (T1), Video Model (VM), Video Feedback (VF), Video Model-Feedback (VMF) and Traditional 2 (T2) demonstrating that 15 minutes of video feedback, in substitution of or in addition to practice, did not lead to significant improvements compared to traditional methods. The similar improvements may have been a result of the trainer acting as an unintended dynamic model, therefore causing additional information (via the video) to become redundant. The intervention alone, irrespective of experimental condition may have been more than sufficient to facilitate the improvements due to the novice participants receiving coaching for the first time, thus rapidly improving them as a collective. In addition, the participants may have forgotten (or ineffectively retained) information provided by the video or model deemed fundamental to further improvement, as a result of the lengthy between-session interval (Emmen et al., 1985; Van Wieringen et al., 1989).

A similar study by Van Wieringen et al. (1989) investigated the effect of video feedback on learning the tennis serve by considering a number of recommendations in the extant literature, e.g. reduce the between-session interval via the inclusion of a second weekly training session. Furthermore, Van Wieringen et al. (1989) utilised a different

criterion task than Emmen et al. (1985), suggesting the Avery Richardson Tennis Service Test (ARTST) 1) to be more motivating owing to its higher face validity and 2) enabled cross-study comparisons due to the provision of performance standard 'norms' (see Avery, Richardson & Jackson, 1979). Both video groups demonstrated performance improvements compared to a control group; however, there was no additional benefit of viewing personal service performance vs. 'top' player groundstrokes and volleys. Van Wieringen et al. (1989) concluded that the study might still not be optimal, suggesting the between-session interval to potentially still be too long.

Cutton and Landin (2007) and Rikli and Smith (1980) supported this suggestion. For example, Cutton and Landin (2007) provided daily tennis coaching investigating the influence of self-talk, self-talk with feedback, and feedback upon learning. Feedback was provided every 5th trial based upon the findings of Weeks and Sherwood's (1994; feedback every five trials or at 20% relative frequency is more effective than every trial). Consequently, outcome and movement sequence scores were greatest for the self-talk with feedback group at post-test. Increasing the active involvement within learning, whilst providing external feedback, appeared more beneficial than the sole provision of external feedback. This finding is consistent with earlier classroom and motor learning research involving self-talk strategies (Bangert-Drowns, Kulik, Kulik & Morgan, 1991). Furthermore, Rikli and Smith (1980) identified a positive effect when participants trained consecutively across 5 days, although both situations are arguably not typical of ordinary club conditions. Notwithstanding, such a scenario may lend itself more positively to the elite environment whereby training on a daily basis is commonplace.

Guadagnoli et al. (2002) developed upon the issues related to 1) the length of between-session interval and 2) the lack of a later or secondary post-test to assess retention. Although Emmen et al. (1985) and Van Wieringen et al. (1989) utilised one

session per week initially and two thereafter within the follow up study, such an interval may still not have been short enough to achieve maximal video-feedback effect (Van Wieringen et al., 1989) as demonstrated by Cutton and Landin (2007) and Rikli and Smith (1980). The absence of a secondary post-intervention test ultimately designed to assess retention (and therefore learning), following a longer period of absorption, may be required. Feedback methods may be immediately effective, for a specific training session, but there is need to investigate long-term effectiveness and whether effective learning is achieved. The study subsequently designed by Guadagnoli et al. (2002) required participants to train across four days (each separated by one day) and be subject to a first (two days following the final training session), and second post-test (two weeks after the first post-test). Positively, such a design effectively shortened the between-session interval significantly and offered a means of investigating longer-term retention.

The video-verbal group performed better than the verbal, which in turn, performed better than the self-guided group at post-test 2. More importantly, when feedback conditions were considered, the two instruction groups (video-verbal and verbal) were significantly less variable than the self-guided method at post-test 2. Consequently, following a training (4 days, every other day) and retention period (2 weeks), the participants provided with video-verbal feedback demonstrated greatest improvement. Although the improvements were far more evident following the second post-test, this should not be considered surprising. Adaptations made to any movement technique, even when designed to be corrective in nature, represent 'a disruption of the ingrained movement' (Guadagnoli et al., 2002) and the consolidation of new information takes time (Shadmehr & Holcomb, 1996). Guadagnoli et al. (2002) made the presumption (although not investigated in any length) that, the greater the disruption to a movement technique, the more likely the learner will illicit initially poor, but improved performance thereafter.

The following conclusions can be drawn from the outlined studies (Cutton & Landin, 2007; Emmen et al., 1985; Guadagnoli et al., 2002; Van Wieringen et al., 1989; Weir & Leavitt, 1990); firstly, following the training and performance of a tennis skill (serving), terminal video-based feedback is not significantly more effective than traditional methods (Emmen et al., 1985; Van Wieringen et al., 1989). The video-based feedback groups achieved greatest performance improvement, albeit marginally more than traditional training methods. Such a marginal increase, at any competitive level (recreational or elite), could be considered a significant practical improvement, and therefore should not be immediately dismissed. Secondly, within a golfing task (Guadagnoli et al., 2002), the video-verbal group achieved the greatest improvements following the retention period. This finding was evident despite the decrease in training time due to feedback provision, thus suggesting that the potential trade-off between additional feedback and training/practice may be warranted. The video analysis methods should be considered an effective means of practice; however, the positive effects may take some time to develop (Guadagnoli et al., 2002).

Clearly, both points appear to act in the same direction, albeit with differing degrees of success or onset, however, based upon a number of variables, e.g. the differences in feedback and session scheduling, and the sports skills utilised, this should not be surprising. In addition, issues related to ecological validity (vision restriction) limit the applicability to the majority of elite environments and should therefore be the focus of future research endeavours.

2.3.4 – Concurrent feedback

Concurrent feedback can be summarised as information presented to the learner during actual performance (Schmidt & Wulf, 1997). Concurrent feedback can be presented

continuously and discontinuously. Discontinuous concurrent feedback, often auditory in nature (Baudry et al., 2006), aims to signal that performance is on target or that a certain level of performance is being achieved (Schmidt & Wulf, 1997). Whereas continuous concurrent feedback signifies momentary performance error (Kohl & Shea, 1995), deviation from an optimal movement pattern (Vander Linden, Cauraugh & Greene, 1993), and is generally delivered visually (Eriksson et al., 2011). Concurrent feedback has been utilised within sports such as gymnastics (Baudry et al., 2006), shooting (Konttinen et al., 2004), swimming (Perez et al., 2009) and running (Eriksson et al., 2011).

Wulf and Shea (2004) suggested concurrent feedback to have a strong and positive effect during the acquisition and performance phase. However, concurrent feedback also resulted in performance decrements (relative to terminal feedback) when feedback was withdrawn in retention tests (Schmidt & Wulf, 1997; Vander Linden et al., 1993). Feedback manipulation during the performance of simple skills, that prevents the athlete consciously or subconsciously engaging within reflection and evaluation, appears to degrade learning (Wulf & Shea, 2004). The findings illustrate the potentially guiding nature of concurrent feedback, whereby the athlete's intrinsic sensory information is inadvertently blocked or overridden (despite potential validity), thus negatively affecting performance. Hodges and Franks (2008), albeit related to feedback more generally, suggest; external feedback has been demonstrated as so powerful, even when erroneous or redundant, the learner downgrades valid intrinsic feedback (see also, Buekers, Magill & Hall, 1992).

Various studies incorporating complex skills such as cycling (Broker, Gregor & Schmidt, 1993) and rowing (Spinks & Smith, 1994) have identified biomechanical skill acquisition/learning enhancements with the use of concurrent feedback. Baudry et al. (2006) assessed concurrent auditory feedback within pommel horse performance. Since the

movement is cyclical in nature, feedback delivery during one cycle can potentially be implemented within subsequent cycles, and therefore facilitate learning. Baudry et al. (2006) demonstrated concurrent feedback to positively affect athlete body alignment, which was also preserved after two weeks of further training without the device. Training without concurrent feedback did not enhance the performance of the control group, however, when provided with the feedback following the traditional training phase, performance was also positively influenced. Notably, concurrent feedback did not elicit significantly greater improvement in body alignment following an initial traditional training period compared with the experimental group (2.3 vs. 2.0%). Athletes can therefore potentially achieve improvement without the need to firstly reinforce the importance of concurrent feedback through a pre-intervention traditional training period.

Konttinen et al. (2004) demonstrated the use of concurrent feedback within rifle shooting to have a similar positive affect to Baudry et al. (2006). When provided during every other trial and following each trial performance was enhanced (stability and outcome score). Furthermore, utilising intermittent concurrent feedback also facilitated improvement in athlete swimming pace control (Perez et al., 2009). The feedback combination within Konttinen et al. (2004) arguably prevented the participants becoming dependent upon external information, thus enabling more effective learning. Unfortunately, however, the study offered no insight into the optimal feedback ratio. A major strength of Konttinen et al. (2004) was both; the inclusion of a secondary retention test and the duration following skill acquisition such tests were implemented. A retention test, utilised to assess longer-term learning (Magill & Anderson, 2014), was sparsely included prior to the review by Salmoni, Schmidt and Walter (1984); however, such tests are commonplace within more recent research (Baudry et al., 2006; Guadagnoli et al., 2002). Consequently, previous studies may have achieved permanent results, however, due

to the lack of either; a retention test *per se*, or one following a significant time interval, the long-term permanency is purely reader speculation.

The type of task is suggested to affect the impact of concurrent feedback on learning and skill acquisition (Hodges & Franks, 2004). For example, an athlete provided with concurrent feedback when performing a cyclical task is able to utilise such information upon the next 'cycle' (e.g. gymnastics pommel horse – Baudry et al., 2006). Whereas a discrete skill (e.g. rifle shooting – Konttinen et al., 2004) may only take place intermittently, thus the athlete has to wait for the next opportunity to implement the feedback. Concurrent feedback may not provide further learning stimuli within certain sporting situations, but in turn, offer a potentially negative learning challenge due to information overload. Therefore, it may be more effective to provide feedback after a longer delay, in a more specific and condensed manner to avoid potential overload (Liebermann & Franks, 2015). Notwithstanding, Eriksson et al. (2011) suggested auditory concurrent feedback to be more effective than visual, which was in part, attributed to the idea that 'auditory feedback imposes itself on the runner [learner] and cannot so easily be ignored' (p. 260). Baudry et al. (2006) further suggested that feedback given in real time could have a powerful effect on the performance of certain sports tasks. Despite the study investigating a complex movement, whereby several kinematic solutions are required to obtain optimal performance, the concurrent feedback potentially served as an information identifier (for the intrinsic system) that could be utilised as a means of enabling on-going performance corrections, positively affecting performance.

2.3.5 – Bandwidth feedback

Bandwidth feedback, defined as feedback provided at a point in time only when a learner's performance falls outside a pre-determined criteria range. The frequency bandwidth

feedback is provided is solely determined by a learner's on-going performance (Smith et al., 1997). Sherwood's (1988) early implementation, utilising 5 and 10% error bands, resulted in significant performance improvements evidenced during retention testing. Goodwin and Meeuwsen (1995) further identified the benefits of 10% and expanding bandwidth conditions on golf putting performance. The expanding nature of the bandwidth effectively provided the athletes with decreasing levels of feedback throughout testing. It could be construed that decreasing the provision of feedback enabled the athletes to become more effective at error detecting, and thus regulating their own performance. The use of bandwidth feedback combined with athlete questioning within Chambers and Vickers (2006) failed to elicit performance improvements surpassing a control group prior to transfer testing. Although greater gains were evident thereafter, the initial absence of improvement may prevent such a method being utilised within an elite sports environment, whereby the need for relatively imminent improvement is often considerably important. Notably however, performance was not adversely affected by the intervention, therefore, given appropriate time, positive performance improvements could be expected. Both viewpoints appear to demonstrate the trade-off and implications of immediate (with shorter-term retention) versus delayed (with longer-term retention) improvement. Utilising a bandwidth method may therefore be more conducive to off-season, where more time is available for the longer-term improvements to develop. Furthermore, Chambers and Vickers (2006) suggested bandwidth feedback within the real world of coaching has encountered various problems. For example, bandwidth feedback resulted in a decreased level of external input, thus giving onus to the athlete to monitor and modify performance. Although the development of athlete autonomy could be expected (and viewed positively), some athletes felt neglected when reduced or delayed feedback was delivered (thus potentially adversely affecting coach-athlete relationships). Athlete characteristics and

personal preferences should be thoroughly considered when proposing to implement a feedback strategy that may ultimately provide feedback (and coach-athlete interaction) less frequently.

2.3.6 – Summary feedback

Summary feedback is a summarisation of performance information and/or themes from a session or group of trials. The feedback is often delivered at the end of a session/block, prior to a subsequent session/block or both. Earlier research (Schmidt et al., 1989) into the use of summary feedback identified varied results. Immediate performance improved to a greater extent following fewer trial, however, results were reversed during retention, whereby; participants receiving feedback following the largest summary length (15 trials vs. 1 trial) demonstrated lowest error, and their performance was less subject to decay (Schmidt et al., 1989). Overall, Schmidt et al. (1989) failed to establish an optimum summary length (number of trials), as an even greater number of trials may have been more beneficial. Schmidt et al. (1990) later identified an 'inverted-U' effect, with the 5-trial condition appearing most effective for learning (relative to 1-, 10- and 15-trials). In contrast to Schmidt et al. (1989), the same general pattern was evident on both, the immediate and delayed retention tests (Schmidt et al., 1990). There was some evidence to suggest that participants within the 5-trial group had developed, albeit not particularly strong, error detection capabilities. For example, during subjective estimation, higher correlations and lower differences in objective-subjective results were observed (Schmidt et al., 1990) inferring that participants were more effective at knowing how they had performed.

Thow et al. (2012) provided summary feedback on an individual basis, immediately preceding and following swim sessions. The authors also provided a summary of all

sessions prior to the 5th and final session, i.e. the retention session. The feedback groups consisted of; 1) individual video assessment (no coach involvement), 2) coach verbal and video feedback and 3) coach verbal and video feedback plus GlideCoach performance variable data, e.g. glide factor, initial velocity, average velocity. The largest improvements occurred after the GlideCoach intervention. In fact, a significant improvement in performance by Group 1 and 2 was only evident following session 5, the first and only session both respective groups received GlideCoach feedback. In addition, Group 3 continued to demonstrate performance improvements following the 4-week retention period. Unfortunately, the exclusion of a control group prevented the contributions of practice upon learning being appropriately assessed. However, the utilisation of summary feedback from a coach, and feedback incorporating GlideCoach data appeared positively beneficial for long-term improvement.

2.3.7 – Self-selected and fading-schedule feedback

Although considered different types, self-selected (Wulf & Toole, 1999) and in some cases bandwidth (Goodwin & Meeuwsen, 1995) can often evolve into fading-schedule feedback. Self-selected feedback enables a learner to choose when they receive information, whereas bandwidth is determined by on-going performance output. Subsequently, as performance improves, learners often (choose to) receive feedback less frequently under both conditions, thus gradually fading the provision of feedback. Smith et al. (1997) highlighted a considerable reduction (53.75%) in the relative frequency of feedback under 10% bandwidth conditions within golf putting. The advantage of fading feedback relates to initially guiding the learner in early practice whilst gradually developing independence from the information later in practice (Winstein & Schmidt, 1990; Wulf & Toole, 1999). Moreover, compared with feedback following all trials, providing learners with a

systematic fading schedule (100% reduced to 25%) produced more effective performance during retention testing (Winstein & Schmidt, 1990).

Empirical studies on the use of self-controlled feedback appear limited, however, the use of self-control, as suggested by Wulf and Toole (1999), may be more effective due to encouraging learners to explore different movement strategies to a greater extent and in turn, adapt accordingly. Furthermore, Chiviacowsky and Wulf (2002) suggested self-controlled conditions might arguably be more tailored to the learner's relative needs. The self-after group (whom had the choice *after* performance whether to receive feedback) elicited similar results during practice and retention, however, the self-after group demonstrated clear learning differences during the transfer test compared with the self-before group (whom had to choose *before* performance whether to receive feedback) (Chiviacowsky & Wulf, 2005). The self-control, *per se*, is arguably not the determining factor for the benefits of self-controlled feedback, rather that, learners normally request feedback when it is most subjectively useful for them (Chiviacowsky & Wulf, 2002, 2005). Therefore, the opportunity to request feedback as a function of learner performance appears a critical factor within the effectiveness of self-controlled feedback.

2.3.8 – Feedback reliance

The frequent provision of feedback guides the athlete to the correct response, resulting in enhanced performance during the skill acquisition phase of learning (Wulf & Shea, 2004). However, such a method can result in a number of negative effects, most prominently, feedback dependence (Liebermann & Franks, 2015; Maslovat & Franks, 2015; Wulf & Shea, 2004) which has been widely demonstrated as detrimental to learning. Feedback dependence has been more commonly referred to as the guidance hypothesis (see Salmoni

et al., 1984). Frequent feedback may begin to condition learners to becoming dependent upon external information, preventing intrinsic processing and error detection that ultimately maintains performance when feedback is withdrawn (Maslovat & Franks, 2008; Mononen, Viitasalo, Konttinen & Era, 2003; Salmoni et al., 1984). Therefore, as learners develop their skill level and experience, they should aim to rely on internal sources as their major correction stimulus (Liebermann et al., 2002). The use of intrinsic information, when successfully fine-tuned (via appropriate extrinsic feedback), will serve the athlete far more positively when feedback is limited and/or later removed (Hodges & Franks, 2004).

The quantity and timing of feedback has a significant impact upon athlete dependency (Hodges & Franks, 2008). One feedback manipulation that has consistently supported the guidance hypothesis is concurrent feedback (Wulf & Shea, 2004). For example, concurrent feedback provided during continuous tasks has been more guiding than terminal feedback (Park, Shea & Wright, 2000; Schmidt & Wulf, 1997; Vander Linden et al., 1993). Such guidance is useful for reducing performance error within initial skill acquisition; however, during retention testing, performance error has also been identified as greater (Vander Linden et al., 1993), which is likely a result of having no on-going feedback to guide performance. Furthermore, utilising concurrent feedback offers no incentive to actively engage within the error-detection process (Hodges & Franks, 2008) and establish; why an error occurred, how to rectify such an error and what changes elicited correct performance upon subsequent trials.

Early recommendation was to provide feedback as soon after performance as possible, as often as possible, and in such a way to reduce errors as efficiently as possible. These feedback schedules were powerful, producing immediate and significant performance improvements. The earlier approach of ‘more is better’ was founded from study designs involving no retention or long-term learning assessment. However, as

research designs shifted to include such assessments, a reversal was observed (Chambers & Vickers, 2006; Salmoni et al., 1984; Schmidt & Lee, 2014). Methods of feedback that ultimately reduced, delayed and summarised the information proved more effective for long-term learning (Goodwin & Meeuwsen, 1995; Weeks & Kordus, 1998; Winstein & Schmidt, 1990). Athletes who received constant, external input grew to rely on information, whereas those who received less extrinsic feedback were required to utilise cognitive processes for detecting sources of performance information, becoming (relatively) self-sufficient during retention testing.

Baudry et al. (2006) failed to support the guiding theory of concurrent feedback, which can be attributed to the feedback device utilised. More specifically, as athletes enhanced body alignment, the auditory feedback signal was activated less frequently. Baudry et al. (2006) further suggested 'the functional mode of the feedback apparatus could have reduced the bandwidth [and faded the provision of feedback], which diminished the feedback dependence phenomenon' (p. 155). Decreasing the bandwidth following performance improvement potentially negates the guiding mechanism, promotes response stability in acquisition thus forces athletes to become self-regulating, and reduces maladaptive short-term corrections (Wulf & Shea, 2004). Further support for this proposition can be found within Janelle et al. (1997), Wulf and Toole (1999) and Lee and Carnahan (1990).

Encouraging learners to self-evaluate performance when deprived of external feedback can be important in avoiding dependency (Hodges & Franks, 2004; Maslovat & Franks, 2008). The key to any feedback pertains to avoiding feedback reliance (and therefore negative performance effects when feedback is withdrawn) whilst providing sufficient and meaningful information to elicit appropriate improvement. An inverted 'U' was proposed by Schmidt et al. (1990), i.e. too much (dependency) versus too little

(insufficient information to elicit learning). Delaying feedback (even for a matter of seconds) can benefit long-term learning compared with immediate/instantaneous feedback (Swinnen, Schmidt, Nicholson & Shapiro, 1990). Swinnen et al. (1990) explained that failing to delay feedback may heighten the tendency for feedback to drive future corrections as learners do not attempt to actively engage within the learning process, and therefore, do not appropriately evaluate performance through comparing the intrinsic feedback to the desired outcome (Maslovat & Franks, 2015).

The initial research regarding the guidance hypothesis was undertaken within relatively closed artificially induced laboratory conditions, where learners were often deprived of intrinsic feedback, e.g. vision. Such a setting could be considered far removed from the sports learning and acquisition domain whereby learners inevitably have access to such information. Many of the earlier experiments also involved single degree of freedom movements such as throwing, and as a result, the transferability of findings to the learning of more complex, multiple degrees of freedom skills, which require extensive practice to master should be questioned. The assessment of complex skill learning within 'real' environments is far more ecologically valid but have generally been neglected due to the; 1) movement complexity and 2) confounding issues related to multiple feedback sources a learner can utilise.

2.3.9 – Section conclusion

In this section, three main areas have been presented, including: (1) an overview and the importance of feedback, (2) the manipulation of feedback type, and (3) feedback reliance and the guidance hypothesis. Overall, the research has been predominantly lab-based with the overriding aim of understanding the effect of feedback on the performance and improvement of simple skills; therefore, many studies bear little resemblance to the 'real

world'. Findings concerning simple and single degree of freedom movements have limited (if any) transferability to the learning of more complex multiple degrees of freedom skills (Wulf & Shea, 2002). More recent studies (Baudry et al., 2006) have begun to demonstrate positive learning and retention benefits upon such complex movements. Furthermore, an absence of improvement immediately following an intervention should be considered unsurprising (Guadagnoli et al., 2002). As a result, conclusions about intervention effectiveness should not be made based upon a single learning or retention test immediately or closely following the provision of feedback. Feedback type, frequency, task complexity, and content all appear to affect feedback effectiveness. Specific combinations of these variables are also likely to be more beneficial to certain skill levels, expertise, personal characteristics and sporting backgrounds (Magill & Anderson, 2012; Phillips et al., 2013; Wulf & Shea, 2002). Unfortunately, limited research exists concerning feedback scheduling over longer, typically more realistic intervention periods. A single (or small group of) feedback session(s) may demonstrate immediate feedback effectiveness but offers limited understanding regarding retention over a longer period.

2.4.1 – Feedback and sports technology

Traditionally, feedback within the sports domain has taken the form of verbal communication via coaches or practitioners following visual assessment of a sporting performance. However, recollection within these situations has been widely demonstrated as limited (< 60% recall ability; Franks & Miller, 1986, 1991; Laird & Waters, 2008; Nicholls & Worsfold, 2016), subjective and affected by a number of confounding variables (e.g. emotional bias, speed of performance; Hughes & Bartlett, 2008). Technological advancement has made it possible to address many of these issues, ultimately improving feedback athletes receive from their respective training and competition environments.

Modern technological advancement has had such a profound impact on sports assessment (and feedback) that many athletes and coaches consider this information invaluable in understanding the why and how behind the performance (e.g. immediate feedback, strength/weakness identification etc.; Liebermann et al., 2002). The acceptance of technology enables novel methods to be implemented, which aim to continually progress the horizons and boundaries of future practice. The on-going technological development within sport has enabled products from simplistic video recording devices to more complex global positioning systems (GPS) to emerge. Initially found within an elite environment due to their considerable expense, such devices have become more widely available to the mass populations (recreational coaches and athletes). The relatively fast development (within the past 40 years) of technology has additionally enabled sports scientists to continually expand their horizons, develop understanding and challenge perceived sporting beliefs with vast quantities of objective data.

The use of the stopwatch in sports such as swimming and athletics provides an obvious and early implementation of technology within the applied environment. Further technological developments have enabled specific measurement tools to be created, and when combined with software technology, appropriate feedback can be formulated to best suit the recipient or type of data collated (Phillips et al., 2013). In addition, developments have enabled the assessment of specific aspects of performance (in-water kinematic, kinetic and electromyography (EMG) – see Pereira et al., 2015) previously unthinkable due to technological and environmental constraints (Phillips et al., 2013). The use and implementation of performance analysis has become far easier, accessible and usable to coaches, with modern day software technologies such as Dartfish (Dartfish, Fribourg, Switzeralnd) and SportsCode (Hudl, Nebraska, USA) requiring no formal qualification, such as a degree in computer programming or statistics to be truly effective. Within sports

such as football, many clubs are now able to subscribe to a service from Opta or SBG Sports Software, whereby they are provided with highly detailed game analysis (technical and locomotive). The challenge is therefore how can this vast quantity of information be interpreted or effectively condensed into a meaningful format to further enhance performance.

Video cameras are perhaps the most widely utilised technological device within sport today by virtue of their 1) relatively low cost, 2) ease of use and implementation within the coaching process and 3) ability to enable retrospective analyses. The underlying assumptions of motor learning through video is arguably based on imitation, more specifically, the knowledge that humans imitate from birth (facial or hand movements, Meltztoff & Moore, 1977). The use of video to support coaching practice was recognised soon after the technology had become available (Underwood & MacHeath, 1977). Video within the coaching process has been apparent for decades, with coaches initially locating the desired clips within videotapes using the fast forward and rewind functions (Wilson, 2008). Fortunately, the development of computer software/hardware has enabled this process to become far easier. Wilson (2008) suggested however, there still remains the unanswered questions relating to the best form and time to implement video feedback. Although video is widely utilised and commonplace, athletes at an early stage of learning (novices) arguably cannot easily improve performance utilising video without assistance from the coach, whom is able to draw their attention to the most important aspects (Hughes & Franks, 2004; Maslovat & Franks, 2015). Video without coach guidance, according to Liebermann and Franks (2004), could be considered rather ineffective owing to the significant filtering required to target appropriate aspects of the video. Augmented feedback (video or otherwise) should be regulated according to the needs of the athlete, as

many widely available technologies provide considerably more information than is potentially required to enhance learning (Liebermann & Franks, 2004).

Lyle (2002) further highlighted the importance of video within the development of complex situational decision-making. Groom and Cushion (2005) and Wright et al. (2012) identified the importance of video within the development of athlete knowledge and game understanding. For example, over 80% felt the video helped improve various decision-making processes (when/where to put pressure on the ball) and over 60% agreeing that video gave them increased confidence and pride regarding aspects of themselves and the team (Groom & Cushion, 2005). The inclusion of video sequence types (negative or positive), which may adversely affect members of the group, should be an important consideration when creating team and individual videos (Groom & Cushion, 2005; O'Donoghue, 2006). For example, some athletes may respond positively to a negative incidence, in that, they utilise the video as a method of improvement, acknowledging their skill set is not perfect. However, other athletes may suffer loss in confidence due to the negativity, therefore, the video becomes detrimental to future performance. Understanding the group dynamic and individual preferences appears key to this process; therefore, the development of a successful athlete/coach/analyst relationship should be considered fundamental.

The rapid development of computer hardware technology (e.g. processing and storage capacity) and, audio and visual software (e.g. data visualisation) has enabled the wide scale implementation of numerous devices within sport to facilitate the roles of coaches (O'Donoghue, 2006). The use and application of video combined with computer-based technology (e.g. SportsCode, Dartfish) within weekly review sessions demonstrates wide acceptance within the feedback process (Mackenzie & Cushion, 2013). An early attempt by Franks and Nagelkerke (1988) combining technology and video sequences

utilised a computer-controlled system allowing the provision of digital and graphical feedback, in addition to linked video corresponding to the outlined data. The program enabled the collection of 'coded' events from a stored database to be brought together for the recipients to view within a simple and easy domain. This process enabled specific performances or longitudinal data to be viewed via filters and dropdown menus. Many of these types of packages (SportsCode and Dartfish) have now been commercially produced and are commonplace within elite sport. However, such systems arguably lack an in depth and sophisticated analysis/editing facility desired by many of their users to be truly effective and relied upon as a standalone product. Emerging systems for data analysis and feedback should include a combination of statistical data, graphical, photographic and videographic sequence types within an informative and effective analysis tool to aid the learning process (Koumi, 2006).

2.4.2 – Section conclusion

This section has briefly outlined the origins and uses of technology, more specifically focusing upon the use of video within sport. The development of technology within recent times has allowed sports practitioners to continuously, and more easily, answer important performance related questions placed upon them by their respective coaches. Furthermore, many of the systems and devices now available collect a considerable quantity of data, making the challenge of filtering and condensing the data into the important aspects required to successfully answer any respective questions posed, that much greater. Thus, a drawback of technology and the information collated is that too much information may be presented by the practitioner (Maslovat & Franks, 2015), thus, the learner may not be able to identify and utilise the most important aspects, especially if they are presented unclearly. A criticism of many modern technologies is the inability to capture, comprehensively

analyse and present the information within a standalone product. New systems for data analysis and feedback should aim to include an amalgamation of data sources to more effectively meet the needs of the users. A combination of quantitative and qualitative feedback enables athletes to view what errors occurred (statistically or objectively), but also establish the reasons why these errors occurred (Launder & Pitz, 2000). Practice and instructional feedback can then be specifically implemented with the overriding aim of addressing the highlighted errors, thus improving performance (Hazen, Johnstone, Martin & Srikamenswaran, 1990).

2.5.1 – The effectiveness of performance analysis

Phillips et al. (2013) state that despite the development and potential of technological tools (and performance analysis interventions) to enhance feedback and facilitate skill acquisition, there is limited systematic research upon the effectiveness of feedback modalities within the applied environment. Video based performance analysis is viewed as an extremely important tool in the provision of feedback to athletes (Groom & Cushion, 2004) and the widespread use demonstrates a perceived practical efficacy and value within the coaching process (Groom et al., 2011). The overriding assumption is that athletes are able to view what they have done correctly or incorrectly and maintain or adapt performance accordingly. Despite the accepted benefit, little is known about how practice is modified with such information (Mackenzie & Cushion, 2013) or how this information should be distributed within the applied environment. Ultimately, if information is effectively distributed and utilised, future performance will be modified (Mackenzie & Cushion, 2013).

The limited research-based understanding regarding the effectiveness, impact and delivery of feedback appears surprising given; 1) the perceived practical efficacy (Groom

et al., 2011) and 2) suggestions related to the importance of effective feedback within athletic development (Carling et al., 2005; Maslovat & Franks, 2008). Few studies to date (e.g. Brown & Hughes, 1995; Jenkins, Morgan & O'Donoghue, 2007; Martin, Cassidy & O'Donoghue, 2004; Murray, Maylor & Hughes, 1998) have attempted to quantify the effectiveness of performance analysis feedback in applied settings, unfortunately leaving much of its purpose and impact unknown (Mackenzie & Cushion, 2013). Without this knowledge and understanding, developed and empirically evidenced within the applied environment, the optimisation of future feedback techniques appears extremely difficult.

Based upon the lack of research within the area, authors (e.g. Court, 2004; Groom et al., 2011) have suggested performance analysis feedback to be largely unstructured, based around critical incidents and therefore reactive in nature, inferring a non-optimised approach to the performance-feedback cycle. In addition, two prime examples arguably encompass why an area significantly intertwined within athlete/team improvement and the coaching process has been largely ignored. Firstly, Hayes (1997) stated 'show me the results of notational analysis, not the notational analysis results'. And secondly, Glazier (2010), although not specifically his suggestion, but a wider summarisation, stated that traditionally, performance analysis has been viewed as 'a methodology rather than a science'. The consideration of performance analysis as a methodology or a medium of data collection is perhaps a reflection of researchers being so fixated upon the development and optimisation of this aspect (i.e. data collection/'the method' – e.g. performance profiles, system reliability, key determinants of success etc.), that data delivery and dissemination has unfortunately become a secondary (perceivably less important) aspect of the process. Groom et al. (2011) further suggested, that while 'academic writing considers the *what* of performance analysis, regarding system design and reliability, the *how* or use of this information in coaching practice remains underdeveloped' (p. 17). Therefore, in order to

enable athletes to utilise (as much of) the information collated by practitioners, significant attention must be given to developing effective methods of delivery, with the overriding aim of improving the feedback process.

The few studies (e.g. Brown & Hughes, 1995; Jenkins et al., 2007; Martin et al., 2004; Murray et al., 1998) attempting to quantify the impact of performance analysis interventions have unfortunately, as a whole, been subject to a number of confounding variables, such as; the effect of increasing opposition quality, the limited feedback sessions and the differences in athlete training patterns upon longitudinal performance analysis interventions. Consequently, it became difficult to successfully quantify performance effects specifically due to the support provided. Jenkins et al. (2007) highlighted a number of team performance improvements (e.g. turnovers gained, goals emanating from turnovers), however, defensive play was also arguably adversely affected (i.e. an increase from 2 to 3 goals per match in losing score line was observed). The investigation 'was unable to provide evidence that the match analysis approach used is effective in enhancing match outcome' (Jenkins et al., 2007, p. 77).

Brown and Hughes (1995) and Murray et al. (1998) employed a pre-analysis technique to determine areas of weakness within squash players. The areas formulated the basis of feedback, enabling specific and individualised information to be offered. A greater number of performance improvements were identified for the sub-elite compared to the elite athletes (Murray et al., 1998). This is potentially a logical finding given the already high level of elite performance. However, improvements were still observed for the elite athletes' performance and given the margins for improvement are much smaller at the elite level, a positive improvement (albeit small) could arguably still be considered an impactful result within elite competition. Moreover, Brown and Hughes (1995) unfortunately indicated no significant improvements: 1) between groups, 2) for unforced error

distribution or 3) as individual members (except 1 experimental group member). The absence of improvement was potentially a result of the number of feedback sessions and the age of the participants, in that, the feedback provided may have exceeded an individuals' information-processing capacity. The provision of feedback consisted of three 15-minute feedback sessions at intervals of four weeks. The duration of the feedback interval is clearly a lengthy period and may well provide a compelling reason as to why a lack of improvement was observed. It is conceivably more likely, although speculated, that participants could have forgotten the information provided well in advance of the next session, and thus, were unable to practice focusing upon the suggested improvement areas.

Both suggestions are in line with Williams' (1999) ten considerations that may influence effective feedback provision, which included: feedback should 1) be constructive, 2) develop a model for comparison – i.e. gold standard, 3) relate to the athlete's skill level, 4) be delivered at a frequency appropriate to the athlete's skill level, 5) not contain too much information, 6) not be too precise, 7) be provided at the appropriate time, 8) include the opportunity to practice the skill, 9) be positive where possible and 10) utilise a variety of delivery types. Arguably however, a number of these aspects are difficult to accurately balance and quantify, in part due to their 'openness', such as; what is too much information and when is the right time to provide feedback? Therefore, the relationships between the coach, athlete and performance analyst, and the appropriate understanding of each variable, will inevitably impact upon feedback effectiveness. Identifying an appropriate, effective, and potentially individualised balance of these 'open' aspects relies heavily upon the success of these relationships.

Due to the limited research investigating the effectiveness of performance analysis interventions, related areas such as; understanding effective and appropriate data dissemination, the use of performance analysis in applied settings, and the impact of these

interventions on athlete performance as part of the performance-feedback process have tended to be neglected (Mackenzie & Cushion, 2013). The learning processes athletes engage within during feedback sessions potentially offer an insight into how athlete learning can be further facilitated and therefore requires further and significant attention (Groom & Cushion, 2004; Groom et al., 2011; Mackenzie & Cushion, 2013). Despite the clear need to develop a better understanding of feedback, its role and subsequent process, little research has been undertaken with the overriding aim of facilitating effective information delivery and retention within applied feedback sessions. Developing a wider understanding of this process has clear implications upon the enhancement and development of not only academic literature, but more importantly, future applied practice.

2.6.1 – Performance analysis within the applied environment

Few studies, until more recently, have investigated the use of video and performance analysis from the perspective of the key users within the applied environment. Many of the studies have primarily focused on larger-team based sports such as, rugby union (Francis & Jones, 2014; Kraak, Magwa & Terblanche, 2018; Middlemas, Croft & Watson, 2018; Painczyk, Hendricks & Kraak, 2017) and football (Groom & Cushion, 2004; Groom & Cushion, 2005; Groom et al., 2011; Reeves & Roberts, 2013; Wright et al., 2013; Wright et al., 2016). However, some studies have also incorporated multi-sport (Bampouras, Cronin & Miller, 2012; Martin, Swanton, Bradley & McGrath, 2018; Wright et al., 2012) and individual-sport (Butterworth, Turner & Johnstone, 2012; Mooney et al., 2016) demographics.

Groom and Cushion (2004) investigated video within the applied environment via semi-structured interviews addressing key areas, including; usefulness, learning, reflection, timing, and mental aspects. The conclusions drawn included that video; 1) aided in

performance recollection and provided a view often reserved for coaches, 2) developed game understanding and encouraged player self-critique, 3) provided the chance to reflect without emotions, 4) sessions initially were too long but became more efficient over time and 5) improved player confidence (Francis & Jones, 2014 made similar references) (see Table 2.1). Groom et al. (2011) subsequently developed a delivery framework through grounded theory to understand the delivery of video-based performance analysis. The framework consisted of 3 concepts (contextual factors, delivery approach and targeted outcome) with each having a number of categories and sub-categories to consider within session construction. A key strength of Groom et al. (2011) was the empirical focus within the framework's development. This focus allowed the study to remain as close to applied practice as possible enabling its creation based upon 'the real world'. Consequently, a number of less obvious complexities (and therefore aspects to consider) inherent within performance analysis delivery, e.g. recipient qualities, role and power interaction of the deliverer in relation to the receiver, social connection between participants, were considered. Unfortunately, however, despite being developed from an elite sports context, the model was not later assessed for its usefulness and impact within the same or similar applied environment(s).

Wright and colleagues (Wright et al., 2012; 2013; 2016) attempted to gain insight into the role, value and engagement of the coach, performance analyst and athlete within the feedback cycle (see Table 2.1). Wright et al. (2012) highlighted 68% of coaches were provided with a video after most games with 72% of these coaches receiving this soon after. Video was deemed the most important element utilised within practice by coaches (Kraak et al., 2018; Martin et al., 2018; Wright et al., 2012). The majority of coaches stated their philosophy impacted upon analysis direction and that time was the greatest factor impacting upon feedback provision (Kraak et al., 2018; Martin et al., 2018; Mooney et al.,

2016). Unfortunately, the coaches were not further questioned on how their philosophy actually impacted the decisions they made. Specifically, which aspects of their philosophy influenced what aspects of the analysis direction? Therefore, the specific information important in, and to the decision-making process, or the level of impact their philosophy had on these decisions remained largely unexplored. A key strength of Wright et al. (2012) was the combination of open and closed response sections to allow context cross comparison whilst enabling additional information specific to their practice to be provided. A clear imbalance in sports representation existed, with 46% of coaches coming from rugby league. Wright et al. (2013) identified the majority of analysts would take 2-3 hours to complete analysis, with 77% indicating they determined which KPIs to analyse with the coach. Moreover, 70% of analysts used an external company to code games, with 87.5% making use of Sportscode within their analysis. Feedback sessions lasted 0-20 minutes; although, only 12.5% of analysts directly led the sessions, with over 60% stating they had input (Wright et al., 2013). However, the level or degree of input provided by the analyst within the session was not stated. Was the analyst simply the laptop/video operator? Did the analyst describe and/or interpret the video/data? Or was the analyst trusted with providing not only the key areas for improvement, but the strategy from a coaching perspective to overcome the team's own weaknesses or exploit those of the opposition?

Positively however, these studies have begun to demonstrate the importance of the analyst's role within the whole feedback process (from capture to feedback) regarding input and, in some instances, session delivery. Wright et al. (2013) stated that analysts delivered feedback either the same or following day within sessions generally lasting less than 20 minutes; however, no indication as to why this was the favoured 0-20 minutes was provided. Wright et al. (2016) investigated the views of players towards the timing, frequency, content, and duration of performance analysis sessions. The majority of players

preferred feedback delayed by 2+ days (58%) within sessions lasting 11-30 minutes (89%). The players felt a greater sense of learning and individual development was achieved through the use of open discussion and questioning; moreover, performance analysis provided them with the opportunity to more easily self-reflect (observed within Francis & Jones, 2014). The inclusion of participant quotes in Wright et al. (2016) provides an insight into the why behind the quantitative responses offered. Overall, a key positive of these studies is the use of qualitative methods in an attempt to gain an in-depth understanding of video, feedback and performance analysis within applied environments. However, individually or comparatively between sports or participant groups, i.e. coach, analyst, athlete, a clear gap still exists regarding sports outside of football and rugby union. Moreover, understanding why analysts and coaches do what they do offers a further area for investigation moving forward.

Table 2.1.1. An overview of performance analysis research investigating the applied environment

Study	Participants + Methods	Key Aims	Key Findings
Groom and Cushion (2004)	2 elite youth coaches. Semi-structured interview. Football.	Understand; 1) Usefulness of video sessions. 2) What had been learnt in the sessions. 3) Whether the sessions influenced reflections. 4) Whether the length of the sessions was right. 5) Whether the sessions had an impact on any mental aspects.	1) Aided in performance recollection. Provided a view often reserved for coaches. 2) Game understanding. Encouraged players to self-critique. 3) Chance to reflect without emotions. 4) Sessions initially too long but became more efficient as season progressed. 5) Improvement of confidence.
Groom et al. (2011)	14 elite youth coaches. Semi-structured interviews	1) Build a theoretical framework to understand the delivery of video-based performance analysis.	Three concepts 1) Contextual factors. 2) Delivery approach.

Table 2.1.2. An overview of performance analysis research investigating the applied environment (continued)

Study	Participants + Methods	Key Aims	Key Findings
	Grounded Theory Football.		3) Targeted Outcome
Wright et al. (2012)	46 elite coaches. Questionnaire. Mixed sports.	1) Investigate how elite coaches use performance analysis tools. 2) Identify the extent to which the information is integrated within coaching practice. 3) Assess how coaches value performance analysis.	1) 91% identified coaching philosophy impacts analysis direction, 43% stating gut instinct. 2) Time greatest factor impacting feedback. 3) 68% of coaches provided with video after every game. 4) 82% use video to feedback individually.

Table 2.1.3. An overview of performance analysis research investigating the applied environment (continued)

Study	Participants + Methods	Key Aims	Key Findings
Bampouras et al. (2012)	3 coaches, analysts, athletes.	1) Generate an exploratory analysis of the in-practice application of performance analysis.	1) Athlete not included in the process itself. 2) Coach acting as gatekeeper.
Butterworth et al. (2012)	7 coaches. Interview.	1) Investigate the perceptions that coaches have in regard to the inclusion of performance analysis within the overall coaching process	1) Coaches directly praised the analysis and usefulness of performance analysis and its potential to aid coaching performance.
Reeves and Roberts (2013).	8 coaches, analysts, athletes. Interview.	1) Investigate perceptions of the effectiveness of performance analysis.	1) Impact of video-based techniques. 2) Tool for reflection. 3) Psychological implications.

Table 2.1.4. An overview of performance analysis research investigating the applied environment (continued)

Study	Participants + Methods	Key Aims	Key Findings
Wright et al. (2013)	48 performance analysts. Questionnaire. Football.	1) Identify the role that performance analysts play within feedback process, and what level of interaction they have within feedback provision.	1) 24% provided feedback the same day. 2) 33% stated their feedback was very effective. 3) 12.5% lead feedback sessions. 4) 53% of sessions last 0-20 minutes.
Francis and Jones (2014)	73 professional players. Questionnaire (all 73). Semi-structured interview (4). Rugby Union.	1) Provide an in-depth understanding of the views and opinions rugby union players have regarding the use of performance analysis in improving performance.	1) Video for player development. 2) Match preparation. 3) Video for player reflection 4) Player suggestions for improvements to the current performance analysis system.

Table 2.1.5. An overview of performance analysis research investigating the applied environment (continued)

Study	Participants + Methods	Key Aims	Key Findings
Wright et al. (2016)	48 professional players. Questionnaire (all 48). Semi-structured interview (22). Football.	1) Explore players' preferred engagement with the performance analysis approach. 2) Identify player perceptions of timing, frequency, content, duration and the environment. 3) Determine how 'involved' players feel they are in the performance analysis process.	1) Level of debate and player interaction. 2) Use of video analysis central to self-reflection. 3) Players preferred some delay before receiving feedback.
Mooney et al. (2016)	298 coaches following qualification filtering. Questionnaire. Swimming.	1) Gain insight into coaching practice and the perception of the performance analysis tools they use within practice.	1) Disparity between importance and the types of analyses conducted. 2) Video-based methods most frequent. 3) Time/cost/resource main constraints.

Table 2.1.6. An overview of performance analysis research investigating the applied environment (continued)

Study	Participants + Methods	Key Aims	Key Findings
Painczyk et al. (2017)	68 coaches. Questionnaire. Rugby Union.	1) Determine the utilisation of performance analysis among rugby coaches.	2) 82% of coaches do not use computerised notation. 3) Budget and time affected provision. 4) 69% of feedback session last 11-40 mins
Middlemas et al. (2018)	24 professional players. Interviews. Rugby Union.	1) Examine the impact of debriefing and previewing in a professional rugby team's environment.	1) Delivery philosophy. 2) Player engagement. 3) Leadership. 4) Reflection vs. preparation.

Table 2.1.7. An overview of performance analysis research investigating the applied environment (continued)

Study	Participants + Methods	Key Aims	Key Findings
Martin et al. (2018)	538 coaches/analysts. Questionnaire. Multi-sport.	1) Establish the level of engagement with performance analysis among coaches. 2) Establish the profiles associated with coaches using performance analysis. 3) Understand how they integrate it into their coaching practice.	1) Level 2 qualification a key distinguisher between using and not. 2) Coaches with support have more regular access to video, spend more time analysing, and regularly use PA to inform training.
Kraak et al. (2018)	46 coaches. Questionnaire. Rugby Union.	1) Compare use of performance analysis across competitive levels. 2) Identify extent to which information is integrated into the coaching process.	1) Coaches completed analysis themselves. 2) 64% indicated KPI selection was informed by coaching philosophy.

2.7.1 – Use of empirical data – rooted within the 'real world'

Although related to understanding the coaching process, Lyle (1999) suggests that too many studies have adopted a quantitative approach, where the need for the control of variables, has restricted a more in depth and insightful analysis of values, behaviours and contexts. The use of this approach within performance analysis is evident (e.g. indicators to quantify key determinants of performance). However, utilising a qualitative approach to better understand certain aspects of/or related to performance (e.g. role and impact of feedback within the applied environment) appears more appropriate given its complex nature (Cushion, Armour & Jones, 2006). Furthermore, throughout future attempts at understanding the role and impact of feedback, lessons may be learnt from the various models and research related to the coaching process (and performance analysis in general). Cushion (2007) argued the various coaching models (Abraham, Collins & Martindale, 2006; Côté, Salmela, Trudel, Baria & Russell, 1995), although positively informed via qualitative methods, have however, attempted to reduce such a complex process into an overly simplistic, definitive, mechanistic and generalisable guide to best practice, and therefore fail to fully encompass the phenomenon. Groom et al. (2011) further stated how the majority of the performance analysis literature reflects the process as a 'linear and unproblematic sequence' (performance, observation/analysis, feedback, planning, training/practice, performance...etc.). Both areas are often illustrated through rudimentary models and schemas 'for a process' (idealistic) in contrast to models 'of a process' developed from research firmly grounded within the applied environment (realistic). The general oversimplification of the areas within the literature has led to practitioners struggling to effectively implement simplistic and disjointed theories and models into the

'real world' of practice (Cushion et al., 2006; Jones, Armour & Potrac, 2004b; Jones & Wallace, 2005).

Furthermore, the coaching environment has been described as complex and messy, whereby it is unlikely that practice and process can be reduced to the application of generic rules, because their functioning is neither entirely reasoned nor planned (Cushion, 2004; Jones et al., 2004b). However, as with all learning environments, not every single situation is unique (Rink, 1993), and to suggest uniqueness ignores the shared aspects of the sessions and participants (Cushion et al., 2006). Therefore, common themes within similar situations may provide influence upon the direction of action within such environments. Given the potentially complex nature of the provision of effective feedback, the notion of similarity (as well as an appreciation of individual contexts) between certain learning situations may provide assistance within the development of future feedback best practice.

The empirically evidenced model developed by Groom et al. (2011) demonstrates a comprehensive assessment of the use and engagement of video-based performance analysis within football. The use of empirical data is a major strength of their approach due to its realistic representation of the environment assessed. Utilising such a method develops a more in-depth understanding and enables researchers/practitioners to more effectively meet the needs of the recipients within their respective environment. Knowledge generated by more sophisticated analyses (qualitative methods) is perhaps fundamental to future understanding and the development of appropriate methods to improve and progress the provision of feedback within elite sport. Overall, a more comprehensive understanding of the use of feedback in performance analysis is unobtainable without studies specifically directed towards; the use and effectiveness of feedback, its current best practices, and potential future directions and aspirations, all rooted within and empirically evidenced by the applied environment.

The value of research to a population can be assessed via the extent to which its findings are utilised as recommended practice (Cushion, 2007; Ward & Barrett, 2002). For example, researchers within the field of nursing have often been criticised for studying problems irrelevant to practice (Camiah, 1997). Although not undertaken similarly within sports science, more specifically the performance analysis domain, it is likely that similar views may be held by a vast quantity of applied performance analysts and coaches. Haag (1994) suggested an 'integration paradigm', whereby research guides practice and vice versa, but this is unfortunately not commonplace. Researchers should arguably offer more attention to the application of future research during the initial development stages, in order to bring the academic and applied environments closer together (Bishop, 2008). Furthermore, there is a lack of clarity related to the scientific approaches employed (basic or applied science). Performance analysis research often utilises the basic science approach whereby authors attempt to uncover new knowledge without the concern of how the discovered knowledge might be implemented (Mackenzie & Cushion, 2013). Bishop (2008) suggests that knowledge and understanding generated through [performance analysis] research needs to more closely align with the requirements of the user, i.e. coaches, athletes and practitioners. Research should therefore be developed in conjunction with the intended users in order to 1) have a significant and meaningful impact upon performance and 2) develop a deeper understanding of performance/practice. Implementing an applied science approach, whereby researchers engage with applied performance analysts to establish common issues for research attention presents a clear and considerable opportunity to positively impact professional practice.

2.8.1 – Literature conclusion and the research problem

The rapid rise and use of performance analysis within sport settings arguably developed from the importance of reliable/accurate information (feedback) within the development of athletic performance. The importance of performance analysis is further highlighted when analysis of coach observations reveals considerable limitations (< 58%, Franks & Miller, 1986; Laird & Waters, 2008; Nicholls & Worsfold, 2016). Academic interest within performance analysis has generally coincided with the growing use and implementation of applied performance analysis within sports environments. However, academic literature has primarily focused upon 'the method' of analysis through the collection of valid and reliable data. As a result, research publications tend to focus upon the development and optimisation of new and current data collection or analysis techniques, e.g. profiling. Although clearly warranted and required to continually progress and develop the literature and theory of performance analysis, it fails to enhance our understanding of the use and delivery of the information within applied practice. Simply put, practitioners are able to utilise research to facilitate the development of data collection methods (system design, reliability etc.), but are conversely unable to access information to facilitate effective and impactful delivery to coaches and athletes.

Understanding performance analysis feedback practice should logically begin with the investigation of applied practitioners working within elite environments, as their knowledge, experience and applied processes can subsequently be shared with other performance analysts to facilitate developments in future applied practice. This collation and transfer of knowledge presents the user(s) or aspiring practitioner with guiding information to help 'frame their roles [practice]' (Gilbert & Trudel, 2001). The use of empirical data collected from coaches and performance analysts (via qualitative or mixed methods) would appear to offer a greatly valuable, important and insightful understanding

of practice within the elite environment; thus, clearly developing and enhancing academic literature within the area of performance analysis and feedback. Aside from the work primarily within football and rugby union (Groom & Cushion, 2004; Groom et al., 2011; Francis & Jones, 2014; Kraak et al., 2018; Martin et al., 2018; Middlemas et al., 2018; Mooney et al., 2016; Painczyk et al., 2017; Wright and colleagues, 2012; 2013; 2016) there appears limited information quantifying and understanding the role of the analyst (the what/when/why/how of their practice), the value coaches place upon performance analysis feedback, and the congruency between the deliverer and the receiver (performance analyst, coach and athlete) in relation to current and desired practice within other elite sports environments.

The provision of performance analysis feedback currently operates without a considerably researched applied guideline for good practice; therefore, the service is often viewed as unstructured and reactive in nature (Court, 2004). Arguably however, this aspect is secondary to understanding what happens within practice, i.e. researchers cannot aim to develop best practice without firstly bringing together current practice from various environments, domains and experiences. Clearly, a guide for best practice (a more systematic, structured approach), if appropriately developed, would be of considerable benefit and interest to those within the field. Performance analysis is still a relatively new sub-discipline of sports science, therefore the current streams of theory developing research is clearly, and always will be required. However, without beginning to comprehensively understand how/when practitioners/coaches deliver information, the area will continue to remain underdeveloped. Given that feedback is a process that has sparsely been examined within performance analysis (applied or otherwise), despite its significant use within the coaching process, it appears of significant interest to practitioners, educators

and coaches alike to gain a further understanding of feedback and its process within applied sport.

The research problem was founded from two key areas, the applied and the academic. There was a clear applied need from the EIS to develop a better understanding of the implementation of performance analysis and feedback within practice (including, the what, when, how and why of delivery), share this knowledge within 'the network', and subsequently use this knowledge to guide practitioners. Secondly, the review of literature demonstrated that a clear gap regarding the understanding of performance analysis feedback sessions exists within the Olympic and Paralympic sports domain. Therefore, the primary aim of the thesis is to address the academic and applied need for empirically based understanding regarding the delivery of performance analysis feedback and investigate; what is the role of and how can performance analysis feedback be comprehensively understood, structured and implemented within the Olympic and Paralympic sports environment, to ultimately enhance applied practice.

Chapter 3: Study 1

The implementation of performance analysis and feedback within Olympic sport: The performance analyst's perspective.

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3.1 Abstract

The study considered performance analysis and feedback from the perspective of the performance analyst through the investigation of the 'what', 'how', and 'when' of practice within a selection of Olympic sports. Twenty-three performance analysts (experience 6.4 ± 4.1 years) engaged in a structured interview (85 ± 15 minutes) regarding their processes within applied practice. Likert scales (All the time, Often, Sometimes, Rarely, Never) were used to facilitate cross sport and environment comparison. The performance analysts highlighted the experience of their coaches as the most prominent feature influencing analysis direction and time had the greatest impact upon feedback provision. The main analysis techniques used were video, profiling and performance reports. Feedback was delivered primarily either, 1) < 1-hour post-performance within sessions lasting < 10-minutes or 2) the following day within sessions lasting 25+ minutes. Video feedback was usually coach led, however data delivery was more evenly distributed between coach and analyst. Very similar processes across the participants were identified, despite a wide

variety of sports and participant experience levels. The findings have begun to illustrate practice within elite sport whilst highlighting the importance and need for further practitioner-based investigation regarding the use of performance analysis and feedback within applied contexts.

3.2 Introduction

Performance analysis is an integral tool within the coaching process by virtue of the desire to provide effective and accurate feedback (Hodges & Franks, 2004; Mayes et al., 2009; Nelson & Groom, 2012). The timing and frequency of feedback has been widely investigated within motor learning research (for a review, see Wulf and Shea, 2004). However, investigations involve predominantly lab-based methods, simple skill performance (e.g. throwing) or restriction of sensory information (e.g. sight). These bear little resemblance to the 'real world' of sports performance that involve complex and multiple degrees of freedom skills that require extensive practice to master (Wulf & Shea, 2002).

Sports feedback has traditionally involved subjective observations based upon a coach's perceptions and experiences (Maslovat & Franks, 2015). Human observation has been studied in relation to memory recall (Neisser, 1982) and criminal identification (Wells & Olsen, 2003) with little attention to sport except for an assessment of a coach's observational role i.e. recall, assessment and appraisal (Franks & Miller, 1986; Laird & Waters, 2008; Nicholls & Worsfold, 2016). Franks and Miller (1986) identified observational accuracy (mean recall – 42%) of novice soccer coaches (3rd year Physical Education students) to be more effective for certain variables (e.g. shooting) than others (e.g. passing), assessed after viewing an International soccer match. Subsequent research (Franks & Miller, 1991; Laird & Waters, 2008; Nicholls & Worsfold, 2016) incorporating

1) memory training, 2) greater task specificity and 3) greater domain experience, further illustrated limitations within an observer's ability to successfully recollect (< 58% recall). However, these studies failed to acknowledge that domain expertise might allow some events to be forgotten, as they were not important for the formulation of effective feedback. Potentially, coaches refine their observational skills, over time through experience, to only focus upon those aspects deemed important or ignore unimportant information. Irrespective of this, the potential for error in a coach's view of a game has been used to substantiate the need for performance analysis to support coaching observations. For example, Butterworth et al. (2013) suggested the efficient and effective use of performance analysis to better interpret the complex nature of performance and provide appropriate, comprehensive and objective feedback is fundamental to learning and development.

Performance analysis research has mainly considered key performance indicators (Hughes & Bartlett, 2002), data collection systems and reliability (Cooper et al., 2007), profiling and prediction (James et al., 2005) and work rate analysis (Cahill et al., 2013). Groom et al. (2011) suggested that while academics consider the 'what' of performance analysis, regarding issues such as system design and reliability, the 'how' or use of this information remains unclear and largely overlooked. A divide between the needs and goals of the academic researcher and the applied practitioner have therefore been identified; although the extent to which this is either an issue or a problem have yet to be determined.

The widespread use of video based performance analysis demonstrates a perceived practical efficacy (Groom et al., 2011), however limited research exists regarding its effectiveness (Brown & Hughes, 1995; Jenkins et al., 2007; Martin et al., 2004; Murray et al., 1998), meaning its impact is unknown (MacKenzie & Cushion, 2013). Studies attempting to discern the effectiveness of performance analysis feedback were confounded,

e.g. opposition quality varied between matches, making it difficult to attribute performance changes to performance analysis support (e.g. Jenkins et al., 2007). Furthermore, intervention studies tend not to have control groups making experimental effects difficult to distinguish from random effects. However, prior to assessing the effectiveness of feedback, the identification of the 'what', 'when', 'how' and 'why' of performance analysis interventions in the applied environment needs to be established.

Applied performance analysis has been studied (Groom et al., 2011; Groom & Cushion, 2004; Francis & Jones, 2014; Wright et al., 2012; Wright et al., 2013; Wright et al., 2016) primarily in football and rugby union to understand 1) 'what' took place within sessions and 2) 'how' performance analysis and the analyst was utilised. Groom and Cushion (2004) concluded that video aided recall, developed understanding, encouraged self-critique, provided the chance to reflect without emotions, and improved player confidence (Francis and Jones, 2014 made similar inferences). Groom et al. (2011) developed a feedback delivery framework through grounded theory consisting of three concepts (contextual factors, delivery approach and targeted outcome), with each having sub-concepts to consider within future session development. For example, to change behaviour (targeted outcome), the contextual factors (e.g. session design) and delivery approach (e.g. motivational videos) are modified to elicit the desired change. Whilst this has been developed from an applied context, it has not yet been assessed for its impact within the applied environment.

Wright and colleagues (2012, 2013, 2016) assessed the role, value and engagement of the coach, analyst and athlete within the feedback cycle. The majority of coaches were provided with video after most games (Wright et al., 2012) with coaches stating their philosophy and time impacted upon both analysis and feedback provision (see also Groom et al., 2011 and Mooney et al., 2016). Analysis took 2-3 hours to complete and feedback

was delivered within sessions lasting 0-20 minutes (Wright et al., 2013). In addition, only 12.5% of analysts primarily delivered feedback sessions, however over 60% stated they had some form of input within the session. These studies have begun to demonstrate the importance of the analyst's role within the whole feedback process (from capture to feedback) regarding input and, in some instances, session delivery. Wright et al. (2016) investigated player views towards timing, frequency, and duration of sessions with the majority of players preferring feedback delayed by two or more days (58%) within 11-30 minute (89%) sessions.

Whilst limited research has provided a useful insight into how performance analysis is utilised in the applied setting, it remains a scarcely explored area particularly in sports other than football and rugby union. Further use of more naturalistic, qualitative or mixed methodological approaches to develop a better understanding of the use of performance analysis (Nelson & Groom, 2012; MacKenzie & Cushion, 2013) is warranted. Therefore, the aim of this study was to consider performance analysis and feedback from the perspective of the performance analyst through the investigation of the 'what', 'how', and 'when' of practice within a selection of Olympic sports.

3.3 Methods

3.3.1 Participants

Twenty-three Performance Analysts (experience 6.4 ± 4.1 years; 3 team and 20 individual sport analysts) working in high performance sport participated in the study. Forty percent of participants had > 8 years experience, 30% had 4-8 years, and 30% had < 4 years experience respectively. All participants had a Sports Science related (74%) or Coaching and/or Sports Development (26%) undergraduate degree, with all but two being in the process of obtaining or having a Master of Science postgraduate degree (50% –

Performance analysis; 15% – Biomechanics). Furthermore, three had or were in the process of completing a Doctor of Philosophy (2 – Biomechanics; 1 – Performance analysis). Ethical approval for the study was gained from Middlesex University's ethics committee.

3.3.2 Interview question design

Questions were themed around current research (Wright et al., 2013) related to the use of performance analysis, feedback and the role of the analyst, as well as discussions/focus groups with applied performance analyst practitioners in order to ensure the study's applied impact. The lead researcher formulated an extensive list of questions, which was condensed/reworded to avoid similar questions being forwarded to review. Five-experienced practitioners/academics provided critical reflection upon question appropriateness, wording, clarity, and response categories in relation to the overall study aims (Gratton & Jones, 2010). The final design incorporated 40 questions (mixture of open and closed) including the themes, 1) Competition/Training Video and Data, 2) Analysis Process and 3) Feedback Process (Appendix 2). Likert scales (i.e. All the time, Often, Sometimes, Rarely, and Never) were used for answers to closed questions to facilitate cross-sport comparison. Open questions were included to enable expanded responses and allow individual reflections on experiences.

3.3.3 Procedure

The interview was completed in a one-to-one format (participant and interviewer) lasting 85 ± 15 minutes and recorded via Dictaphone in a similar manner to Wright et al. (2016) and Francis and Jones (2014). Interviews were transcribed within Express Scribe (NCH Swift Sound) and then offered back to each participant to verify response accuracy and

provide additional information where appropriate. Closed responses were imported into Excel and collated as frequency counts in relation to the response category and Likert scale. The written transcriptions were imported into the qualitative analysis software, QSR Nvivo 11 (Qualitative Solution Research 2002) for exploration.

3.3.4 Data analysis

Responses were grouped by question and investigated for similarities and differences in relation to participant experience and sports environment. Spoken responses were cross-compared with the respective quantitative results to draw out the 'why' of practice. In conjunction with an experienced qualitative researcher, participant quotations were condensed into the most prominent ones deemed to best illustrate the trends in quantitative response. Finally, a findings summary was presented to a selection of analysts involved to verify accuracy and provide feedback upon data interpretation, including quotation selection. Statistical analysis was carried out using SPSS (V21). All questionnaire sub-sections demonstrated *good* to *high* reliabilities (Cronbach's α between .72 and .82; Appendix 3). Kruskal-Wallis tests were used to test for differences between the three levels of analyst experience. A significance level of .05 was used for all analyses.

3.4 Results and discussion

3.4.1 Factors influencing performance analysis and feedback provision

Over 90% of analysts indicated their coaches' experience/philosophy impacted upon analysis direction (> 60% within Mooney et al., 2016) suggesting the ability to articulate their philosophy into variables and behaviours, which could be analysed, as an important

aspect within the analysis process. The time of season and athlete interaction also played a considerable role highlighting a number of influencing factors outside of the coach-analyst dynamic (Figure 3.1). Of the analysts, 43.4% indicated coach with analyst input was the primary influence upon aspects to analyse (Wright et al., 2013 – 72.9%). Consequently, an effective coach-analyst relationship whereby both can contribute their views and knowledge within an open environment to best guide performance analysis provision appears important. In addition, when sporting group was considered (Combat, Timed, Individual, and Team), the analysts reported that performance analysis experience, training goals, forthcoming competition and athlete characteristics impacted performance analysis provision differently. For example, 66.7% of team sport analysts suggested that the level/age of the athletes they worked with never impacted provision. Whereas 40% of analysts within individual sports stated their experience impacted provision all the time, which was twice that of any of sport group. For further comparison regarding the main sport groups analysed, see appendix 6.1.

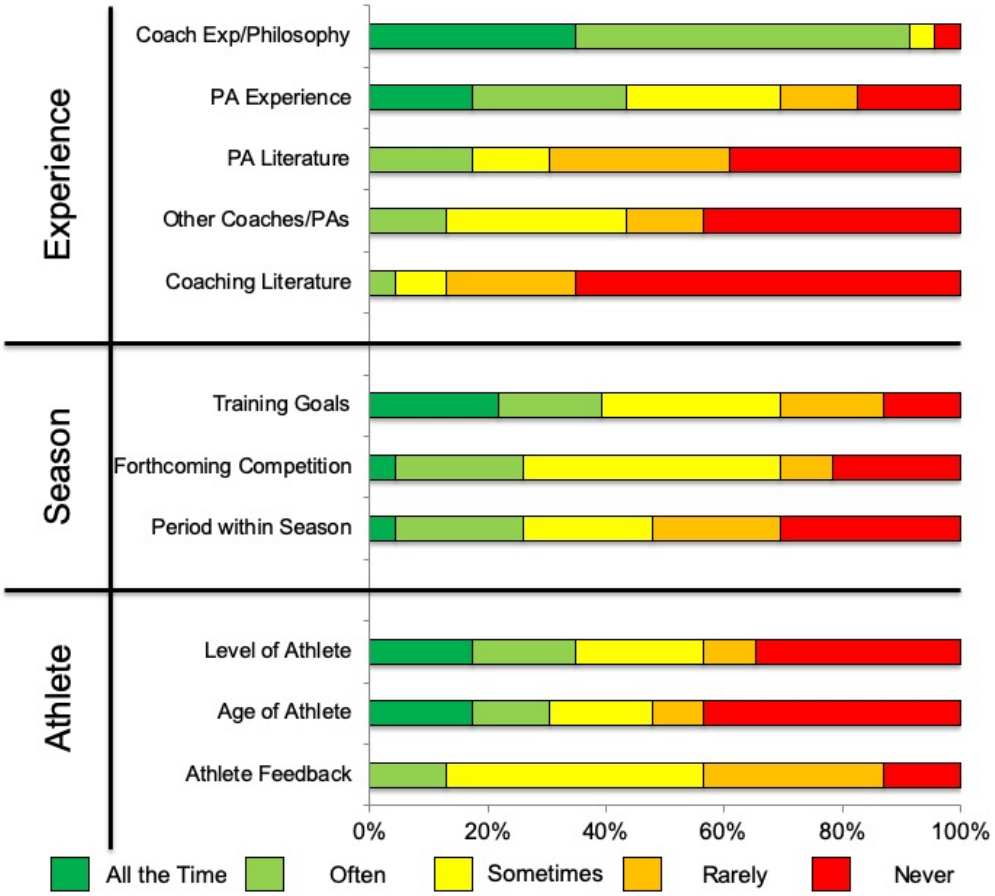

Figure 3.1. Factors influencing analysis direction

In line with Wright et al. (2012) and Mooney et al. (2016), time, i.e. how much time was available between performance and subsequent performance due to scheduling or as a result of the level of analysis required to be undertaken prior to feedback, was the main factor impacting the ability to feedback. This was followed by concerns over the quantity of feedback, i.e. the amount of feedback or information available to the coach that needs to be condensed prior to feedback, and content of feedback, i.e. what should be delivered (Figure 3.2). However, to negate the impact of time could be difficult due competition constraints or analysis processes. Specifically, processes could be simplified to enable the quicker completion of the desired analysis, but such a change would likely

compromise information depth, potentially affecting usefulness and impact to the coach. Furthermore, recipients could view information in their own time; however, a clear limitation exists regarding whether recipient attention has been successfully directed towards the key messages. Such an approach may likely require direct follow up questioning (e.g. on the phone or in person) to establish whether the feedback had successfully delivered its message. In addition, when sporting group was considered (Combat, Timed, Individual, and Team), a similar pattern was evident in the majority of response categories. The main differences included: 28.6% of analysts within timed sports reported that time taken was never an issue and 33.3% of analysts within team sports stated that analysis reliability was often an issue. For further comparison regarding the main sport groups analysed, see appendix 6.2.

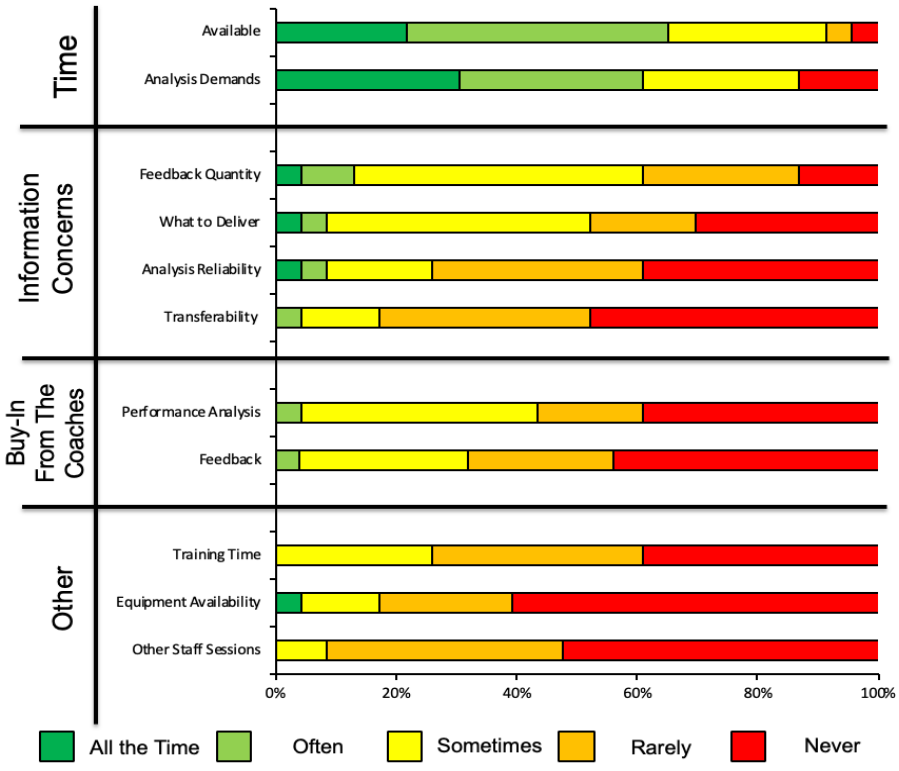

Figure 3.2. Factors affecting feedback provision

3.4.2 Type and elements of performance analysis undertaken

Approximately twice as many analysts consistently provided competition support (62%; pre- or post-competition) compared to training (35%) inferring a greater competition focus. The main areas utilised regularly included, 1) full unedited footage, 2) profiling and 3) review documents. Trend and data analysis and strengths and weakness video/reports were the least used aspects (Figure 3.3). In addition, when sporting group was considered (Combat, Timed, Individual, and Team), analysts reported the use of video of strengths and weaknesses, reports, video of individual athletes, video of key action points, and profiling differed depended upon which sport they worked for. For example, 40% of analysts within individual sports prepared video of strengths and weaknesses all the time, whereas 40% never did so for combat sports. Analysts working in timed (71.5%), individual (50%), and team (33.3%) sports stated that reports were used often or all the time, whereas 60% of analysts within combat sports never used this. For further comparison regarding the main sport groups analysed, see appendix 6.3.

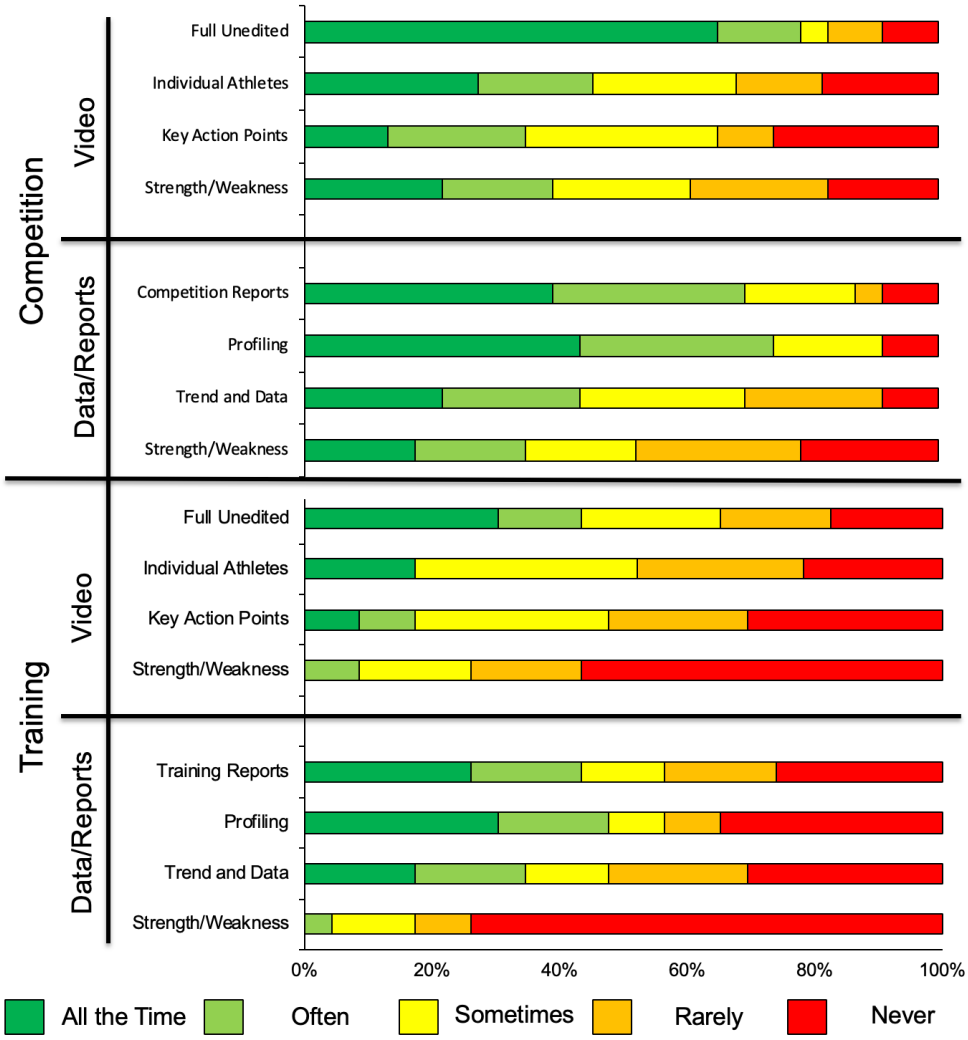

Figure 3.3. Type of performance analysis provided

The assessment of performance and funding sports receive is often largely affected by competition performance (e.g. Olympic Games). For example, UK Sport state 'success is measured by the medals won, the number of medallists developed…' (UK Sport, 2018). The prioritisation of competition support over training is likely an attempt to facilitate effective performances at these events, and thus meet/exceed their targets. The analysts indicated they utilised video, in full/edited form, on a regular basis within current practice inferring a significant level of recipient *buy-in*. This observation is in line with previous research (Wright et al., 2012) that identified the 'vast majority of elite coaches surveyed

receive a video, DVD or edited clips'. A number of participants reported how video formed the foundation of performance analysis provision, for example: 'Full video of performance, it doesn't matter what the event is, they'll always get…that's kind of the basic, the bones of it' (Participant 23: 0-4 years' experience).

3.4.3 Feedback frequency

The importance of information to enhance performance has been discussed considerably; however, the frequency and timescale of feedback delivery within an applied setting has received limited attention. Similar to Mooney et al. (2016), 71.8% of participants provided video/data post-performance frequently, with > 86% suggesting that increasing this would be beneficial to learning, although this mainly affirms their belief in their role. Francis and Jones (2014) and Wright et al. (2016) also suggested the use of video and data supports individual reflection and enables a deeper understanding of performance through a more holistic view. Moreover, increasing feedback, either directly (coach input) or indirectly (individual reflection) may create greater opportunity to impact development. A specific example outlined why increasing feedback was preferable: 'More feedback is the gold standard really, because of the amount of learning that they can immediately do…it's something that everybody is pushing very hard for' (Participant 1: 0-4 years' experience).

Analysts made use of during-performance support within competition far less frequently than desired. A few reasons became evident why this was the case; firstly, many competitions restrict the provision of information during performance. Secondly, the level of information consumed during performance could be considered limited due to the 1) speed of performance and 2) time required to collect/feedback. Two pertinent examples highlighted a desired 1) increase and, in contrast, 2) decrease in during-performance feedback.

> They [The athlete] would watch it [the performance] straight away to then be able to rectify it there, rather than waiting till afterwards to watch it. I just think in terms of their learning process they'd be able to implement that change, or see whether that was effective or not straight away, rather than trying to remember. (Participant 11: 4-8 years experience)
>
> The type of sport that [*sport*] is, it's quite a feel and it's quite a style-based sport. Sometimes [*sport*] can be too focused on a specific number, rather than the overall performance, sometimes they'll overthink one particular skill, which throws off the routine. (Participant 15: 8+ years experience)

Although 86% of participants preferred an increase in feedback, it would appear that a standard approach to feedback frequency might not be effective for all (Wright et al., 2016), particularly those conducive to 'overthink one particular skill'. Therefore, learning preferences, personality types and the type of information being presented should be thoroughly considered when deciding upon feedback frequency. Furthermore, the type of performance under review may also influence desired feedback frequency. For example, during the Olympics, hockey nations play 8 games in 14 days (if reaching the final), whereas at club level matches are far less frequent, thus the desire to receive competition feedback will likely increase during the Olympics compared to a usual competitive schedule.

3.4.4 Feedback timing

Feedback delivery within competition was split between within 1 hour and > 1 day post-performance; however, Sometimes was the main response provided regarding the timing of feedback within training, indicating no clearly favoured approach. More accurately, the point at which feedback occurs within training will likely depend upon various influencing factors, e.g. what is being practised. A greater number of analysts (14.7%) desired to deliver feedback within 1-hour moving forward. These results contrasted with Wright and colleagues (2013; 2016) and Francis and Jones (2014) where feedback was primarily

delivered > 2 days post-performance. A more immediate approach to feedback arguably 1) allows the performance to stay fresh in the mind, facilitating performance reflections of greater honesty (McArdle, Martin, Lennon & Moore, 2010) and 2) allows the recipients to review and focus upon how to rectify errors more immediately (Wright et al., 2016). A number of examples were provided to demonstrate why more immediate feedback was preferable:

> To make sure that it's fresh, that it's kept up to date and, that if a coach came to you, for example, if there was no session in the afternoon and the coach came to you with some more detailed questions, you have the ability to talk them through one-to-one. (Participant 1: 0-4 years experience)

However, some participants, either through sport involvement or experience, voiced their opinions regarding the importance of delaying feedback. McArdle et al. (2010) and Groom et al. (2011) highlighted the psychologically useful effect and importance of providing *reflection time* to promote objectivity, effective self-reflection and clarity within feedback sessions through the removal of emotions. Previous research (see Maslovat and Franks, 2015 for an introduction to feedback literature) regarding immediate feedback highlighted the potential for athletes to fail to actively engage within the self-reflection process if the *answers* are consistently provided

> We'd like to have everything ready within the hour but not necessarily immediately, like give people time to take away the emotion before they view video and data. (Participant 12: 8+ years experience)

> Within 10 minutes...is too quick, because they haven't actually had time to debrief themselves and actually think it through in their heads, before they actually watch it. I think that it's important that they have time to debrief it in their own heads, and even to...some extent a coach having a chat with them first and saying, right, so how did you feel about that. (Participant 9: 4-8 years experience)

Wright et al. (2016) outlined the use of technology to facilitate the individualistic delivery required by certain recipients. Sharing technology could distribute information quickly, whilst allowing recipients to delay their own access if required, to more effectively remove the emotion and promote objectivity pre-feedback (McArdle et al., 2010). Furthermore, McArdle et al. (2010) highlighted that feedback was an on-going process whereby it could be positive to engage in a combination of both approaches (i.e. delayed and immediate).

3.4.5 Feedback session length

No clear approach was apparent regarding feedback session length. However, these findings are arguably not surprising given the wide variety of factors to consider within feedback design, such as; situation (competition/training), content (technical/tactical), and athlete (age/level), among various others. Furthermore, Groom et al. (2011) outlined context, delivery approach, and purpose/targeted outcome as important factors for consideration within the overall design of feedback sessions. In contrast, Wright et al. (2013) identified the majority of analysts reported 0-20 minute (53%) and 21-40 minutes (28%) respectively. However, these findings differed from Groom and Cushion (2005) where 30-40 minute sessions were felt to be 'about right' and 70% stated that they were actually too short. It must be noted that the level and age (U17 1st year scholars) of athletes within Groom and Cushion (2005) may provide explanation for the desire to receive an increased duration of feedback.

A preference for a future shift to < 20-minute feedback sessions was indicated. A benefit of shortening sessions is the need for athletes to remain focused for a shorter period, potentially positively affecting engagement. However, shorter sessions require a clear, more concise and thought about approach that is compiled of extremely key

performance information. As a result, more time would be required pre-feedback to effectively select appropriate information. A specific example was provided to outline why a shortened session would be beneficial:

> It's quite important to keep feedback relatively concise because it's very easy to spend hours going through something actually you haven't really hit on the key points. The hours need to happen before the feedback happens, so you go in with a very clear message, these are the outcomes of that session or that competition, these are the key feedback parameters, these are the key performance parameters…you need to keep people engaged with the process as well and I think sometimes people will switch off after 15-20 minutes. (Participant 1: 0-4 years experience)

3.4.6 Feedback delivery approach

Analysts delivered feedback within a consistent manner (78%) and within an individual setting (> 60%), with a clear desire to increase this moving forward. Face-to-face was the primary method of delivery with the use of video/phone very rarely utilised. Video feedback sessions were primarily coach led (similar to Wright et al., 2013) whereas data delivery was more evenly distributed between each group. However, over half of participants desired to feedback via a coach/analyst-combined approach. Over one third of analysts reviewed their feedback methods on an annual basis, whereas, 30% tried to maintain the same or similar feedback methods throughout one Olympic cycle (4-year period).

3.4.7 Technology and literature

The development of computer technology has enabled a wide variety of computer-based tools (e.g. SportsCode, Dartfish) to be utilised. Dartfish was the primary tool (87%), whereas, 60% and 87.5% of participants investigated by Wright and colleagues (2012; 2013) utilised SportsCode. The ingrained use of a specific technology highlights that the aspiring analyst should aim to have a good knowledge of the main tool utilised within their

desired environment; however, it was apparent that a wide variety of sports specific tools were also frequently utilised. In contrast to Wright et al. (2013), but comparably to Wright et al. (2012), the majority of participants did not use an external information provider inferring a considerably *hands-on* approach. Data reliability, specificity, and the publicly funded nature of Olympic sport may offer further explanation to the lack of external information collation.

Academic literature, their findings and processes, currently has a limited use within applied practice as only 13% (compared to 39% for technological developments) of analysts stated they actively kept up to date with current developments as it was often 'not relevant'. Approximately 45% of analysts stated they regularly liaised with analysts/academics regarding technological developments, whereas 30% did for literature. A large portion of research to date arguably focuses upon understanding the best at the expense of how this information can be implemented within applied practice (MacKenzie & Cushion, 2013; Williams & Kendall, 2007). Therefore, for practitioners to consistently implement research within the elite environment, research needs to better reflect the *real world* of elite sport by incorporating elite populations within investigations useful to them (i.e. practitioner or sport).

3.5 Conclusion

The findings add to the limited investigation outside of football/rugby union and provide detailed insight into the use and implementation of performance analysis within the Olympic feedback process. The study has also highlighted how analysts working within Olympic sport might make use of certain methods or analysis techniques, whilst additionally highlighting a number of external impacts upon their role which all need to be sufficiently and effectively managed. The majority of analysts stated their coaches'

experience/philosophy impacted the direction of analysis they undertook. As such, the ability to develop an effective coach-analyst relationship in order to translate their philosophy/experience into measurable variables appears key to effective and impactful practitioner support. Time was the largest constraint upon the ability of the analysts to provide feedback. Furthermore, the quantity and content of feedback was highlighted as an underlying factor to many of the analysts; consequently, demonstrating the need for further research to address these concerns. Profiling was suggested as the second most used aspect of analysis (behind video), therefore current or aspiring analysts should ensure they are knowledgeable within profiling, specifically, what profiling is, how profiling is undertaken, and how profiling can be illustrated/disseminated. The duration of feedback sessions currently provided was relatively varied and likely influenced by a number of variables, e.g. sport type (individual/team), situation (competition/training), content of the session (technical/tactical), and athlete (level/age/seniority). Academic literature was highlighted as playing an insignificant role within the analyst's applied practice. Consequently, research needs to make greater attempts to reflect the problems and questions that arise from the real world of elite sport. Closer collaboration between *the academic* researcher and *the applied* practitioner is therefore highly encouraged.

Not only does the study outline the 'what', it has extended upon current research through unearthing the 'how' and 'when' behind practice within Olympic/Paralympic sports providing a broad and detailed understanding of the implementation of performance analysis and feedback by practitioners within the applied environment. The insight gained into performance analysis practice has generated understanding of the various tools and delivery methods utilised, as well as the challenges faced by the applied practitioner on a daily basis. The questionnaire and subsequently, the information generated, could be shared between practitioners to assist within idea development, identify sports who operate

in a similar or contrasting manner to enable discussion/collaboration, as well as being a means of 'checking and challenging' practice between environments. Moving forward, additional practitioner-based investigation utilising in-depth interviews with the overriding aim of unearthing the 'why' behind practice appears a key and obvious progression within future research. In addition, the investigation of performance analysis and feedback, 1) within other applied contexts and/or 2) within case-study approaches focusing upon a specific sport(s) may also positively benefit the development of future practice.

Overall, the use and analysis of empirical data has provided a more realistic representation of the environment. Moreover, the 'on the ground' nature of the study has highlighted some of the complexities that practitioners need to consider when delivering applied performance analysis and feedback support (e.g. the coach's philosophy and how this impacts upon what is analysed or how information is fed back to them). Consequently, it would appear prudent to investigate the use and value of feedback from the user's perspective, i.e. the coach, to more effectively meet the demands of those utilising the information to facilitate improvements.

Chapter 4: Study 2

Elite coaches' use and engagement with performance analysis within Olympic sport

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4.1 Abstract

The use and implementation of performance analysis and feedback by 18 elite Olympic/Paralympic coaches (coaching experience 16.1 ± 7.4; experience using performance analysis 8.3 ± 4.8 years) was explored via an online questionnaire (mean time to complete = 29 minutes). Likert scales were used to facilitate cross-sport comparison. Comment boxes were included to enable additional information to be provided if deemed necessary. Training goals, athlete discussion and coaching philosophy were the most prominent features influencing analysis direction. Time available had the greatest impact upon feedback provision. The main analysis techniques used were video, performance reports, and trend analysis. Coaches with greater experience delivered significantly more feedback sessions within 1-hour of performance. Feedback sessions were < 20-minutes in duration and delivered in a balanced (experienced) or mostly positive (inexperienced) approach. Feedback was delivered consistently according to a preferred schedule, face-to-face, and within an individual format. Sessions were usually coach led, however considerable value in a combined or analyst led approach was demonstrated. The findings

have begun to illustrate practice within elite sport from the perspective of a key user of performance analysis, i.e. the coach, and have clear implications for practitioners by identifying the key areas coaches' value from performance analysis.

4.2 Introduction

The preparation of athletes towards elite performance is a vital aspect of a coaches' role within day-to-day practice. This is often achieved through structured and targeted training regimes that aim to develop various aspects of an athlete's performance e.g. tactical, technical (Mooney et al., 2016). As such, the use of various Sports Science support mechanisms e.g. performance analysis, physiology, is commonplace within the elite sports environment. Performance analysis has seen considerable growth within the past 20 years in both, academic interest and applied support. In addition, the implementation of performance analysis has become increasingly more accessible to coaches and athletes by virtue of technological advances. Subsequently, a multitude of software programs such as Dartfish, SportsCode and Quintic and specific hardware devices have been developed, enabling a coach to easily collate, process, and interpret vast streams of information deemed important within future improvement. Consequently, coaches have arguably been making use of analysis techniques for years within their practice whilst recording, reviewing and providing video feedback. What remains unclear is the extent to which coaches utilise these various tools and techniques, but also the precise nature of a coaches' interaction with performance analysis throughout their appraisal of elite performance (Martin et al., 2018). Moreover, performance analysis is widely accepted as beneficial to the coaching process, yet little is known about how it is used to modify practice in elite sport. This limited knowledge is likely due to the secretive nature and perceived

competitive edge their respective process offers. Coaches/teams are therefore reluctant to share information, as to do so, may risk compromising their 'competitive edge'.

The coach is often considered the link between practitioner and athlete; therefore, it is important to further develop and understand their views regarding performance analysis practice within elite sport (Mooney et al., 2016). Furthermore, real world research regarding the perceptions, practices, and engagement of coaches with performance analysis is fundamental to the discipline's development (Groom & Nelson, 2013). However, despite their critical role in the feedback process, the views of these coaches have been rarely reported within academic writing to date. Many of the studies investigating coach, analyst, or athlete perceptions have primarily focused on larger-team based sports such as rugby union (Francis & Jones, 2014; Kraak et al., 2018; Middlemas et al., 2018; Painczyk et al., 2017) and football (Groom & Cushion, 2004; Groom & Cushion, 2005; Reeves & Roberts, 2013; Wright et al., 2013). However, some studies have also incorporated multi-sport (Bampouras et al., 2012; Martin et al., 2018; Wright et al., 2012) and individual-sport (Butterworth et al., 2012; Mooney et al., 2016) demographics, thus providing a wider insight into the perceptions and utilisation of performance analysis within applied practice.

Groom and Cushion (2004) utilised semi-structured interviews to investigate: usefulness, learning, reflection, timing, and mental aspects of video-based performance analysis. The conclusions drawn included that performance analysis; 1) aided in performance recollection and provided a view often reserved for coaches, 2) developed game understanding and encouraged player self-critique, 3) provided the chance to reflect without emotions, 4) sessions were initially too long but became more efficient over time and 5) improved player confidence (Francis & Jones, 2014 made similar inferences). Wright et al. (2012) extended upon this work, incorporating a greater number of coaches within a wider variety of sports (rugby, hockey, football and basketball), with the

overriding aim of understanding the use of performance analysis tools by coaches within various high-performance environments. Wright et al. (2012) used a closed online questionnaire via an online survey site and identified that 68% of coaches had access to video after every game, whilst 39% received written reports. Furthermore, nearly 50% of coaches stated their 'gut instinct' impacted upon variable selection. Overall, the results provided insight into how and when coaches provide feedback via performance analysis whilst demonstrating the impact upon their weekly coaching practice. The use of qualitative methods enabled a richer understanding of an individual's experiences regarding their use of performance analysis to be achieved. Such methodologies have been reflected upon positively and have been suggested as an important tool within the further exploration of practice within the applied environment (Nelson, Potrac & Groom, 2011; Wright et al., 2016).

Coaches within previous research have stated their coaching philosophy significantly impacts upon analysis direction (Kraak, et al., 2018; Mooney et al., 2016; Wright et al., 2012). Furthermore, Butterworth et al. (2012) suggested that coaching philosophy was a potential reason for the elder participants not embracing performance analysis as a tool within their coaching practice (badminton). To substantiate this, Butterworth et al. (2012) suggested that their coaching journey and therefore philosophy pre-dated the prevalent use of performance analysis within badminton prior to the introduction of a system by Downey (1973). Various studies (e.g. Kraak et al., 2018; Martin et al., 2018; Mooney et al., 2016; Wright et al., 2012) highlighted time (availability and time to complete analysis) as a significant constraint upon feedback provision. Video was deemed the most important element within practice by coaches (Kraak et al., 2018; Martin et al., 2018; Wright et al., 2012). This observation may also suggest that video plays a systematic role with their coaching. Moreover, video is very accessible and easy to

use, which was subsequently identified by Mooney et al. (2016) as the most important user requirement of tools incorporated within coaching. Wright et al. (2012) stated that coaches delivered feedback either the same or following day within sessions generally lasting less than 20 minutes; however, the analysts working within the environment and not the coaches themselves provided this.

Overall, there is a lack of research concerning the views of elite coaches towards performance analysis from an Olympic and Paralympic sports perspective, more specifically, what coaches' value from the performance analysis and feedback service. Therefore, a clear gap exists between research knowledge and applied practice. Furthermore, developing an understanding of how these services could be implemented more effectively to further benefit the coaching process is a considerable opportunity for applied practitioners. Therefore, the aims of this study are to survey elite coaches within Olympic and Paralympic sport to 1) identify what coaches' value within performance analysis, 2) understand how coaches utilise performance analysis and feedback within applied practice and 3) investigate the difference, if any, between experienced and inexperienced performance analysis users.

4.3 Methods

4.3.1 Participants

Eighteen coaches (coaching experience 16.1 ± 7.4; experience using performance analysis 8.3 ± 4.8 years) working within Great Britain (GBR) Olympic/Paralympic sport had been actively using performance analysis within their coaching for 8.3 ± 4.8 years. The participants were split into two groups based upon their experience using performance analysis (see Table 4.1 for distribution) in order to ascertain whether experience impacted upon 1) the needs and demands of the coach or 2) the coaches' level of awareness

regarding externally impacting factors. Great Britain (GBR) can be regarded as one of the top Olympic/Paralympic nations and consistently ranks towards the top of the medal table (top 5). Ethical approval for the study was gained from Middlesex University's ethics committee.

Table 4.1. Distribution of coaches within the two groups of experience using performance analysis

Sport Type	Experienced (8+ years)	Inexperienced (< 8 years)
Olympic	13 ± 3.1 (6)	4.5 ± 2.2 (7)
Paralympic	10.7 ± 0.9 (3)	3.5 ± 0.5 (2)
Total	12.2 ± 2.8 (9)	4.3 ± 2.0 (9)

Key: Mean ± SD. Parentheses illustrate absolute number of coaches.

4.3.2 Questionnaire design

Questions were themed around the current research regarding, 1) coaches' engagement with performance analysis (Wright, et al., 2012) and 2) the main themes identified within an earlier study on the analyst's use and implementation of performance analysis and feedback (Study 1). The lead researcher formulated an extensive list of questions, which was condensed/reworded to avoid similar questions being forwarded to review. Two-experienced practitioners and academics reviewed and provided critical reflection upon question wording, clarity, and response categories (Gratton & Jones, 2010). Following review, modifications to the wording of certain questions took place to enhance clarity. The final questionnaire incorporated 16 questions including three main sections, 1) demographics, 2) feedback structure, and 3) analysis provision and the influencing factors

(Appendix 4). Likert scales (All the time = 5, Often = 4, Sometimes = 3, Rarely = 2, and Never = 1) were used to facilitate cross-sport comparison.

4.3.3 Procedure and data analysis

The survey was completed within January/February 2017 at a time suitable to the coach via the online site, Survey Monkey (www.surveymonkey.com) in a similar manner to Wright et al. (2012). Participants took 28.7 ± 22.4 minutes to complete the survey. All responses were imported into Excel and collated as frequency counts and percentages in relation to the response category and Likert scale. Median Likert score values were presented where appropriate. Statistical analysis was carried out using SPSS (V21). All survey sub-sections demonstrated *good* to *high* reliabilities (Cronbach's α between .85 and .94; Appendix 5). The relationship between the different levels of experience using performance analysis and response was assessed using Chi-squared and Cramer's V. A significance level of .05 was used for analyses.

4.4 Results and discussion

4.4.1 Factors affecting performance analysis provision

All aspects with the exception of academic literature played a considerable role at some level within how the coaches directed the provision of performance analysis (Figure 4.1). The main factor that influenced analysis direction was training goals (83%), followed by coaching philosophy/experience (72%) and athlete interaction (72%). The experienced participants felt other coaches and the athletes they were coaching had a greater impact within directing analysis provision than their less experienced counterparts. In addition, when sporting group was considered (Combat, Timed, Individual, and Team), coaches tended to agree on the factors that affected analysis direction, however, a few key

differences were evident. For example, all coaches from team sports reported the period within season only sometimes impacted direction, however > 75% of coaches within combat, timed, and individual reported this impacted direction often. For further comparison regarding the main sport groups analysed, see appendix 7.1.

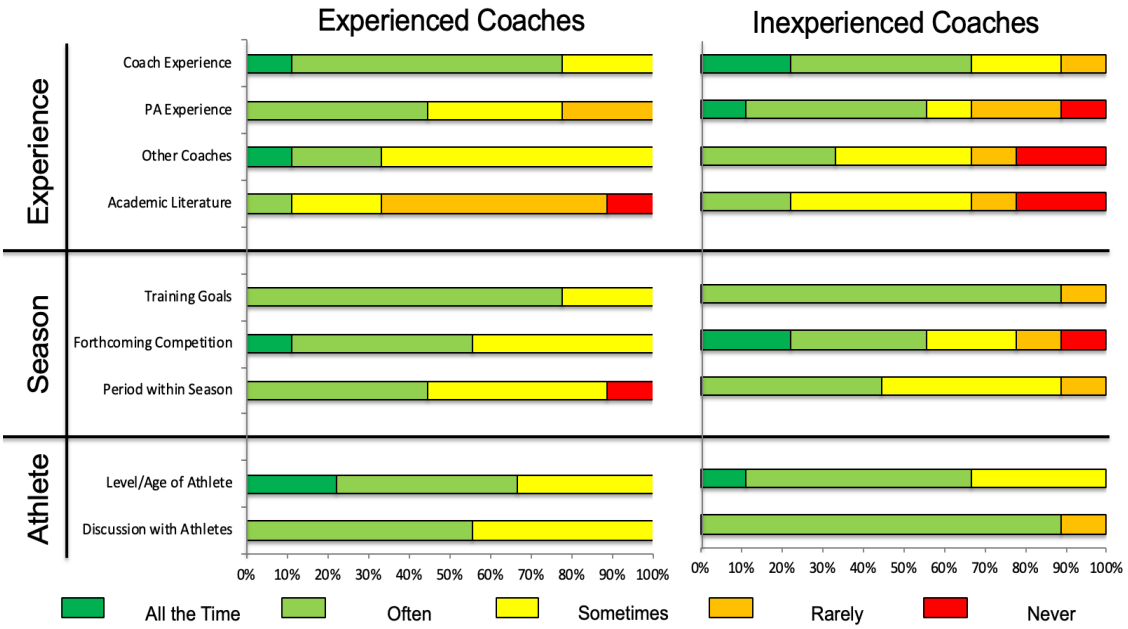

Figure 4.1. Factors influencing analysis direction.

These results were, in part, similar to Wright et al. (91%; 2012), Kraak et al. (64%; 2018) and Mooney et al. (~ 60%; 2016) with coaching philosophy being identified as the main influence. However, the other main factors highlighted by the coaches played little influence within Wright et al. (2012) whereby 'training emphasis that week' (training goals) and 'player discussion/feedback' (athlete interaction) influenced direction 5% of the time. The greater influence of training goals and athlete interaction potentially infers the utilisation of a more athlete centred approach within Olympic sport. However, in contrast, despite being considered an Olympic sport, the swimming coaches within Mooney et al. (2016) inferred a coach-centred approach by virtue of the importance of discussions with other coaches (~ 45%) as the next significant factor.

The majority of sports investigated were individual in nature, potentially allowing athlete centred approaches to be employed far more easily. These approaches have the overriding aim of more effectively meeting specific requirements, whilst enabling the athlete to 'learn through their own mistakes and take ownership of the process' (Groom et al., 2011). For example, What it Takes to Win (WITTW) within a woman's canoe single (C1W) class is arguably different to a man's kayak single (K1M) despite being under the same sporting umbrella (i.e. Canoe Slalom) and may therefore require tailored or athlete centred analysis. Furthermore, evidence from athlete development research has illustrated a more athlete centred approach to be effective within the fostering of elite athletes and decision-makers (Kidman, 2010; Potrac, Brewer, Jones, Armour & Hoff, 2000).

A similar pattern was observed between the two main sports invited to participate (i.e. combat and racing) across the majority of response categories; however, a number of pronounced differences were identified. Forthcoming competition was far less of an influence within the racing sub-group (racing: 63%; combat: 85% for the majority of the time and above response categories), which may be a result of the sports competitive structure. More specifically, racing sport athletes are often only required to produce the fastest time to achieve victory. Whereas in contrast, athletes within combat sports are required to compete directly against their opponent in order to score points; therefore, forthcoming competition (who the opponent is) is likely to have a far greater impact upon tactical strategies.

4.4.2 Factors affecting feedback provision

The main constraints highlighted as impacting feedback provision were time (time available – 61% and time to complete analysis – 55%), and the quantity of feedback to deliver. The impact of time was highlighted within previous research (Kraak et al., 2018;

Martin et al., 2018; Mooney et al., 2016; Wright et al., 2012) as the main constraint upon the participant's ability to feedback. The coaches' receptiveness to performance analysis and feedback was identified as the least impactful factor, which potentially highlights the buy-in to performance analysis within the various sports. A further explanation may be that the coaches are educated within the use and process of performance analysis, and subsequently understand the benefits the discipline can bring to their coaching through enhancing recall and observation whilst providing objective evidence to support performance appraisal (Franks & Miller, 1986, Laird & Waters, 2008, Nicholls & Worsfold, 2016). Coaches with greater performance analysis experience highlighted a significantly greater impact of Other Support Staff Sessions upon feedback provision (X^2 = 10.0, df = 3, $p < .05$, Cramer's V = 0.75; Figure 4.2). The inexperienced coaches indicate they are 'Never' affected by the various factors far more than the experienced coaches. This is likley a result of the experienced coaches being more open and aware of the impacting factors that affect their feedback provision than their lesser experienced counterparts (Figure 4.2). Coaches working within individual sports tended to report that a number of the factors never affected feedback provision, whereas coaches within team sports reported that each of the factors impacted upon feedback provision to some degree. A greater concern over information reliability was identified within the timed sports group. The success within timed sports can often be decided by tenths, even thousandths of a second, therefore placing a greater 'perceived' emphasis upon reliable information when analysing and reviewing performance. For further comparison regarding the main sport groups analysed, see appendix 7.2.

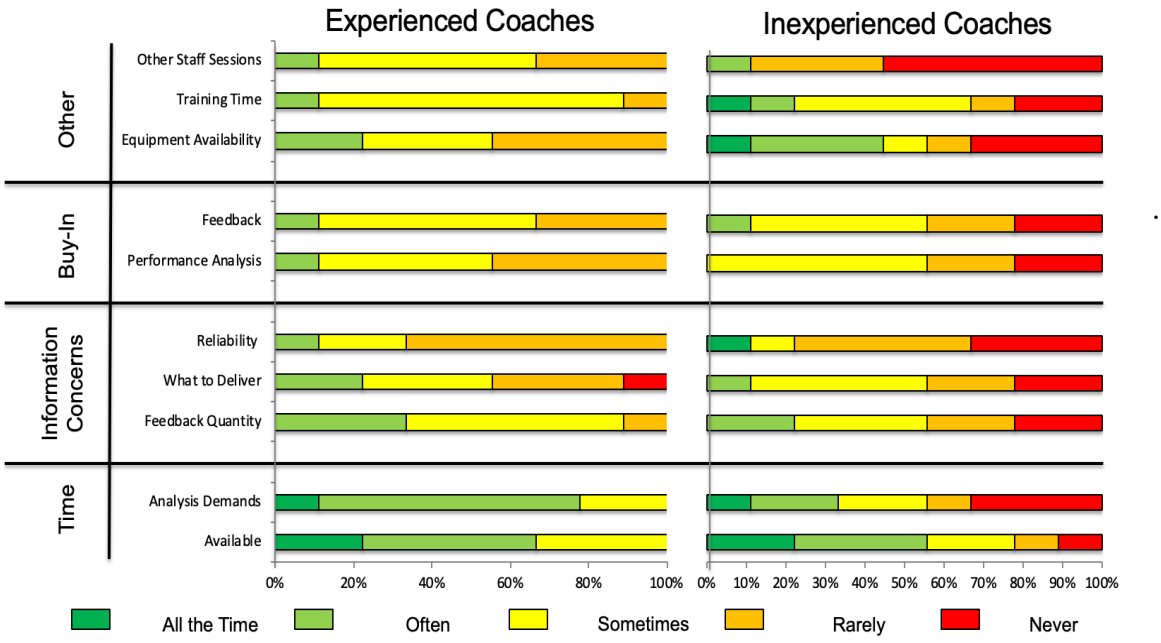

Figure 4.2. Factors affecting feedback provision.

4.4.3 Elements of performance analysis provided

The most popular areas the coaches would like to be provided were video post-performance (Competition – 4; Training – 4) and video during-performance (Competition – 4; Training – 3). Video was deemed considerably more important to receive on a regular basis post-performance in comparison to data, with post-video and during-performance video highlighted as the standout responses (Figure 4.3). Similar findings were observed within Wright et al. (9/10; 2012) and Martin et al. (7/9; 2018) where the majority of top responses included a variation of video (e.g. video of full game, video of opposition). The clear favour of video is not surprising given its simplicity, versatility, and ease of access, whereby the coach only requires a handheld camera to effectively implement such a technique within their practice. Participant 11 summarised the benefits and impact simple video review can have within practice stating '[Video] allows the athletes to see how they have performed and how they may perform the skill next time'. Consequently, video

presents a visual reminder of what happened, allows multiple replays, provides a model to help replicate best practice or avoid poor technique within future performance, and facilitates understanding towards 'why' and 'how' performance occurred (O'Donoghue, 2015). The benefits of video modelling upon future performance have been highlighted within a vast number of studies, for example, Guadagnoli et al. (2002), Baudry et al. (2006), and Boyer et al. (2009) within golf and gymnastics respectively.

The specific elements desired regularly by the coaches were: 1) full video of competitive performance (77%) or edited video of training performance (50%), 2) performance reports (55%), and 3) trend analysis (44%). The inexperienced coaches demonstrated limited value in full video, performance reports, and live coding within training, whereas this was observed for opposition strengths/weakness information within the experienced coaches responses (Figure 4.3). Over three-quarters of all coaches made use of video regularly, demonstrating an ingrained use and considerable engagement towards video. Furthermore, inline with Wright et al. (2012) and Martin et al. (2018) this might also suggest that the use of video plays a systematic role within their coaching. Moreover, it is clear that data in the form of reports or performance trend analysis plays a vital role within a large proportion of the coaches surveyed. Consequently, the aspiring analyst would be prudent to develop a good knowledge and practical understanding of the techniques required to successfully investigate trends and significantly explore data beyond the descriptives within their potential working environment. Whilst some sports favour video feedback over data and vice-versa, it is apparent that focusing too heavily on either analysis process would likely limit their effectiveness as a practitioner within current and future working environments. In addition, when sporting group was considered (Combat, Timed, Individual, and Team), coaches reported the type of performance analysis provided differed dependent upon the sport worked for. For example, all coaches within

team sports stated they often used competition reports, however all coaches within individual sports reported that they never used these. Similarly, all team sport coaches made use of full video sequences, however > 80% of individual and combat sports coaches never used full video sequences. For further comparison regarding the main sport groups analysed, see appendix 7.3.

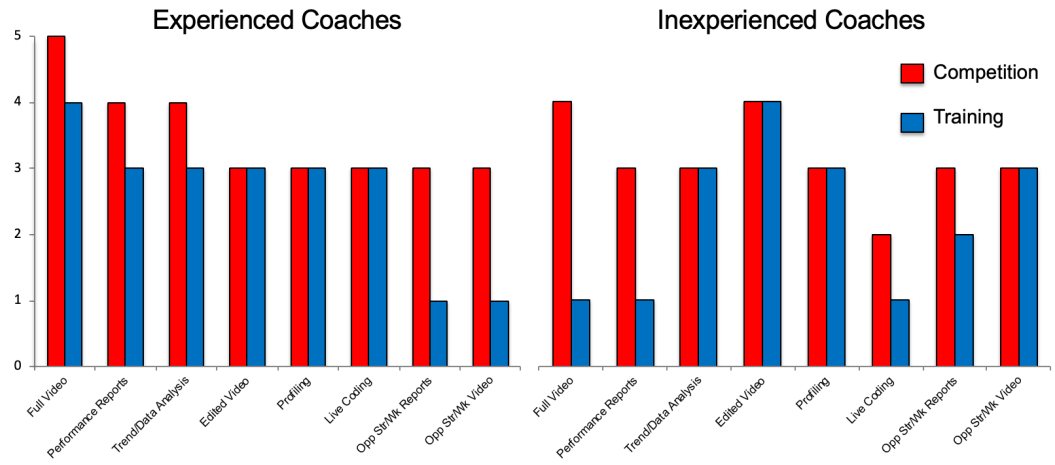

Figure 4.3. Type of performance analysis provided.

4.4.4 Feedback timescale, session length and session balance

Feedback was preferred to be given either < 1 hour after the event or the next day and beyond for both competition and training, which mirrored Wright et al. (2012). McArdle et al. (2010) also argued that it was not uncommon for coaches to utilise more immediate feedback because they felt this was the point at which the athlete's recall was at its clearest. Furthermore, a slightly greater desire to provide feedback within an hour following a training session was identified. The majority of coaches (77.8%) with greater experience provided feedback more consistently (i.e. All the time or Often) within 1-hour of competition than their less experienced counterparts (22.2%; $X^2 = 10.0$, df = 4, $p < .05$, Cramer's V = 0.75). Furthermore, 44.4% of the inexperienced group 'Never' provided

feedback within 1-hour (Experienced = 0%). These coaches provided a few examples to support why they felt providing feedback within 1-hour was important, for example,

> Participant 15: Clarity of message can be lost when too long is taken and also quite often can create too many things for an athlete to think about.
>
> Participant 17: Needs to be fresh in mind. However this can vary with emotional state of paddlers – especially mindful in competition, where this becomes the most important variable (i.e. acceptance of data) rather than the availability of data/video)

The coaches highlight a number of key points, namely maintaining the balance between the time elapsed following performance and amount of feedback required to achieve an accurate, impactful but 'fresh in mind' message. Keeping the performance 'fresh in [the] mind' enables the athlete to more easily visualise their performance through mental imagery, which was highlighted by Cumming and Hall (2002) as a highly relevant and effective tool within improving performance. Furthermore, Cumming and Hall (2002) highlighted athletes of a higher standard reported using more imagery surrounding their performance, whilst Hall (2001) suggested that imagery for the rehearsal of skills should be given similar importance to physical practice (for a review, see Cumming & Ramsey, 2009). Therefore, facilitating the development of effective imagery techniques through deliberate practice could be considered a key coaching tool within performance preparation, execution and review. Notably however, participant 17 made reference to athlete emotional state post-performance suggesting the athlete may not wish to engage within or accept feedback they are provided following a poor performance. Therefore, within such situations, feedback should potentially be delayed in an attempt to remove the emotion surrounding the performance and ultimately, promote a greater degree of objectivity and effective self-reflection (McArdle et al., 2010). Furthermore, Carson (2008) stated that information generated by performance analysis should be utilised as a tool to

facilitate more effective self-reflection. The various factors raised highlight that a standard approach regarding the point at which feedback is provided may not be effective in all situations (Wright et al., 2016).

A considerable proportion of participants (65%) favoured feedback sessions lasting less than 20 minutes, which mirrored the professional environment analysts of Wright et al (2013). Unfortunately, coaches within Wright et al.'s study (2012) were not questioned upon the duration of the feedback sessions they provided to their athletes. Furthermore, sessions were delivered with a balanced (66%) or mostly positive approach (61%) all the time or often. Coaches with less experience delivered significantly more mostly positive feedback sessions ($X^2 = 8.4$, df = 3, $p < .05$, Cramer's V = 0.38). However, this was only the participant's perceptions of their delivery and not a direct observation itself, thus a potential difference between perception and actual delivery is acknowledged. Over 88% of the less experienced group felt this should be the primary approach, whereas the experienced group demonstrated a more varied response. Negative approaches (mostly negative and always negative) were rarely used. Groom and Cushion (2005) suggested, although arguably context dependent and not to be considered 'gold standard', that a balanced approach of 1:1 with a greater focus upon positive instances if the recipient was struggling for form or confidence should be used. Viciana, Cervello and Ramirez-Lechuga (2007) echoed Groom and Cushion (2005) further suggesting players receiving positive and negative feedback demonstrated lower levels of boredom and higher scores of enjoyment. Furthermore, Hoigaard, Safvenbom and Tonnessen (2006) stated that if positive instances were always shown then the player(s) might begin to believe they did not need to improve and thus, start to idle in training and matches negatively affecting performance.

Over half of the coaches stated they made use of 60-80% of the information they were provided by their analyst, with 21% stating they utilised < 50%. Clearly a vast amount of information is not incorporated into feedback sessions by the coaches. In addition, Middlemas et al. (2018) identified only limited information (< 20%) generated by the performance analysis process was incorporated into the player's formal feedback sessions. This may appear concerning to the applied practitioner due to the large amount of work undertaken yet ultimately absent within feedback. Arguably however, the performance analyst has access to a vast amount of information via various sources that incorporating 100% of the information within a feedback session would likely cause, 1) information overload, 2) the session to last significantly longer and 3) athlete confusion/lack of clarity within the 'take-home messages'.

Overall, both groups of coaches demonstrated a similar pattern within their preferred feedback delivery structure (Figure 4.4). Specifically, coaches desired feedback to be delivered in a consistent manner (type, layout, content; 61%), face-to-face (88%), and within an individual format (55%) all the time or often. Sessions were generally coach led, however, participants demonstrated considerable value in a combined and/or analyst led approach at certain instances. The order of information delivery slightly favoured video followed by data, however, sometimes was the main Likert scale response provided (Figure 4.4). These findings begin to demonstrate the general feedback approaches used by coaches with their athletes, whilst also highlighting that a 'one-size fits all' approach may not be optimal within all situations. A number of other variables may likely impact upon these decisions (e.g. athlete personality, type of performance reviewed, result of performance being reviewed), and thus understanding the athlete in greater detail or having an effective coach-athlete relationship will likely help unearth what type of feedback should be used in what situation with each specific athlete. When sport type was

considered Timed, Individual, Combat, and Team) a similar pattern of delivery structure remained. For further comparison regarding the main sport groups analysed (Combat, Timed, Team, and Individual) see appendix 7.4.

Figure 4.4. Feedback delivery structure.

4.5 Conclusion

The results demonstrate that a wide spectrum of performance analysis and feedback techniques are utilised by coaches working within Olympic/Paralympic sport; however, significant and consistent themes emerged throughout. The main factor that influenced analysis direction was training goals, followed by coaching philosophy/experience and athlete interaction. In addition, the experienced coaches consciously acknowledged that other coaches and the views of the athletes they were coaching had an impact upon direction. Consequently, the development of effective coach-analyst relationships appears key to translating philosophy and the ever-changing training goals into measurable variables, to ultimately maintain impactful support moving forward. The lack of time was

outlined as the most significant constraint impacting upon feedback provision, with the experienced coaches outlining that time taken to complete the required analysis considerably impacted upon their ability to feedback. Unfortunately, however, it is not known whether feedback would be more effective if this barrier was reduced in some way. Furthermore, coaches with greater experience (> 8 years) delivered a significantly greater number of feedback sessions within 1-hour post performance in comparison to their less-experienced counterparts (< 8 years). The coaches' desire to use more immediate and terminal feedback is, knowingly or unknowingly, positively evidenced by the findings observed within the movement and feedback literature (Guadagnoli et al., 2002). Experienced coaches favoured a balanced approach to feedback, whereas 88% of the less experienced group were in favour of mostly positive feedback sessions. Feedback sessions lasting < 20-minutes were generally employed; however, the athlete's emotional state was a key factor within the overall design.

The findings have implications for practitioners by identifying the key areas coaches' value from the performance analysis service. This should help practitioners and educators' target/design appropriate educational support to more effectively prepare their practice for many of the demands highlighted within applied support. Future case study approaches appear useful to help further understand the individual delivery by specific coaches and/or sports within applied practice. Comparative studies between: 1) coach and analyst, and 2) successful Olympic/Paralympic nations may also provide further useful information. In addition, quantifying the impact of different performance analysis or feedback methods, and/or investigating the evolution of performance over time, taking into account a number of confounding variables (e.g. opposition quality, home/away etc.) may offer further insight into the overall effectiveness of the performance analysis process.

Chapter 5: Study 3

Coach and analyst viewpoints of performance analysis practice within Olympic and Paralympic sports

5.1 Abstract

The concordance between 18 coaches (mean performance analysis experience: 8.3 ± 4.8 years) and 23 performance analysts (mean: 6.4 ± 4.1 years) regarding their performance analysis delivery within applied Olympic and Paralympic environments was investigated using survey-based methods. There was clear agreement on the provision, importance and need for full video. The majority of analysts (73.9%) provided profiling often or all of the time whereas only one third of coaches felt this was the required amount. Coaches agreed that coaching philosophy was the main factor directing analysis, but also emphasised that training goals, level or age of athlete and discussions with athletes were influencers, far more than the analysts realised. A potential barrier for better communication was time, highlighted by all analysts as a major factor impacting their role. The majority of analysts (87%) attempted to provide feedback to athletes within one hour of performance, often or all the time, with low (10% or less) levels of feedback provided at later times. Coaches expressed a similar philosophy but were far more likely to want to provide feedback at later times. These findings should be utilised by analysts and coaches to review practice, identify gaps within practice, and highlight areas for development.

5.2 Introduction

The primary goal of performance analysis is to provide coaches and athletes with information, via quantitative and qualitative methods, to assist decision-making and facilitate positive change in performance (O'Donoghue, 2006). As a result, performance analysis practitioners have become commonplace within elite environments and play an essential role within the coaching and feedback process. Research within performance analysis has primarily focused upon 'the method' of analysis and subsequently the information generated via such methods, e.g. profiling. For example, performance profiling deemed as a methodology analysing potential performance patterns, attempts to offer some degree of prediction for future performance (Butterworth et al., 2013; O'Donoghue, 2013). As such, the understanding and potential to predict future performance is considered a powerful tool to the coach and analyst and as a consequence, has resulted in researchers developing a number of publications surrounding method development and specific sporting trends. What currently remains unclear is how this information is incorporated within applied practice.

Recently some studies have investigated how feedback and performance analysis is used within applied practice by the coach, performance analyst, athlete, or a combination of them (Francis & Jones, 2014; Groom et al., 2011; Martin et al., 2018; Wright et al., 2012; Wright et al., 2013). These studies have taken a qualitative approach, in an attempt to more effectively uncover the various complexities inherent within applied delivery, through the use of interviews and questionnaires (see Groom et al., 2011). The main factors found to influence feedback and the use of performance analysis included, coaches' philosophy, time to carry out analysis and provide feedback, athlete interaction and training goals. Full video has been identified as the main deliverable by performance analysts, to coaches and athletes within applied practice (Martin et al., 2018; Wright et al.,

2012). This approach has strengths and weaknesses which need to be managed to enable effective impact. For example, no additional time or processing capacity is required, and the analyst can simply record the performance of interest and deliver easily e.g. via USB or online (O'Donoghue, 2006). All contextual information is retained, since no cropping of video deemed insignificant by the analyst takes place. Thus, a coach can view a number of seconds or minutes prior to a key incident to help establish why or what contributed to the incident/outcome (O'Donoghue, 2006). The full video can include a large amount of 'dead space', particularly in some team sports such as rugby where ball in play is approximately 44% of overall match time (World Rugby, 2015). To counter this, various analysis software packages, e.g. Dartfish (Dartfish, Fribourg, Switzerland) and SportsCode (Hudl, Nebraska, USA), provide the ability to time stamp a video in multiple places using adaptable tagging panels, usually according to a team or coach's analysis philosophy, such that key performance indicators (KPIs) can be viewed easily. The caveat of this efficiency lies in the potential for event selection bias as well as the need for the analyst to have sufficient game understanding to direct the software to accurately read, organise and report the information of interest. This usually requires a knowledge and ability to write computer code as well as use video editing software to present and highlight performances of interest.

Whilst the role of the analyst may primarily lie in the delivery of the information to the feedback session, studies have also investigated the feedback session itself. For example, the most common duration of feedback sessions has been identified (0-20 minutes – 53%, Wright et al., 2013 and 30-40 minutes – 70%, Groom & Cushion, 2005). Coaches play a significant role within this feedback process whilst generally controlling the selection and delivery of information; for example, 73% of analysts within Wright et al. (2013) stated their coach led feedback sessions. Research has also suggested that

coaches adapt their feedback approach to account for a multitude of variables, such as, performance outcome (positive/negative), future performance schedule (competition/training), venue/feedback environment and type of athlete/group of athletes (personality, relationship, dynamics). In light of these variables, the coach must develop an appropriate feedback delivery strategy either: 1) immediately following performance or delayed until a later time, 2) face-to-face or online, 3) within a short or long session, and 4) using a positive, balanced, or negative approach. To assist this process, Groom et al. (2011) developed a grounded theory framework consisting of three main categories (contextual factors, delivery approach, and targeted outcome) as well as sub-categories. For example, if the goal was to elicit a change in an individual's game related technical performance (contextual factor) the coach might select the most appropriate delivery approach. This might include a number of positive and negative examples of the athlete's performance whilst making comparison to an elite performance.

Whilst limited studies have highlighted the factors associated with suggested effective feedback from coach, athlete and analyst perspectives in a cross section of sports (Martin et al., 2018; Middlemas et al., 2018; Wright and colleagues, 2012; 2013, 2016), there still exists a clear need to explore the degree of congruency between coach and analyst within elite sport, essentially highlighting if and where potential adaptations could be made within current practice to ensure the needs of the coach are fully and consistently met. It may be argued that a coach led analysis approach should provide such a consistent and aligned performance analysis programme, however this is often not the case. For example, how much of the performance analysis support, delivered by performance analysts, is aligned with the needs of the coach? The purpose of this study, therefore, was to investigate the concordance between elite analysts and coaches regarding the use of performance analysis and feedback within Olympic and Paralympic sports.

5.3 Methods

5.3.1 Participants

Forty-one participants working in high-performance sport participated within the study. Thirty-five per cent of participants had < 5 years experience, 32% had 5-10 years, and 32% had 10+ years experience using or delivering performance analysis within their practice respectively. Participants were split into two groups, coaches (n=18, mean performance analysis experience: 8.3 ± 4.8 years) and performance analysts (n=23, mean performance analysis experience: 6.4 ± 4.1 years). Ethical approval for the study was gained from Middlesex University's ethics committee.

5.3.2 Survey design

Questions to be used within the survey were themed on current research regarding: 1) coaches' engagement and use of performance analysis (Kraak et al., 2018; Painczyk et al., 2017; Martin et al., 2018; Wright et al., 2012) and 2) analyst's use and implementation of performance analysis (Wright et al., 2013). The exhaustive list of questions, from the research referenced here, was condensed by removing similar questions and amended to better fit the target demographic and study aims. Two-experienced practitioners and the research team reviewed and provided critical reflection upon question wording, clarity and response categories (Gratton & Jones, 2010). The final survey consisted of 16 closed questions (with additional text box to allow more detailed responses) with three main sections: 1) feedback structure, 2) analysis provision and 3) influencing factors. Likert scales (All the time, Often, Sometimes, Rarely, and Never) were used to facilitate cross-sport comparison.

5.3.3 Procedure and data analysis

The survey was completed between June 2016 and June 2017 at a time suitable to the participant either in person or via the online site, Survey Monkey (www.surveymonkey.com) in a similar manner to previous research (Francis & Jones, 2014; Painczyk et al., 2017; Wright et al., 2012; Wright et al., 2013). All responses were imported into Excel and collated as frequency counts and expressed as percentages in relation to the response category and Likert scale. Median Likert score values were presented where appropriate. Statistical analysis was carried out using SPSS (V21). All survey sub-sections demonstrated *good* to *high* reliabilities (Cronbach's α between .85 and .94).

5.4 Results and discussion

The aspects of performance analysis provided by the analysts were similar to the requirements of the coaches across the majority of variables with clear agreement on the provision, importance and need for full video (Figure 5.1). The main difference being that 73.9% of analysts provided profiling all of the time or often whereas only one third of coaches felt this was the required amount. This discrepancy suggests the need to better understand 1) why coaches use, and do not use, profiling, 2) whether coaches' understanding of profiling differs from analysts' and 3) were the analysts always providing the profiles their coaches required. Aspiring analysts, at least those studying performance analysis post-graduate courses, are usually taught the profiling techniques outlined in the introduction (Hughes et al., 2001; James et al., 2005; O'Donoghue, 2005). Whilst the specific profiling techniques were not discerned in this study further exploration is needed to determine whether the techniques are, as taught at universities or fit for purpose. Mackenzie and Cushion (2013) argued that much performance analysis research in football

failed to address the needs of practitioners, with little evidence to demonstrate how findings were applicable to coaching practice. This limited transferability produced what they called a 'theory-practice' gap between academically identified findings and the specific contexts found within an applied environment. More specifically, a large proportion of academic research fails to investigate problems found within an applied environment or similarly fails to incorporate elite athletes within these studies. This theory-practice gap may similarly apply to the current profiling techniques taught in universities and those used within the Olympic and Paralympic teams sampled here.

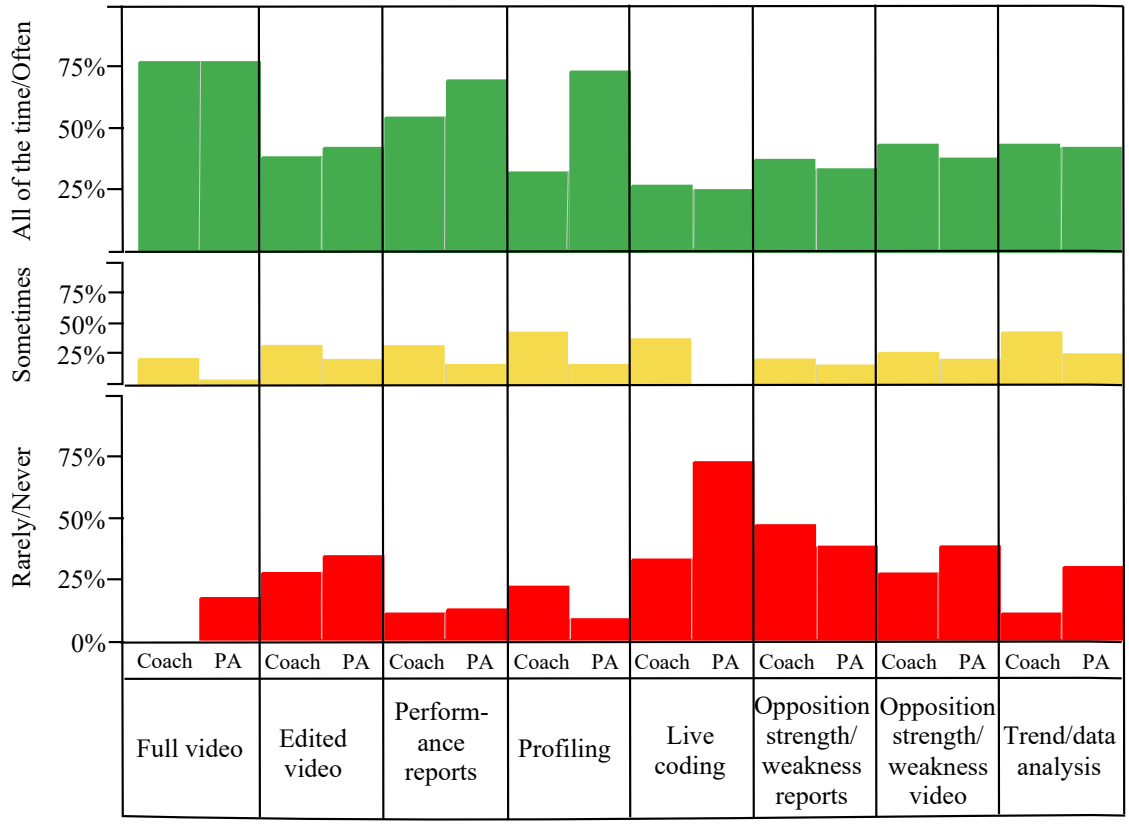

Figure 5.1: Comparison of the aspects of performance analysis provided or desired by the analysts and coaches

There was a discrepancy between coaches' desire to receive live coding (77.8% wanted this at least sometimes) and analysts providing this (60.9% never did; Figure 5.1). This may be explained by the inability to provide live output during performance. Many competitions restrict or prevent communications to the coach e.g. in Judo "it is strictly

prohibited for the coach to communicate from the field of play with other persons during the entire contest period" (International Judo Federation: Sport and Organisation Rules, 2018, page 49, section 7.1). Other events do not provide or allow an appropriate infrastructure to enable live analysis. However, it is also possible that the skill set of an analyst or a lack of functionality of the software may be the cause of the lack of provision.

Performance analysts tended to think that coaching philosophy (Figure 5.2) was the main factor directing analysis provision, concurring with the findings of Wright et al. (2012) and Mooney et al. (2016). Whilst coaches were of a similar opinion, they also emphasised the role that training goals, level or age of athlete and discussions with athletes influenced the analysis direction far more than the analysts realised (Figure 5.2). Similarly, coaches most often (94.4%) reflected that the analysis was Sometimes influenced by specific demands determined by the time of the playing season which was something far fewer analysts (69.6%) realised.

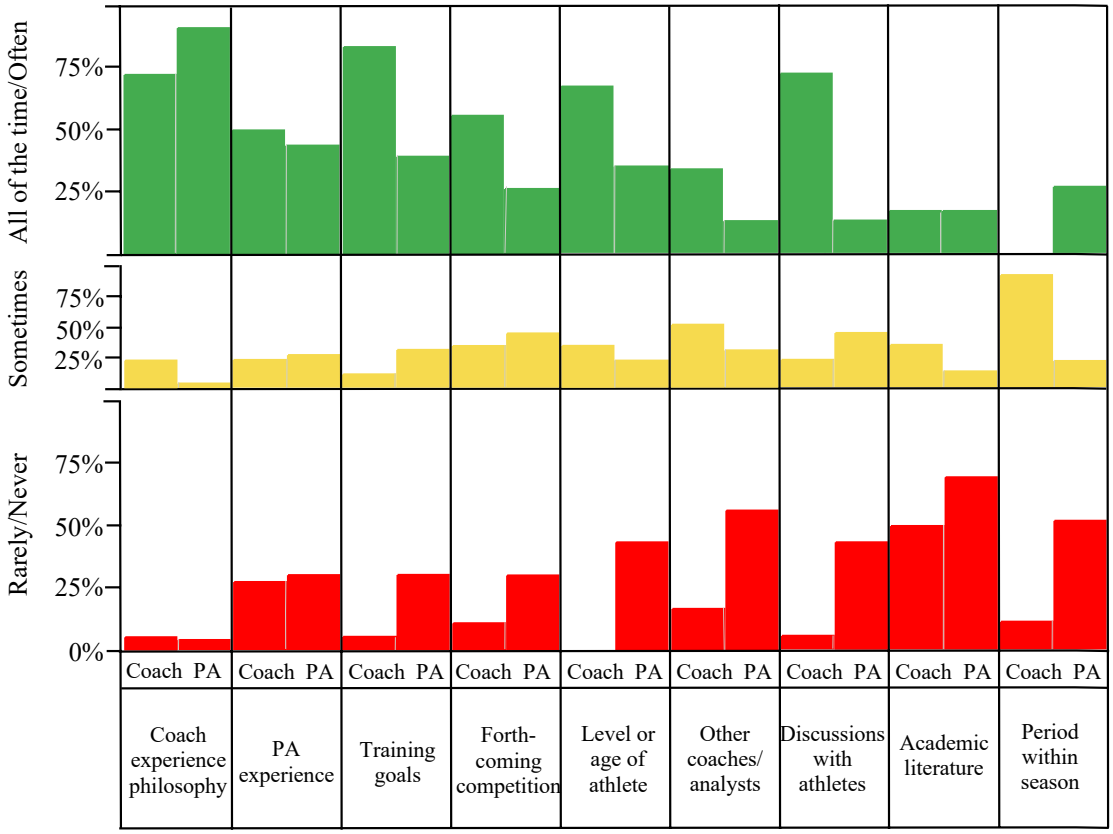

Figure 5.2: Comparison of the factors affecting performance analysis direction

These incongruences are most probably a consequence of a lack of communication, with coaches perhaps thinking it unnecessary to inform analysts of these decisions. However, better communication regarding these issues may facilitate better clarity of training goals for the analyst and hence the possibility of more targeted analysis in line with the coaches' goals. Shared knowledge and understanding between coach and analyst has been argued as critical for ensuring effective practice (Groom & Cushion, 2004; Kuper, 2012; Wright et al., 2013). Conversely, Wright et al. (2012) and Martin et al. (2018) found that the majority of coaches (93% and 60% respectively) indicated that information received from performance analysis support informed their short-term planning. It would seem, therefore, that many coaches value the analysis support but do not recognise a need to include the analyst in decisions regarding planning. This may be

perceived to be the sole remit of a coach but a more adaptable and responsive approach to analysis may well positively impact on planning decisions, particularly in terms of providing evidence for performance changes over time. A potential barrier for this cooperation was time, highlighted by all analysts as a major factor impacting their role. The majority of analysts (87%) stated they attempted to provide feedback to athletes within one hour of performance often, or all the time (Figure 5.3), with low (10% or less) levels of feedback provided at later times. Coaches expressed a similar philosophy but were far more likely to desire providing feedback at later times. The extent of this disparity adds weight to the previous finding that a lack of communication between coach and analyst occurs in some Olympic and Paralympic sports. In terms of when feedback should be given, differences of opinion still exist. For example, McArdle et al. (2010) suggested it was not uncommon for coaches to utilise immediate feedback as coaches often feel this is when the athlete's recall is most clear. However, the authors also suggested that delayed feedback may positively remove emotion from the athlete and thus facilitate a greater degree of objectivity and self-reflection. A consistent regime of feedback, in this case less than an hour post performance, could be an optimal strategy, although athletes may not be able to receive feedback during competition when other tasks need to be achieved. Some coaches expressed a desire to move towards a more varied approach to feedback, with the aim of developing critical thinkers and independent learners who can respond more effectively to their opponent's decisions and performance without external input.

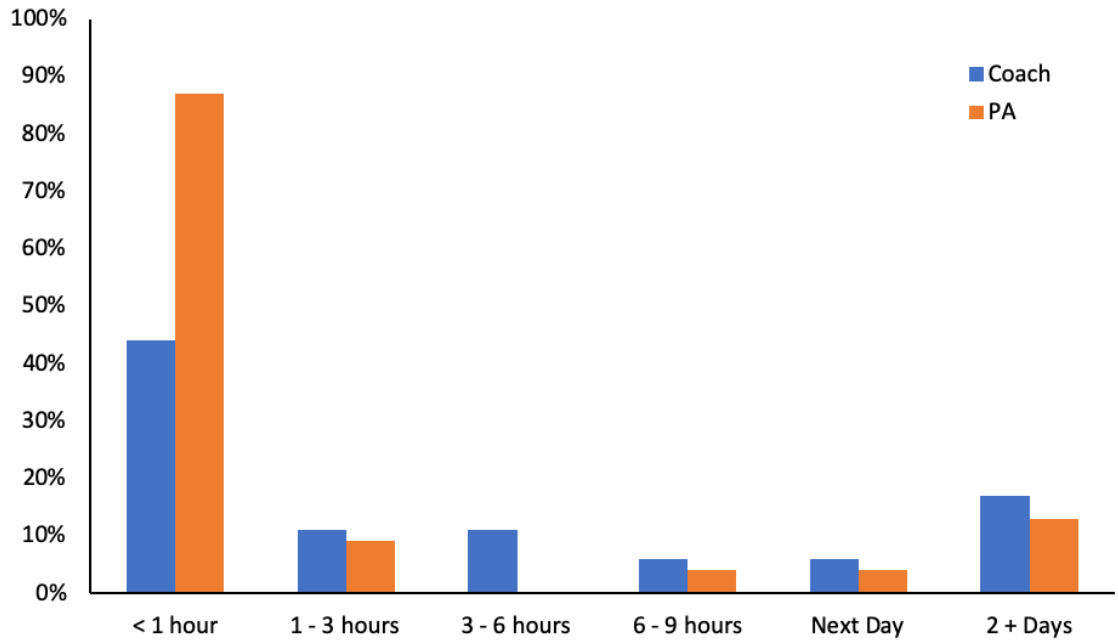

Figure 5.3: Feedback point following performance for Sometimes and above Likert response

5.5 Conclusion

This study has clearly demonstrated coach and analyst agreements on the provision of performance analysis in Olympic and Paralympic sports. Whilst this is not unexpected given the extent to which performance analysis provision is now prevalent, the details of the agreements and disagreements provides useful guidance for improving this aspect of applied sports science support. The importance and need for full video recordings were evident with stronger support from the coaches compared to the analysts. Some disparity existed for the provision of profiling with uncertainty regarding whether coaches and analysts agreed on what this entails, what methods were being used by analysts and whether these techniques were, as taught at universities, or fit for purpose. Many coaches valued the analysis support, but some did not seem to recognise a need to include the analyst in some decisions regarding planning training sessions. Whilst good communications between coach and analyst would seem an obvious positive goal, some coaches may perceive, perhaps correctly on occasion, that some decision-making is the sole remit of the coach. However, a more adaptable and responsive approach to analysis by

a coach, may well positively impact on planning decisions, particularly in terms of providing evidence for performance changes over time. This is more likely in an environment where time is made available for coach analyst discussion, time being highlighted by all analysts as a major impediment. Coaches and analysts expressed a similar philosophy with regard to when to provide feedback although coaches were far more likely to wish to provide feedback at later times.

The surveys should be utilised by analysts and coaches to help facilitate reviewing practice within their respective sport, identify gaps within practice and highlight areas for potential development, i.e. where can the sport align more effectively. Whilst the findings were derived from Olympic and Paralympic sports, the findings may be applicable to all other sports. Of course, there will be examples of sports where they have addressed these issues and coach analyst relationships that are better developed than evidenced here. However, even at the elite level of sport, clear messages and dissonance within coaching staff was evident. Future work should endeavour to investigate a single sport, analyst team and coaching group with a longitudinal focus across a season or performance cycle e.g. 4-year Olympic period, whilst making use of a combination of qualitative approaches including observation, informal conversations, reflective researcher notes, and formal one-to-one or group interviews/sessions. This research avenue would aim to identify whether, by how much, and why, the process of performance analysis and feedback changes throughout the course of a season. How much is reactively changed based on results or the next opponent? Are there specific points throughout a season where process is reviewed and changed? Or do coaches rigidly stick to the process outlined at the onset of the season? Moreover, extensions could be made to include academy and elite level environments to gain an understanding of the development versus performance outlook and its effect upon the performance-analysis-feedback process. Ultimately, such research should aim to

understand the: 1) interactions between coach and analyst, 2) changes in performance analysis delivery and 3) evolution of the feedback cycle based upon results, period within the season, and overall performance goals.

Chapter 6: General Discussion

6.1 – Summary of the thesis

This thesis aimed to better understand the use of performance analysis and feedback within elite Olympic and Paralympic sport from the perspective of key users within the applied environment, i.e. the coach and the analyst, whilst further comparing and contrasting the needs and desires of both with respect to current and future practice. Whilst investigating these aims new questionnaires were developed and presented which have built upon the previous research outlined within the literature review.

During the onset of the thesis (early 2015) the literature review identified limited research (see Table 2.1) investigating the, 1) use and application of performance analysis and 2) coaches'/analysts' perceptions of performance analysis delivery and future direction within applied practice. Positively, since the thesis onset, the related research in Table 2.1 has almost doubled in size, however, the general focus upon football or rugby union performance environments still remains, with little focus being given to Olympic or Paralympic sports. Nonetheless, a key strength adopted from these research studies was the use of qualitative research methods, e.g. open and closed questions (Wright et al., 2012), thus allowing for a more personal understanding of the participants' practice. The open aspects enabled the participant to expand upon any of their answers, whilst the closed aspects facilitated the cross-comparison between participants and environments.

Chapter 3 presented how analyst's deliver performance analysis within their practice, whilst highlighting that in almost all situations it was often the coach whom ultimately delivered this feedback to the athletes, thus acting as a gatekeeper link between analysis and feedback (Bampouras et al., 2012). Analysts acknowledged that they only really delivered first hand in more 'data driven' feedback sessions. This became a key

aspect within the direction of Chapter 4, specifically, this finding highlighted the need and importance of progressing our understanding towards how coaches view and use performance analysis. This was a clear next step by virtue of the analyst's general lack of either involvement or direct feedback delivery. If this had been neglected the analyst's responses could have been viewed with reduced value as ultimately the delivery of the information could have significantly changed from analyst to coach and then coach to analyst. Such drastic change is arguably unlikely from a content perspective, i.e. what the analyst identified, but could have changed in regard of when or how it was delivered, e.g. how long after performance feedback was delivered or was the delivery face-to-face or otherwise. A further key finding identified throughout the thesis was the impact or constraint of time upon the: 1) analyst's ability to analyse information, 2) depth of analyses that could be undertaken, and 3) coach's ability to feedback at the desired point in time. The management and use of time, which was universally considered as an extremely limited resource within the thesis (and arguably applied sport more generally), is arguably a vital aspect affecting the effectiveness of performance analysis delivery.

Despite a number of publications since the initial onset of this thesis (Kraak et al., 2018; Martin et al., 2018; Middlemas et al., 2018; Mooney et al., 2018; Painczyk et al., 2017; Wright et al., 2016) a clear gap remained regarding the degree of congruency between coach and analyst. This is an important aspect to further understand for both, the academic researcher and applied practitioner, essentially highlighting if and where potential adaptations could be made within current practice to ensure the needs of the coach are fully and consistently met. It may be argued that a coach led analysis approach should provide such a consistent and aligned performance analysis programme, however this is often not the case. Specifically, this is often due to the number of other programme influences (e.g. performance director, other coaches, funding body demands) that impact

upon the analyst's role and consequently the amount of available time the analyst has to meet the coaches individual or bespoke requirements. Chapter 5 identified that deliverables such as video were consistently provided by the analysts and valued by the coach. However, despite full video being highlighted as the most prominent deliverable of performance analysis it was unclear what parts of the video the coach specifically focused upon. Did coaches pick out specific team dynamics or off the ball movements that may have been removed in an edited video? Whilst knowledge of what was focused on was unknown, it makes sense that athletes will view specific scenarios to help enhance learning in some way, potentially evidenced in future performance. For example, video-based evidence of a future opponent's preferred attacking movements may facilitate an improvement in a player's defensive capability against the targeted player.

The provision of profiling, what that entailed and how coaches perceived it was an area requiring future investigation. Coaches and analysts seemed to disagree on the value of this analysis technique on both, an overall and sporting group basis (see appendix 6.3 and 7.3). In addition, questions remained regarding the specific profiling techniques utilised, the reason(s) why coaches did not use profiling consistently and whether coaches and analysts differed in what they considered profiling is. For example, is it only considered profiling if it involves analysis on their own team, their opponents, or when identifying actions that occur regularly? Chapter 5 suggested that dissonance within coach-analyst communication was likely to exist in many applied environments, maybe evidenced by an analyst's lack of understanding of why profiling was not used or more importantly, a lack of knowledge of when profiling was not being used very much or at all. Communication between the coach and analyst is vital as if either the coach or the analyst fails to articulate what they want or are looking to provide precisely, then it becomes difficult for the analyst to provide that service or for the coach to effectively utilise this

information to benefit their coaching. As a consequence, an interpretation of what the coach wants may lead to the coach saying they do not use specific aspects of performance analysis. On the flip side of this would be the ability of the analyst to demonstrate the utility of analysis techniques unknown to the coach.

A continually effective dialogue between coach and analyst would serve to further benefit the analyst ensuring the delivery of performance analysis remains focused upon the needs and wants of coaches moving forward. Additionally, the building of trust over time, understanding the philosophy and terminology of the coaches becomes a key part of developing effective communication and relationships. In summary, the creation of positive coach-analyst relationships, the ability to translate a coach's philosophy or performance questions into analysis processes, and the management of the limited time available regarding planning, analysing, and feedback appears to be a key, yet experienced-based (i.e. not directly taught), set of 'soft skills' which need to be quickly, efficiently and firmly developed.

6.2 – Key Limitations

It is important to reflect upon the research process, specifically the limitations that were evident within the research as this process helps to better place the findings in context whilst highlighting key areas to develop and overcome within future research designs. Given the applied nature and demographic focus of the project, inevitable limitations exist regarding the potential influence of various confounding variables at each stage of study. For example, Study 1 with the performance analysts, was conducted early 2016 which preceded the Olympic and Paralympic Games; whereas Study 2, investigating the coaches use and perceptions was undertaken within 2017 and thus followed the Olympic and Paralympic Games. This is important to consider because within the year prior to the

‘Games’ the processes and practices of sports are firmly set in place with very little change occurring. Conversely, within the first year of a new ‘Games’ cycle sports often go through a significant reflection, evaluation and potentially redirection process (dependent upon ‘Games’ performance, funding changes, staffing changes, and/or results of the reflection process). Although no evidence from the coaches existed inferring that a recent and significant change occurred regarding feedback and performance analysis delivery within their sport, it remains an area to consider.

The approach adopted within Study 1, specifically the face-to-face interviews, was only made possible due to the level of immersion and ‘buy-in’ I had established within the Olympic/Paralympic setting. Throughout the course of the project I was firmly within the EIS environment, working as an analyst on a short-term basis within a number of sports e.g. Canoe Slalom, Cycling, whilst also attending various workshops and Continuing Professional Development (CPD) opportunities, e.g. software training sessions, research conferences, technical delivery sessions, which allowed myself to develop significant working relationships with the analysts. Whilst this was a clear strength of Study 1, the same relationship could not be developed with all of the coaches involved due to a similar lack of these network and relationship building opportunities. In an attempt to negate this limitation, efforts were made to connect with coaches and visit them within their environment in order to understand their use and views of performance analysis and feedback. Whilst efforts were made to minimise the impact of relationship (or limited relationships) upon depth of responses provided within the questionnaires, it is acknowledged that the level of relationship developed with some of the coaches would not have been to the level of the researcher-analyst relationship.

A further criticism could be made regarding the self-selected sample of coaches who took part. The participant coaches were potentially people who engaged and ‘bought-

in' to performance analysis, whereas those who do not buy-in arguably would not want to answer questions on performance analysis within their practice (because it may not have existed). This may also be evidenced by the overall positive responses to performance analysis from all coaches involved. Although it is hoped that all coaches buy-in to performance analysis, this is realistically and unfortunately not the case, thus a 'buy-in skew' likely existed. It would have been extremely interesting if a number of coaches that openly did not buy-in to performance analysis responded, thus enabling the thesis to further explore and contrast the applied reasoning behind both viewpoints.

The increase in funding towards performance analysis and the technology employed within the various performance environments indicates general buy-in towards performance analysis, however, further efforts could have been made to fully explore the internal and external validation of responses throughout the thesis. Efforts were made to: 1) engage with participants to informally discuss responses and identify whether the same responses were given (internal validation), in contrast to a formal interview or via an online questionnaire where participants might feel like they are being 'tested' and 2) observe coaches and analysts in an attempt to view their responses in action (external validation, i.e. did participants practice what they preach?). The internal validation was undertaken with the majority of participants, however, external validation could only be observed at a number of canoe slalom and cycling competitions. As such, it is acknowledged that external validation wasn't always possible due to the number of sessions, competitions, and geographical spread of participants involved.

6.3 – Implications of the thesis for applied performance analysis

One of the key aspects outlined by the EIS during the onset of the initial project was the need to ensure benefit to their analysts working within the applied setting. The requirement

and need for applied impact directly reflect comments by Mackenzie and Cushion (2013) whom stated that there exists a paucity of research directed towards problems found within applied performance analysis and that research should engage with applied practitioners to establish issues for research attention. As such, the constant link between researcher and researched was maintained, often taking the form of formal and informal discussion, the presentation of ideas with feedback, and direct involvement of the participants within areas such as questionnaire design.

The information generated within the thesis has highlighted the various tools and delivery methods utilised within applied practice, including the key challenges, e.g. time, faced when attempting to deliver effectively. Furthermore, the coaches' philosophy was often highlighted as an impactful factor with performance direction, and as such, should be an aspect that analysts work hard to ensure they can effectively translate into analysis tasks (e.g. performance questions and associated variables) and feedback methodologies (e.g. visualisation). In addition, the impact of training goals upon the analysis process further infers that analysts need to be able to work 'reactively' within their daily or weekly workflow ensuring the ever-changing training goals can be monitored on a regular basis. As a consequence, the ability to develop and enhance the coach-analyst relationship is arguably a vital aspect of delivering effective applied performance analysis and should therefore not be overlooked.

The most provided and requested deliverables of performance analysis were video, reports, and trend/profiling information; therefore, the applied practitioner should ensure the skills associated with these are firmly developed. Video sessions were primarily coach led however data sessions were delivered with a more evenly distributed approach. Whilst only being given limited opportunity to directly feedback to athletes, analysts should endeavour to gain as much experience directly feeding back to athletes and coaches as

possible. When opportunities arise, such experience should ensure the analyst is able to communicate at an appropriate level and complexity, whilst making further considerations for the amount of information presented or the outcome goal/desired change in performance to be achieved, among various others.

Not only can the generated results be shared between sports, analysts, and coaches alike, but it would be encouraged to share and utilise the questionnaires further within applied sport, to 1) facilitate future reflection and 2) identify areas that may require improvement within future practice through a 'check and challenge' approach. In addition, the utilisation of the questionnaires may help identify sports which operate in a similar or contrasting manner to further facilitate idea sharing and practice development.

6.4 – Implications of the thesis for performance analysis literature

Researchers often strive to investigate problems and produce research we think is impactful, yet as academics, we unfortunately do not really know much of what is going on within elite sport settings, thus a 'theory-practice gap' is often created (Mackenzie & Cushion, 2013). This restriction of knowledge is likely a result of elite sport's secretive nature; specifically, the fact that teams/athletes are reluctant to expose (and potentially lose) their perceived competitive edge. Consequently, this secretive nature, and thus the inability for academics to consistently research and openly publish details of current performance problems contributes to the on-going 'theory-practice gap'. The underlying requirement of the thesis to remain focused around the applied environment aims to ensure clear and positive benefits for the performance analysis literature. This thesis helps to address these limitations and the pertinent and valid points made by Mackenzie and Cushion (2013) regarding a wide proportion of performance analysis research and its lack of impact within the real world. This thesis therefore provides new insight and knowledge

into a relatively under-explored aspect of the performance analysis literature, i.e. feedback delivery within Olympic and Paralympic sport.

The information generated within the thesis should be used to assist within the development and design of educational support to help prepare upcoming students of the challenges identified within applied sport. From here, students can begin to develop skills within highly used aspects of performance analysis delivery. The questionnaires and techniques developed and utilised within data collection should be incorporated within future research as they offer a standardised basis to facilitate cross-environment or cross-sport comparison and thus, provide an opportunity to understand a greater sporting demographic moving forward.

6.5 – Future research directions

The use of qualitative empirical data from a number of different perspectives in this thesis allowed a more realistic representation of the studied environment to be investigated, compared to most previous research. Building upon this work in future endeavours, researchers wishing to delve deeper into the use and implementation of performance analysis within applied practice should now attempt to move beyond the generally unconnected study of analysts, athletes, or coaches in isolation. A wider approach investigating the interaction between coach-analyst-athlete within the feedback process would be warranted. Furthermore, this approach could be expanded to investigate 'in classroom' and 'in performance' feedback moments. Methodologically, such an approach may be challenging, but would however provide a significant step forward within the area, thus connecting a number of different aspects.

Another key but challenging area for future study should involve intervention-based research within the applied environment. For example, a performance question may

be related to the execution or defence of the jab in boxing. An intervention, considering a number of variables e.g. content, timing of the feedback, amount of feedback given, time between feedback periods etc., could be developed using video and/or data-based methods in order to demonstrate the boxer (for execution) or the opponent (for defence, e.g. que identification) performing the jab. This type of research would ultimately aim to identify the extent to which the intervention positively (or potentially negatively) impacted performance. Does the methodology improve the performance/defence of the jab in general or does the intervention only improve performance against the specific opponent it was designed around? Further study could undertake a number of other approaches, for example work could;

1. Look to revisit participant responses in an attempt to uncover any change or modification of practice. This approach would be encouraged to unearth potential reasons behind any significant or lack of change within practice, e.g. period within season, recent results etc.
2. Look to investigate all coaches and analysts within a single sport's World Class Programme (WCP) in an attempt to more closely align practice within the sport and ultimately understand why the WCPs operate in the way they do from an analysis and information delivery perspective.
3. Undertake a comparative approach incorporating sport vs. sport or nation vs. nation with the overriding aim of uncovering whether major differences exist, which may potentially highlight differences in a sport's or national cultural approach.
4. Investigate whether the use of feedback methodologies, e.g. content, design, length, etc. differs based upon whether the reviewed or previewed performances are 1) against higher/lower quality of opposition or 2) are at home or away, among various others.

6.6 – Conclusions

A wide proportion of previous performance analysis research has tended to focus upon 'the method' of performance analysis through; 1) the collection of valid and reliable data, 2) attempts to reduce performances into variables associated with successful performance, or 3) the development and optimisation of new and current data collection and analysis techniques, e.g. profiling. Although clearly warranted and required to progress and develop the literature and theory of performance analysis, it fails to enhance our understanding of the use and delivery of the information within applied practice. Until more recently, a limited number of research studies have emerged which focus on the complexities and factors impacting upon the use and implementation of performance analysis within elite sport, with even fewer emerging within Olympic/Paralympic sport. As a result, this thesis has attempted to investigate performance analysts' and coaches' use of feedback and performance analysis within the elite Olympic and Paralympic environment. Specifically, to uncover what current practice looks like (what, when, how and why) whilst sharing what each group believes is required moving forward. The various complexities within the coach-analyst relationship (e.g. impact of buy-in and trust in the other parties' knowledge and experience to guide analysis provision) as well as the numerous intertwining factors that impact upon practice (e.g. competition scheduling upon feedback frequency) have also been presented. A critical feature of the research was the use of the analysts within questionnaire development enabling the research to incorporate various questions deemed important to them, whilst facilitating information sharing between a number of sports, and ultimately ensuring applied impact (Mackenzie & Cushion, 2013). Additionally, this thesis has provided new questionnaires within data collection which have subsequently been published in international journals with the hope that future research endeavours make use of these resources to facilitate cross-context comparison, e.g. sport, or nation.

Chapter 7: References

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Appendix 1: Ethical Approval Letter

London Sport Institute REC

The Burroughs
Hendon
London NW4 4BT

Main Switchboard 0208 411 5000

26/01/2016

Application Number: 1187

Dear Scott Nicholls

Re your application title: Feedback within Olympic sports

Supervisor: Nic James

Thank you for submitting your application. I can confirm that your application has been given approval from the date of this letter by the London Sport Institute

Please ensure that you contact the ethics committee if any changes are made to the research project would could affect your ethics approval

The committee would be please to receive a copy of the summary of your research study when completed

Please quote the application number in any correspondence

Good luck with your research

Your sincerely

Chair Dr Rhonda Cohen
London Sport Institute REC

Appendix 2: Study 1 – Final Interview Questionnaire

Demographic Questions

1. What is your; Name, Age and Role?

Name	Age	Role

2. How long have you been employed within your current position?

   ……

3. Please state your previous performance analysis positions (including internships) indicating the duration of each (e.g. Performance Analyst, British Cycling, 5 years).

Previous Position	Employer	Duration

*** How long they have been involved within PA? ***

4. Please list the university qualifications you possess (e.g. MSc, Performance Analysis, 3 years).

Qualification Type	Area	Held

Competition Video / Data

5. Do you provide your athletes / coaches with video / data following / during competitive performance? (*Mark D – Data and V – Video*)

		Following	During
A	All the time (after / during every performance)		
B	Often (after / during most performances)		
C	Occasionally (4 – 6 times a year)		
D	Rarely (1 – 3 times a year)		
E	Never (choice not to provide)		
F	Does not apply (unable to provide / capture)		

*** Please provide some examples of each ***

6. How often do you feel you should provide your athletes / coaches with video / data following / during competitive performance?

		Following	During
A	All the time (after / during every performance)		
B	Often (after / during most performances)		
C	Occasionally (4 – 6 times a year)		
D	Rarely (1 – 3 times a year)		
E	Never (choice not to provide)		
F	Does not apply (unable to provide / capture)		

*** Why do you feel this would be most appropriate / effective? ***

7. How long is it before you provide the video / data of competitive performance to the athletes / coaches? (Rate each: 5 – every time, 4 – majority of the time, 3 – sometimes, 2 – rarely, 1 – never, 0 – n/a)

		Video	Data
A	Immediate (< 10 minutes)		
B	Within 1 hour ($10 \leq x \leq 60$ minutes)		
C	1 - 3 hours		
D	3 - 6 hours		
E	6 - 9 hours		
F	The next day		
G	> 2 days		
H	I do not provide the video / data to the athletes / coaches		

8. How long do you feel it should be before you provide video / data of competitive performance to the athletes / coaches? (Rate each: 5 – every time, 4 – majority of the time, 3 – sometimes, 2 – rarely, 1 – never, 0 – n/a)

		Video	Data
A	Immediate (< 10 minutes)		
B	Within 1 hour ($10 \leq x \leq 60$ minutes)		
C	1 - 3 hours		
D	3 - 6 hours		
E	6 - 9 hours		
F	The next day		
G	> 2 days		
H	I do not provide the video / data to the athletes / coaches		

*** Why do you feel this would be most appropriate / effective? ***

9. What do you feel are the barriers preventing your desired video / data delivery timescale (i.e. Q11) becoming current practice (i.e. Q10)?

Note: e.g. Amount of video, hardware/software constraints, athletes/coaches tied up elsewhere and other demands

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Training Video / Data

10. Do you provide your athletes / coaches with video / data following / during training? (*Mark D – Data and V – Video*)

		Following	During
A	All the time (after / during every training session)		
B	Often (after / during most training sessions: ~ 3 a week)		
C	Occasionally (~ 3 a month)		
D	Rarely (~ 3 a year)		
E	Never (choice not to provide)		
F	Does not apply (unable to provide / capture)		

*** Please provide some examples of each ***

11. How often do you feel you should provide your athletes / coaches with video / data following / during training performance?

		Following	During
A	All the time (after / during every training session)		
B	Often (after / during most training sessions: ~ 3 a week)		
C	Occasionally (~ 3 a month)		
D	Rarely (~ 3 a year)		
E	Never (choice not to provide)		
F	Does not apply (unable to provide / capture)		

*** Why do you feel this would be most appropriate / effective? ***

12. How long is it before you provide video of training performance to the athletes / coaches? (Rate each: 5 – every time, 4 – majority of the time, 3 – sometimes, 2 – rarely, 1 – never, 0 – n/a)

		Video	Data
A	Immediate (< 10 minutes)		
B	Within 1 hour ($10 \leq x \leq 60$ minutes)		
C	1 - 3 hours		
D	3 - 6 hours		
E	6 - 9 hours		
F	The next day		
G	> 2 days		
H	I do not provide the video / data to the athletes / coaches		

13. How long do you feel it should be before you provide video of training performance to the athletes / coaches? (Rate each: 5 – every time, 4 – majority of the time, 3 – sometimes, 2 – rarely, 1 – never, 0 – n/a)

		Video	Data
A	Immediate (< 10 minutes)		
B	Within 1 hour ($10 \leq x \leq 60$ minutes)		
C	1 - 3 hours		
D	3 - 6 hours		
E	6 - 9 hours		
F	The next day		
G	> 2 days		
H	I do not provide the video / data to the athletes / coaches		

*** Why do you feel this would be most appropriate / effective? ***

14. What do you feel are the barriers preventing your desired video / data delivery timescale (i.e. Q16) becoming current practice (i.e. Q15)?

Note: e.g. Amount of video, hardware/software constraints, athletes/coaches tied up elsewhere and other demands

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Analysis Process

15. What type of analysis do you complete? (Rate each: 5 – all the time, 4 – majority of the time, 3 – sometimes, 2 – rarely, 1 – never/choose not to, 0 – Does not apply/not applicable to my sport)

		Video	Data
A	Live competition (during performance)		
B	Live training (during performance)		
C	Pre competition		
D	Pre training		
E	Post competition		
F	Post training		
G	I do not provide anything in addition to video / edited clips		
H	Other, please state		

16. What elements of performance analysis do you use / provide to your coaches / athletes? (Rate each: 5 – every time, 4 – majority of the time, 3 – sometimes, 2 – rarely, 1 – never, 0 – n/a)

		Training	Comp
A	Full video of performance		
B	Edited video of individual athletes (i.e. individual coding)		
C	Edited video of team units (i.e. defence)		
D	Edited video of key action points (i.e. set plays, race starts)		
E	Performance reports, including sport specific statistics		
F	Athlete profiling to enable performance monitoring		
G	Live coding / analysis during performance		
H	Opposition strength / weakness reports		
I	Opposition strength / weakness video sessions		
J	Post-performance feedback shortly after (< 2 hours)		
K	Micro-performance feedback (e.g. between races, rounds, HT)		

L	Trend and data analysis		
M	Others, please state and describe		

17. Think of a specific analysis example you regularly undertake within your practice. Please could you describe;
    a. What it is?
    b. How long the specific analysis takes?
    c. When it is fed back to the coaches / athletes?
    d. Why it is fed back at that point?

Note: If the participant has more than one prime example, ask them to describe a second

18. Who decides what aspects of performance to analyse? (Rate each: 5 – every time, 4 – majority of the time, 3 – sometimes, 2 – rarely, 1 – never)

A	Coach only	
B	Performance Analyst only	
C	Coach mostly with Performance Analyst input / advice	
D	Performance Analyst mostly with Coach input / advice	
E	Coach and Performance Analyst combined effort	
F	Other, please state (e.g. PD, players, other staff members)	

*** How many coaches / staff members are involved within this decision-making process? ***

19. What factors influence the aspects of performance that are analysed? (Rate each: 5 – always, 4 – regularly, 3 – sometimes, 2 – rarely, 1 – never influences)

A	Coach experience / philosophy	
B	Performance analysis experience	
C	Training goals	
D	Forthcoming competition	
E	Level of athlete (i.e. International, National)	
F	Age of athlete (i.e. Senior, Junior)	
G	NGB awards	
H	Other Coaches / Performance Analysts	
I	Athlete feedback	
J	Discussions with athletes	
K	Performance analysis literature	

L	Coaching literature	
M	Period within season	
N	Other, please state	

Feedback Process

20. a. How is information generally fed back to your coaches / athletes? (Current)

    b. How do you feel information should be fed back to your coaches / athletes to be most effective? (Desired)

    Rate each: 5 – every time, 4 – majority of the time, 3 – sometimes, 2 – rarely, 1 – never. (*Use D – Data or V – Video if appropriate, e.g. D4*)

		Current	Desired
A	Immediately (< 1 hour following performance)		
B	Shortly after (2 – 4 hours)		
C	Some time after (4 – 8 hours)		
D	After a much longer delay (> 8 hours)		
E	In a consistent manner (i.e. presentation, information type)		
F	In a varied manner (i.e. avoid feedback becoming boring)		
G	In a team / squad group		
H	In a small group		
I	Individually		
J	Online formats (e.g. Email, Dartfish online, Tableau)		
K	Video chat / phone conversation		
L	Face-to-face		
M	Coach led feedback sessions		
N	Performance analyst led feedback sessions		
O	Coach, Performance analyst combination approach		
P	Qualitative only (video)		
Q	Quantitative only (data)		
R	Qualitative (video), followed by quantitative (data)		
S	Quantitative (data), followed by qualitative (video)		
T	Other, please state		

*** Why do you feel this approach would be most appropriate / effective? ***

21. How often do you change how you feedback to your athletes / coaches?

A	Always, I try to vary how I feedback information	
B	I try to maintain the same feedback methods throughout one Olympic cycle (i.e. allow athletes to become accustomed)	
C	I try to modify / review how information is fed back on an annual basis	
D	I try to modify / review how information is fed back when I learn of new methods of delivery / presentation	
E	I try to maintain consistency between all areas of feedback (i.e. everything is fed back the same where possible – e.g. format, time)	
F	I try to maintain consistency within specific aspects of feedback (i.e. all timing information consistent, all technique information consistent, but each area may differ from one another)	
G	Others, please state	

22. a. How long do your feedback sessions generally last? (Current)

b. How long do you feel feedback session should last to be most effective? (Desired)

Rate each: 5 – every time, 4 – majority of the time, 3 – sometimes, 2 – rarely, 1 – never. (*Use D – Data or V – Video if appropriate, e.g. D4*)

		Current	Desired
A	< 5 minutes		
B	5 – 10 minutes		
C	10 – 15 minutes		
D	15 – 20 minutes		
E	20 – 25 minutes		
F	25 – 30 minutes		
G	Other, please state		

*** Why do you feel this approach would be most appropriate / effective? ***

23. What is the primary process of feeding back within your practice? (Rate each: 5 – every time, 4 – majority of the time, 3 – sometimes, 2 – rarely, 1 – never)

A	I deliver the feedback to the athletes and coaches based upon pre-determined goals / plans	
B	I deliver the feedback on my own, to the athletes only (i.e. the coach trusts me to delivery / interpret the information)	
C	I deliver the feedback to the coaches first, and then the athletes thereafter following coach input (i.e. coach tweaks what information I deliver)	
D	The coach delivers the feedback following conversation between myself and the coach	
E	Both myself and the coach deliver the feedback (i.e. combined approach)	
F	Other, please describe	

*** Why is that the process? ***

24. What factors impact on your ability to feedback to your coach / athletes? (Rate each: 5 – all the time, 4 – majority of the time, 3 – sometimes, 2 – rarely, 1 – never)

A	Time taken to complete the analysis required	
B	Time available (due to your role, coaching or athletes demands elsewhere)	
C	Conflict between practise and feedback	
D	Equipment availability	
E	Coach / athlete receptiveness to performance analysis	
F	Coach / athlete receptiveness to feedback	
G	Information reliability	
H	Information generalisability / transferability	
I	Other support staff sessions	
J	Concerns over what information should be delivered	
K	Concerns of feeding back too much information	
L	Other, please state	

Other

25. What performance analysis tools do you make use of? (Rate each: 5 – all the time, 4 – majority of the time, 3 – sometimes, 2 – rarely, 1 – never)

A	SportsCode	
B	Dartfish	
C	Opta	
D	Apps for iPhone / iPads / Android phones	
E	Focus X2	
F	Quintic	
G	GPS systems	
H	Video editing packages, please list those you use regularly	
I	Statistics packages, please list those you use regularly	
J	Microsoft packages, please list those you use regularly	
K	Other, please state	

26. Do you use an external performance analysis service provider, if yes, what services do they provide? (Rate each: 5 – all the time, 4 – majority of the time, 3 – sometimes, 2 – rarely, 1 – never)

A	Does not apply (i.e. No, I do not use an external provider)	
B	Video of your athletes	
C	Video of opposition / other athletes	
D	Performance statistics of the opposition / other athletes	
E	Performance statistics of your athletes in addition to those you provide	
F	Performance statistics of your athletes (i.e. you do not carry out any analysis yourself)	
G	Bespoke projects	
H	Other, please state	

*** Why do you use / not use an external provider? ***

27. How up to date are you with performance analysis technologies and literature developments?

		Tech	Lit.
A	I always and actively try to keep up to date with developments		
B	I keep up to date with developments when they are brought to my attention by a coach / another PA		
C	I keep up to date with developments on an annual basis		
D	I regularly (5+ times a year) liaise with other PAs / academics to help keep up to date with developments		
F	I occasionally (3-4 times a year) liaise with other PAs / academics to help keep up to date with developments		
G	I rarely (1-2 times a year) liaise with other PAs / academics to help keep up to date with developments		
H	Other, please describe		

Open

28. What has your experience as an analyst made you change or develop about how you feedback?

29. Have you got any comments in relation to how effective feedback is, and how it is received?

30. Do you assess / monitor the effect your feedback is having? How?

31. Do you assess / monitor the integrity of your data? How?

32. What do you use a) video and b) data for / to achieve?

33. What a) soft and b) hard skills should an effective analyst possess?

34. How have you gained 'buy-in' and developed 'right hand man' relationships with the coaches?

35. How much of your analysis do you feel the coaches make use of / implement?

36. What do you see as the future of PA?
    a. Globally
    b. Sport specific
    c. How do you think this will impact upon your daily role

37. Any additional comments?

Appendix 3: Study 1 – Cronbach's Alpha (α)

Question Area	Cronbach's Alpha (α)
Competition Frequency	.790
Training Frequency	.815
Type of Analysis	.785
Session Length	.786
Factors Influencing Analysis	.720
Overall	.864

Key: > 0.9 = Excellent, > 0.8 = Good, > 0.7 = Acceptable.

Appendix 4: Study 2 – Final Questionnaire

Demographics

1. What is your name, age, role, and sport?

    a. Name .....

    b. Age .....

    c. Role .....

    d. Sport .....

2. How long have you been coaching within your sport?

.....

3. Do you use performance analysis within your coaching?

.....

4. How long have you been using performance analysis within your coaching?

.....

Feedback Structure

Note: Please fill in all of the spaces within the table with the most appropriate response (i.e. All the time, Majority of the time, Sometimes, Rarely, Never)

5. How often do you feel feedback on performance should be provided? (All the time, Majority of the time, Sometimes, Rarely, Never)

Pre-Competition
Pre-Training
Post-Competition
Post-Training
Live-Competition
Live-Training

Why do you feel this would be most effective?
.....
.....

6. How long following performance do you feel feedback should be provided?

< 10 min
10–60 min
1–3 h
3–6 h
6–9 h
Next day
> 2 days

Why do you feel this would be most effective?
.....
.....

7. How long do you feel feedback sessions should last?

< 5 min
5–10 min
10–15 min
15–20 min
20–25 min
25+ min

Why do you feel this would be most effective?
.....
.....

8. What type of feedback do you feel should be delivered?

Always positive
Mostly positive
Balanced
Mostly negative
Always negative

Why do you feel this would be most effective?
.....
.....

9. How do you feel feedback should be delivered?

Consistent approach
Varied approach
In a team/squad
In a small group
Individually
Online formats
Video chat/phone
Face-to-face
Coach led sessions
Analyst led sessions
Combined approach
Video followed by data
Data followed by video

Additional comments? If your desired response is not within the above list please state and rate here. .....
.....

10. How much of the analysis that you are provided do you make use of?

.....

11. What aspects of the analysis that you are provided do you consistently use/do not use?

Do USE.....
Do USE.....
Do NOT USE.....
Do NOT USE.....

Analysis Provision and Influencing Factors

Note: Please fill in all of the spaces within the table with the most appropriate response (i.e. All the time, Majority of the time, Sometimes, Rarely, Never)

12. What type of analysis would you like to be provided by your performance analyst?

Live-Competition
Live-Training
Pre-Competition
Pre-Training
Post-Competition
Post-Training

Why do you feel this would be most effective?
.....
.....

13. What elements of performance analysis would you like to be provided?

Full video of performance
Edited video of key actions
Performance reports
Profiling
Live coding/analysis
Opposition strengths/weakness reports
Opposition strengths/weakness video
Trend and data analysis

Additional comments? If your desired response is not within the above list please state and rate here. .....
.....

14. What factors do you feel affect the ability to feedback?

Time taken to complete analysis
Time available (due to your role etc.)
Conflict between training time and feedback Equipment availability
Receptiveness to performance analysis Receptiveness to feedback
Information reliability
Other support staff sessions
Concerns over what should be delivered Concerns of feeding back too much information

Additional comments? If your desired response is not within the above list please state and rate here. .....
.....

15. What factors influence the aspects of performance that are analysed?

Coach experience/philosophy
Performance analyst experience

Training goals
Forthcoming competition
Level of athlete
Age of athlete
Other coaches/analysts
Discussions with athletes
Academic literature
Period within season

Additional comments? If your desired response is not within the above list please state and rate here. .....
.....

16. Are there any other issues you'd like to raise or discuss that you have not been able to?
.....
.....
.....
.....

Appendix 5: Study 2 – Cronbach's Alpha (α)

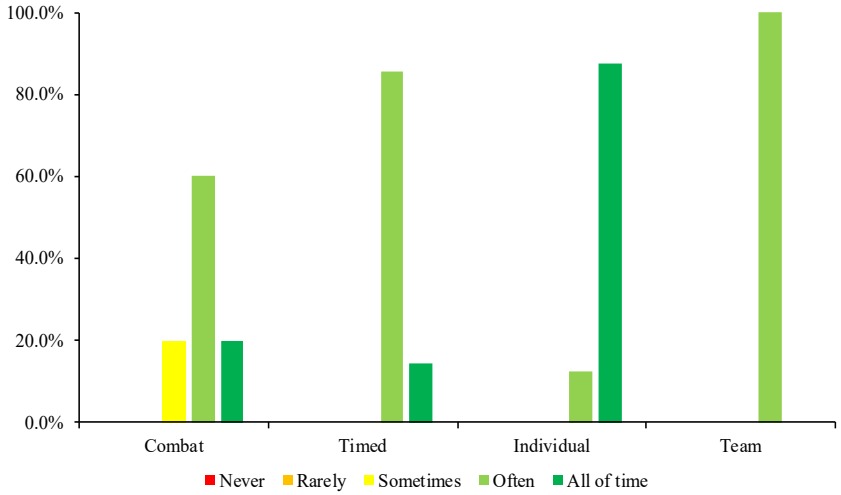
Question Area	Cronbach's Alpha (α)
Influencing Factors	.897
Desired PA Provision	.908
Feedback Provision	.851
Delivery Approach	.882
Overall	.944

Key: > 0.9 = Excellent, > 0.8 = Good, > 0.7 = Acceptable.

Appendix 6.1 Factors influencing analysis direction

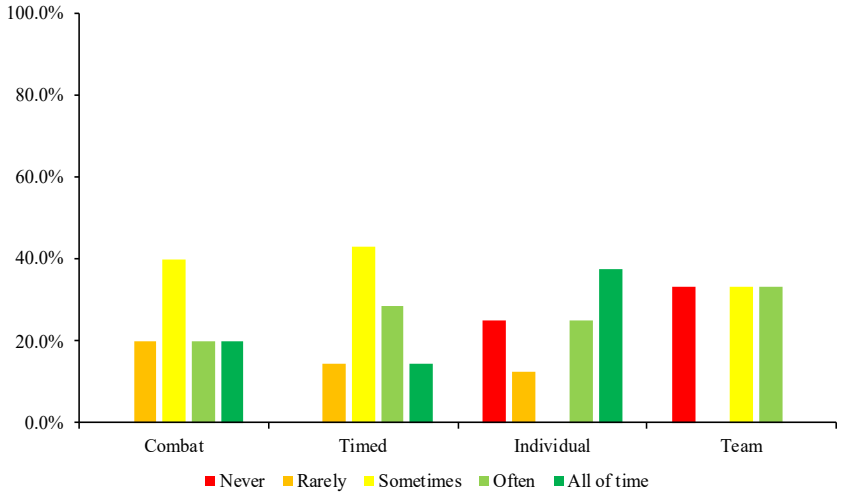
6.1.1 Coach Experience / Philosophy

Analysts reported the influence of coaching experience/philosophy differently dependent on the type of sport worked for (Kruskal-Wallis H = 11.25, df = 3, p<.05; $eta^2 = 0.62$). Analysts working in individual sports tended to report (87.5%) this influenced them all of the time whereas team (100%) and timed (85.7%) said this occurred often.



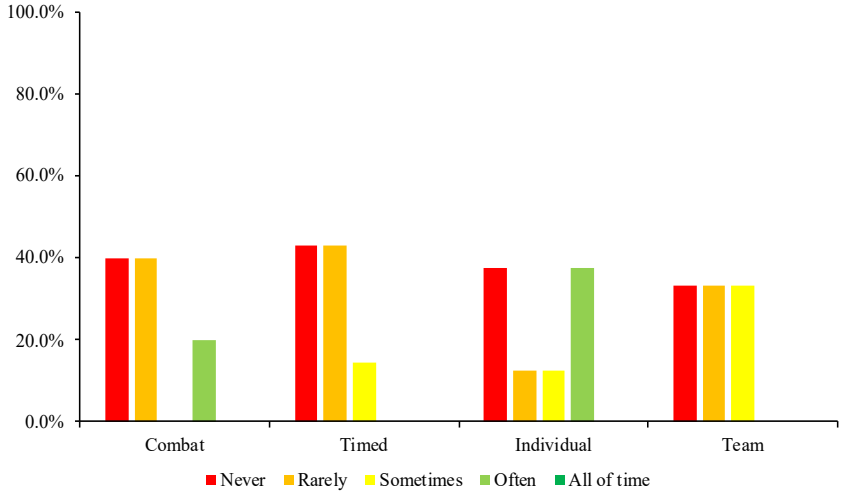
6.1.2 Performance Analysis Experience

Analysts reported the influence of performance analysis experience differently dependent on the type of sport worked for (Kruskal-Wallis H = 0.77, df = 3, p>.05; $eta^2 = -0.15$). Over 50% of analysts working within individual sports reported their experience often or all the time impacted analysis direction, whereas 25% of analysts within individual sports and 33.3% within team sports reported their experience never influenced direction.



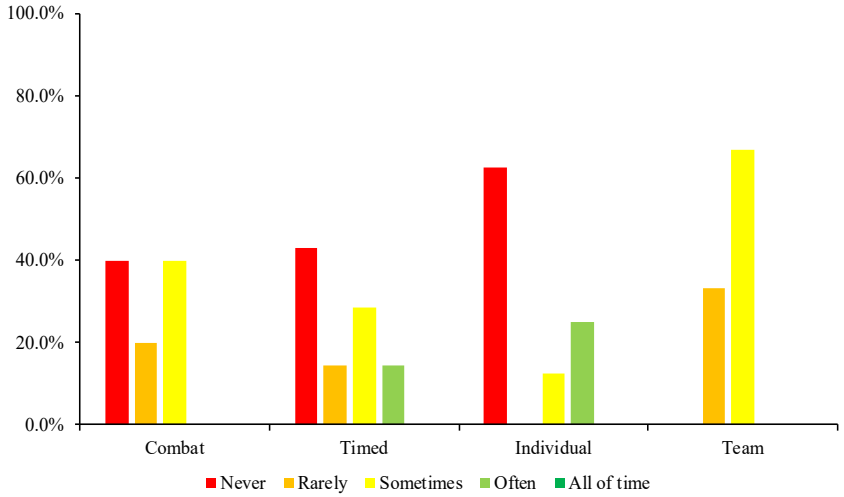
6.1.3 Performance Analysis Literature

Analysts reported there was a lack of influence of performance analysis literature upon the direction of practice within their sport (Kruskal-Wallis H = 1.15, df = 3, p>.05; eta^2 = -0.13). Over 50% of analysts working in all sports tended to report this influenced them rarely or never. However, some analysts within individual (37.5%) and combat sports (20%) reported analysis literature influenced their practice often.



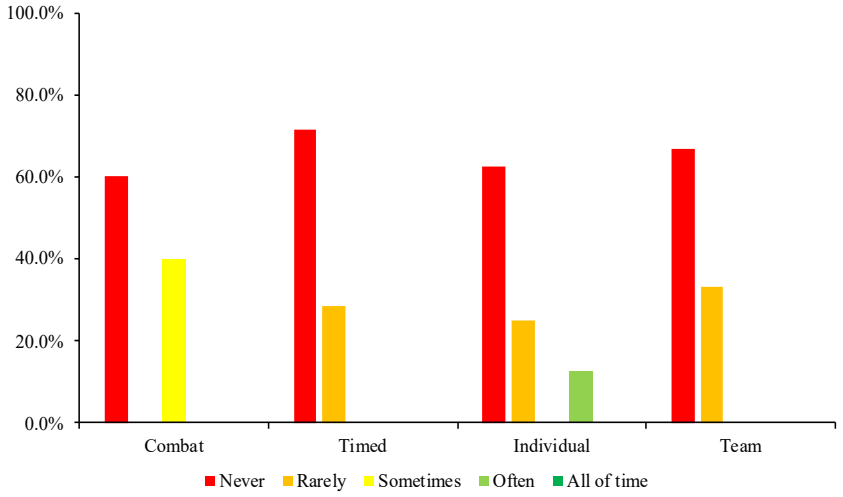
6.1.4 Other Coaches / Analysts

Analysts reported the influence of other analysts differently dependent on the type of sport worked for (Kruskal-Wallis H = 1.03, df = 3, p>.05; eta^2 = -0.14). Analysts working in team sports tended to report (66.7%) this influenced them sometimes whereas analysts within timed (14.3%) and individual (25.0%) sports said this occurred often.



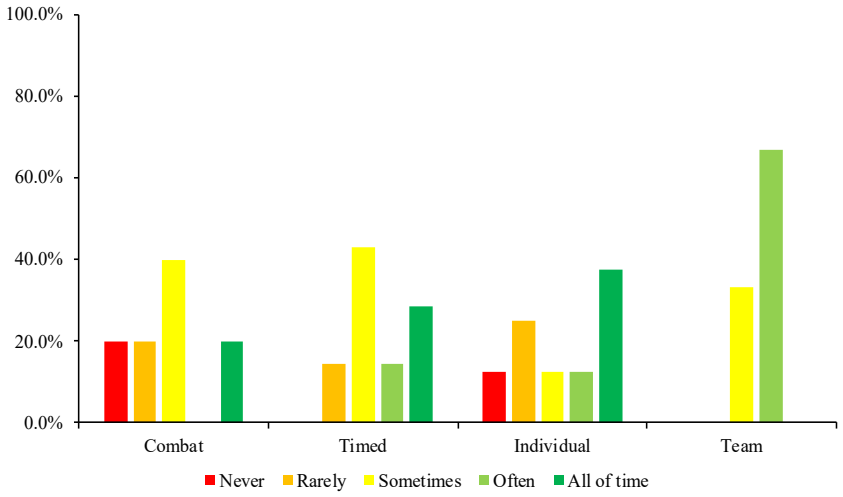
6.1.5 Coaching Literature

Over 60% of analysts reported coaching literature never impacted upon direction irrespective of the type of sport worked for (Kruskal-Wallis H = 0.65, df = 3, p>.05; eta^2 = -0.15). Only 12.5% of analysts working within individual sports reported this influenced their practices often.



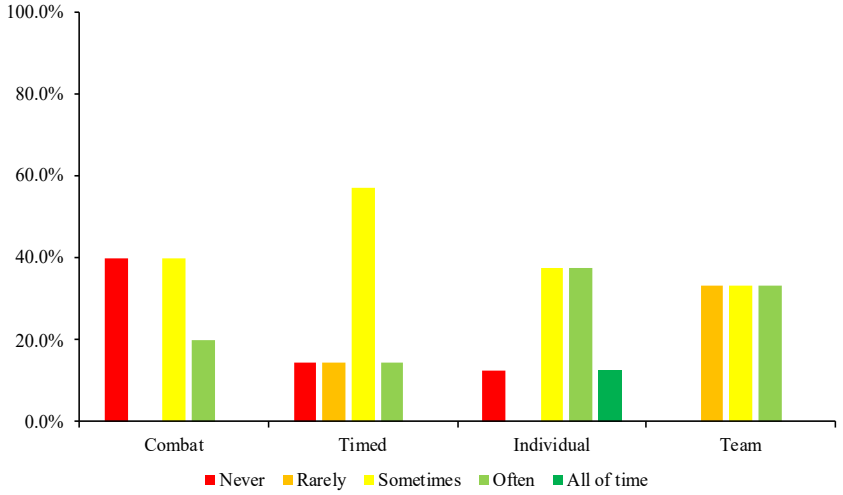
6.1.6 Training Goals

Analysts tended to report that training goals often or all the time impacted upon analysis direction (Kruskal-Wallis H = 1.20, df = 3, p>.05; eta^2 = -0.13). Analysts working in team sports reported that training goals consistently impacted upon them often (66.7%), whereas < 50% of analysts within all other sports reported this impacted them all the time or often.



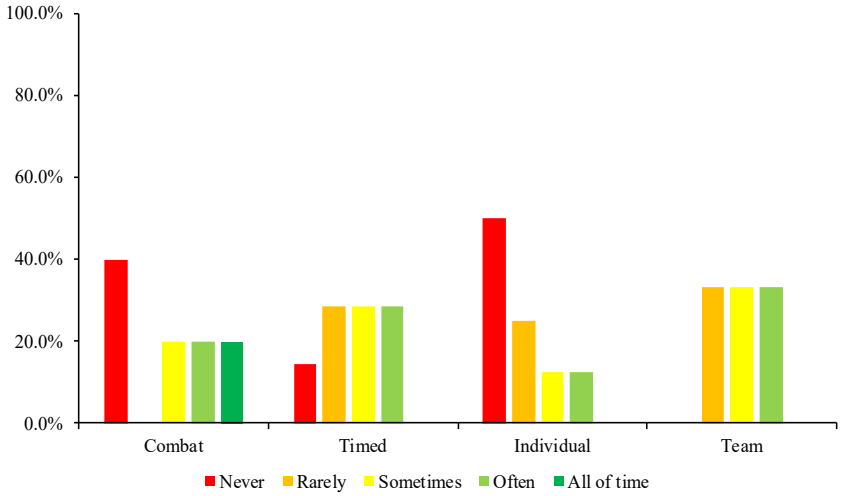
6.1.7 Forthcoming Competition

Analysts reported that forthcoming competition influenced practice differently dependent on the type of sport worked for (Kruskal-Wallis H = 2.68, df = 3, p>.05; eta^2 = -0.07). Analysts working in individual sports tended to report (50.0%) this influenced them all of the time or often, whereas team (33.3%), combat (20.0%), and times (14.3%) said this occurred often.



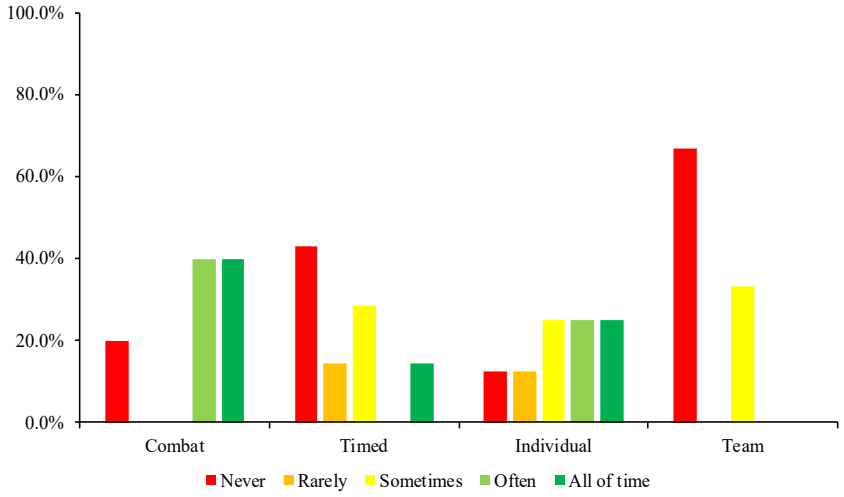
6.1.8 Period within Season

The analysts provided a similar distribution of responses regarding the influence of the period within the season they were currently working within, irrespective of the type of sport worked for (Kruskal-Wallis H = 2.92, df = 3, p>.05; eta^2 = -0.05). Half of analysts working in individual sports reported this aspect never influenced analysis direction.



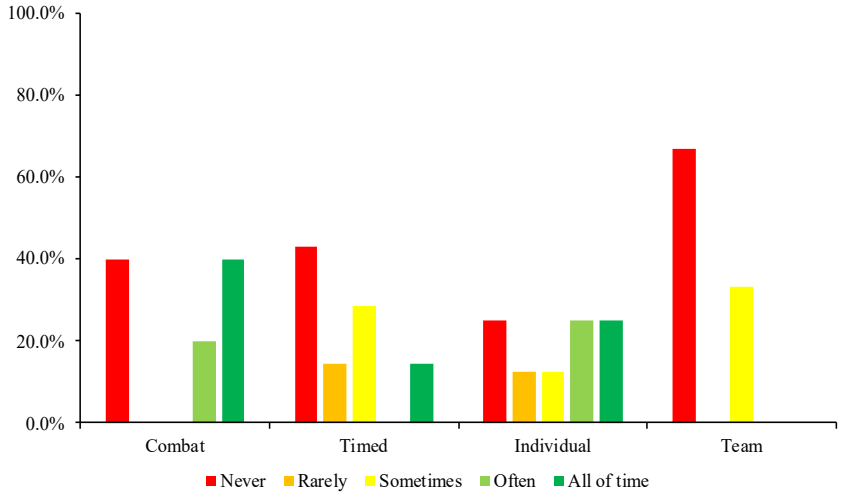
6.1.9 Level of Athlete

Analysts reported the level of the athlete they were working with impacted upon direction depending on what sport they worked for (Kruskal-Wallis H = 5.43, df = 3, p>.05; eta^2 = 0.08). Analysts working in team sports tended to report (66.7%) this never influenced them, whereas those working within combat sports tended to report this impacted upon them often (40%) or all the time (40%).



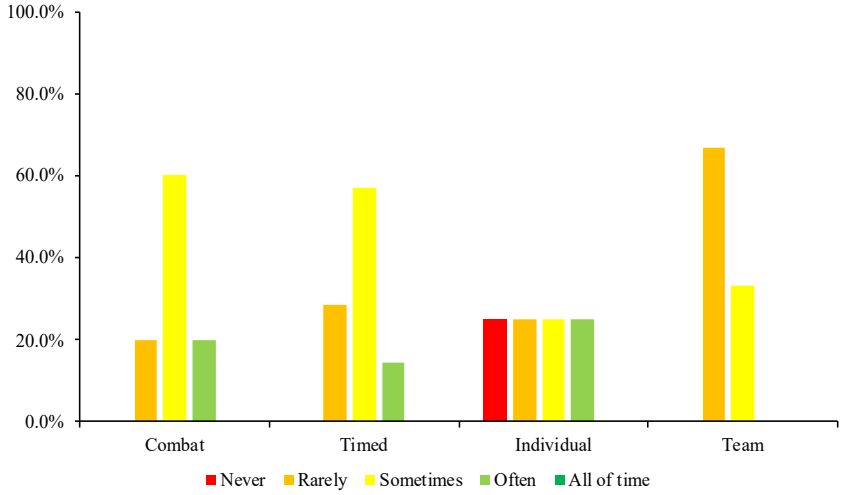
6.1.10 Age of Athlete

Analysts reported the level of the athlete they were working with impacted upon direction depending on what sport they worked for (Kruskal-Wallis H = 2.56, df = 3, p>.05; eta^2 = -0.07). Analysts working in team sports tended to report (66.7%) this never influenced them, whereas those working within combat sports tended to report this impacted upon them often (20%) or all the time (40%).



6.1.11 Athlete Feedback

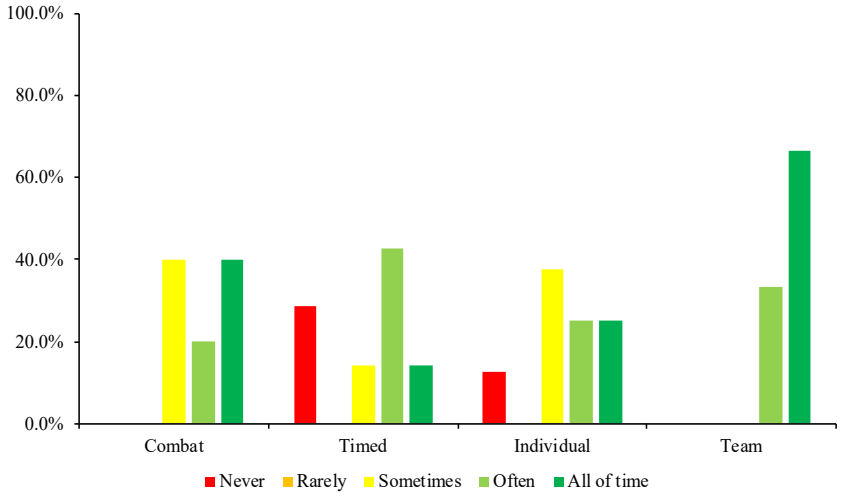
Analysts tended to report that athlete feedback sometimes or rarely influenced analysis direction (Kruskal-Wallis H = 1.80, df = 3, p>.05; eta^2 = -0.10). However, some analysts working in individual sports (25%), combat (20%), and timed (14.3%) sports did report that athlete feedback often influenced analysis direction.



Appendix 6.2 Factors affecting feedback provision

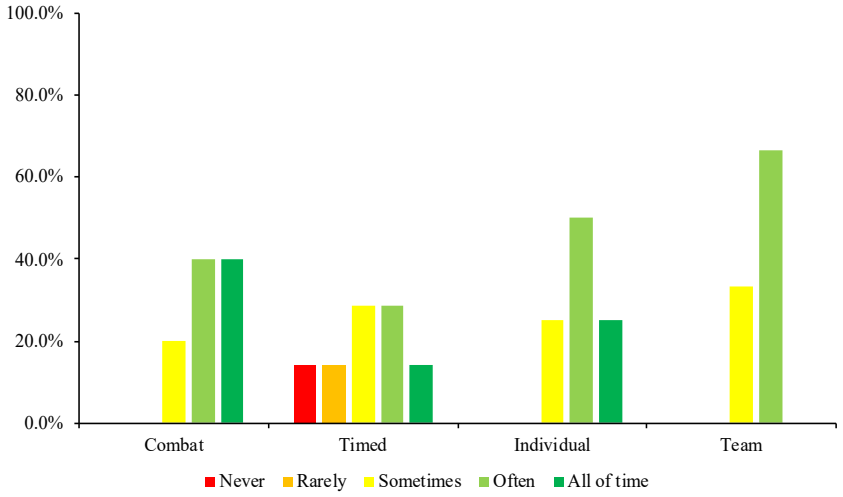
6.2.1 Time Taken

Analysts generally reported time taken to complete analysis considerably influenced feedback provision, irrespective on the type of sport worked for (Kruskal-Wallis H = 3.35, df = 3, p>.05; eta^2 = -0.03). Analysts working in team sports reported (100%) this influenced them all of the time or often, whereas timed (28.6%) and team (12.5%) said this never occurred.



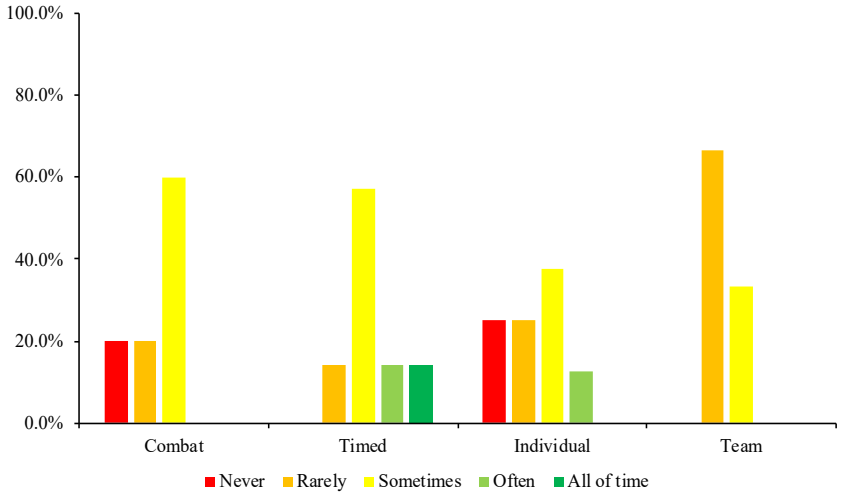
6.2.2 Time Available

Analysts reported the time available to feedback considerable influenced feedback provision (Kruskal-Wallis H = 3.18, df = 3, p>.05; eta^2 = -0.04). Over 50% of analysts working in individual, team and combat sports reported this often or all the time, whereas analysts working within timed sports reported a more varied response.



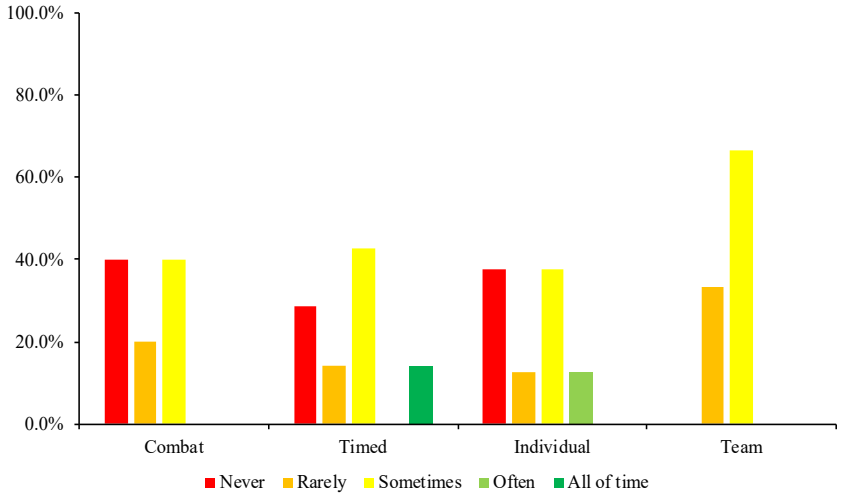
6.2.3 Feedback Quantity Concerns

Analysts generally reported the quantity of feedback to be provided has limited impact upon feedback provision (Kruskal-Wallis H = 3.83, df = 3, p>.05; eta^2 = -0.01). Only timed (28.6%) and individual sports analysts (12.5%) reported this impacted them often or all the time.



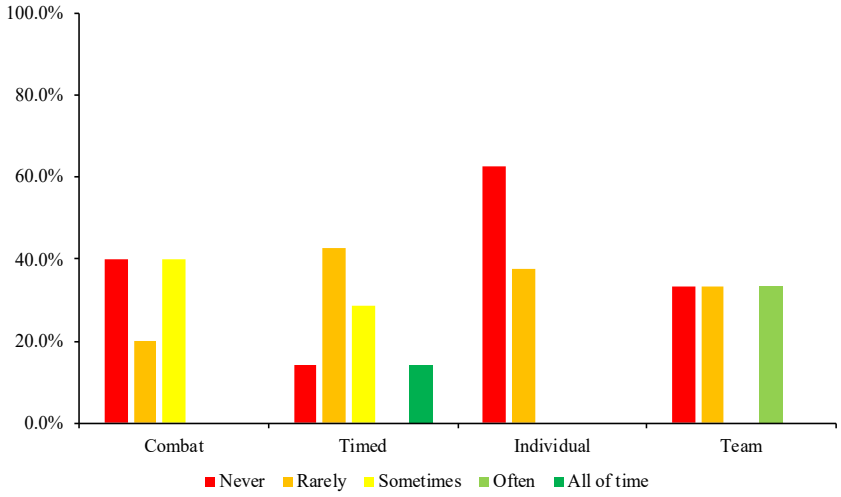
6.2.4 What to Deliver Concerns

Analysts generally reported that concerns over what to deliver has limited impact upon feedback provision (Kruskal-Wallis H = 0.94, df = 3, p>.05; eta^2 = -0.14). Only timed (14.3%) and individual sports analyst (12.5%) reported this impacted them often or all the time.



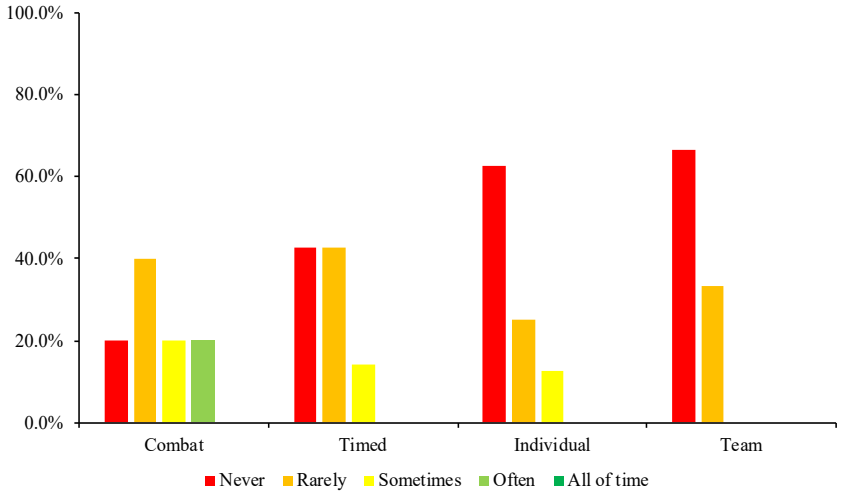
6.2.5 Analysis Reliability

Analysts generally reported (> 50%) the influence of analysis reliability rarely or never impacted upon them (Kruskal-Wallis H = 4.94, df = 3, p>.05; $eta^2 = 0.05$). However, analysts working in team sports reported (33.3%) this influenced them often, whereas timed sports (14.3%) said this occurred all the time.



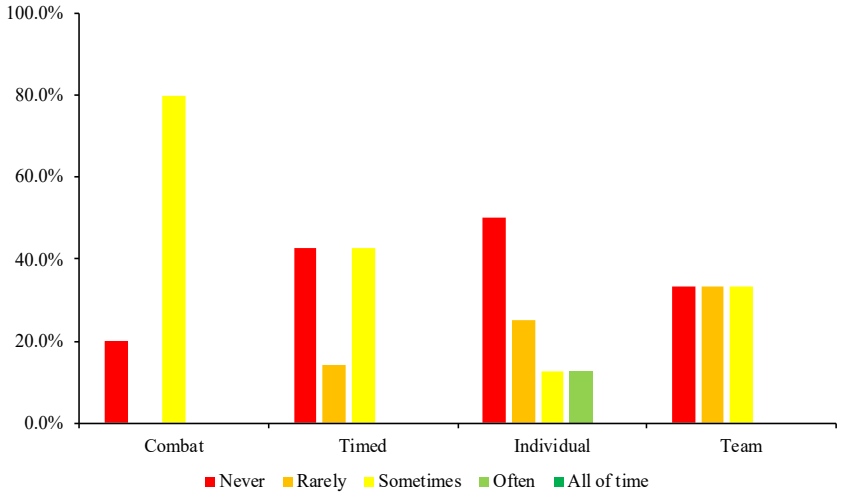
6.2.6 Transferability

Analysts tended to report (> 80%) that concerns over information transferability rarely or never impacted upon feedback provision for analysts working within timed, individual and team sports (Kruskal-Wallis H = 3.52, df = 3, p>.05; $eta^2 = -0.02$). However, 20% of analysts working in combat sports indicated this influenced them often.



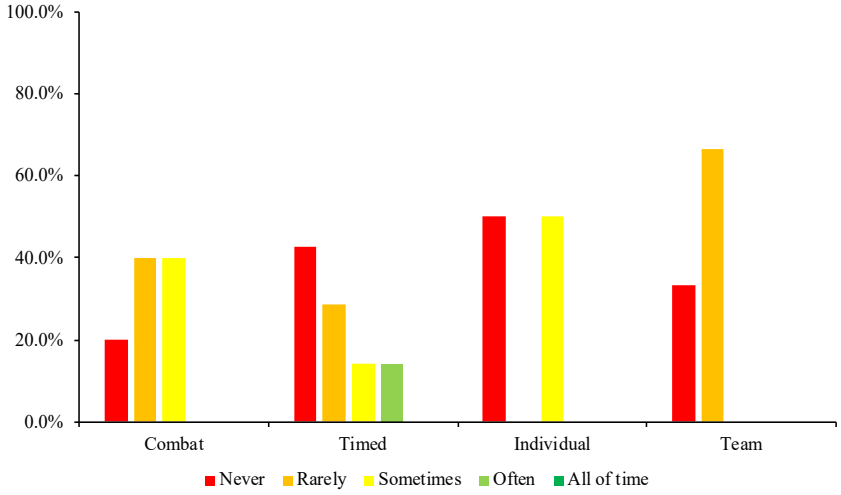
6.2.7 Buy-In to Performance Analysis

Analysts tended to report that their coaches buy-in to performance analysis tended to have limited impact upon feedback provision (Kruskal-Wallis H = 1.94, df = 3, p>.05; eta^2 = -0.10). Only 12.5% of analysts within individual sports reported this impacted upon provision often.



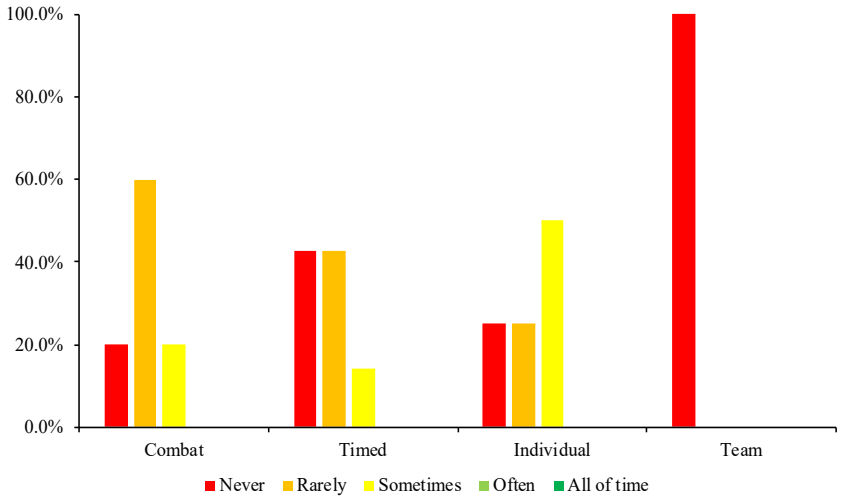
6.2.8 Buy-In to Feedback

Analysts tended to report that their coaches buy-in to feedback tended to have limited impact upon feedback provision (Kruskal-Wallis H = 0.62, df = 3, p>.05; eta^2 = -0.15). Only 14.3% of analysts within timed sports reported this impacted upon provision often.



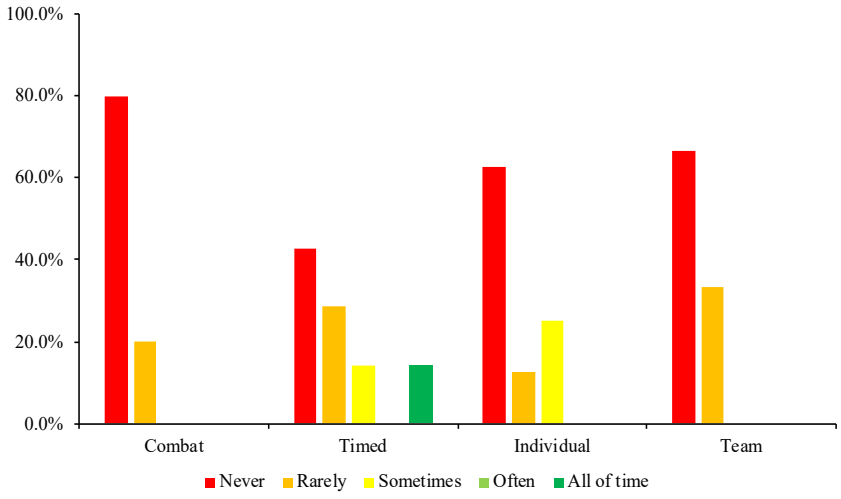
6.2.9 Training Time

Analysts tended to report that conflict between training time and feedback has limited impact upon feedback provision (Kruskal-Wallis H = 5.66, df = 3, p>.05; $eta^2 = 0.10$). All team sport analysts reported this never impacted upon feedback provision.



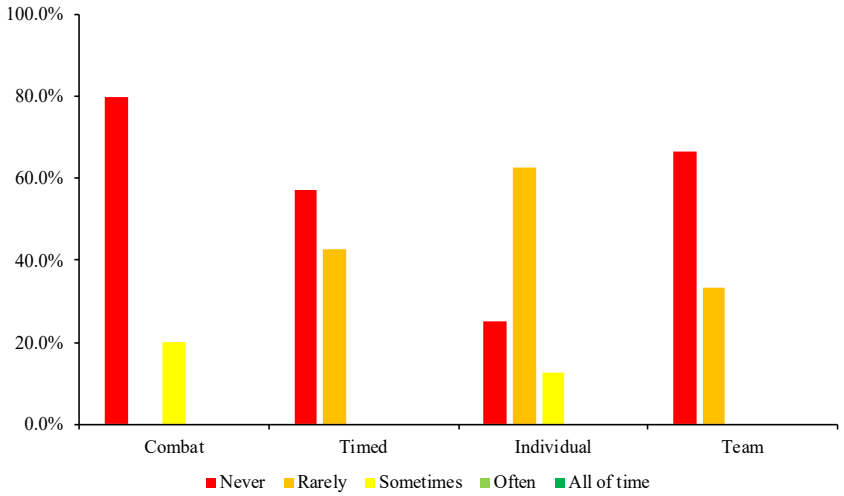
6.2.10 Equipment Availability

Analysts tended to report that equipment availability tended to have limited impact upon feedback provision (Kruskal-Wallis H = 2.22, df = 3, p>.05; $eta^2 = -0.09$). Only 14.3% of analysts within timed sports reported this impacted upon provision all the time.



6.2.11 Other Staff Sessions

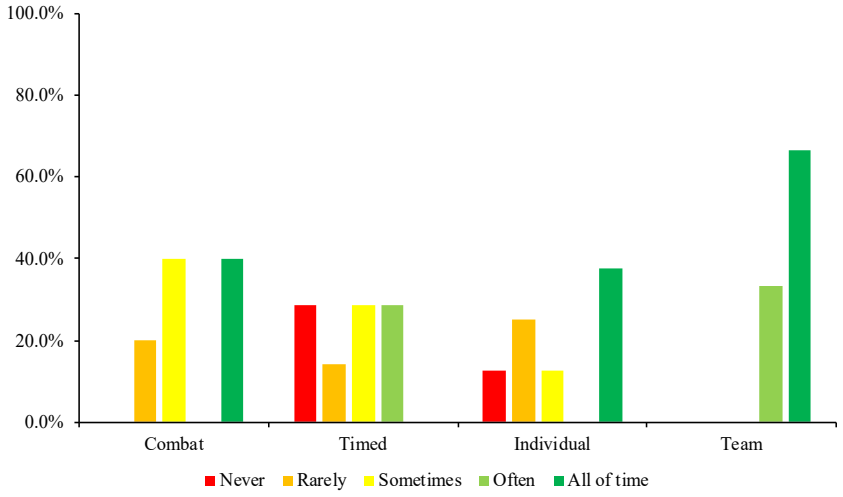
Analysts tended to report that other staff sessions tended to have limited impact upon feedback provision (Kruskal-Wallis H = 3.28, df = 3, p>.05; eta^2 = -0.04). Only analysts working in combat (20%) and individual (12.5%) reported this influenced them sometimes.



Appendix 6.3 Type of Performance Analysis Provided

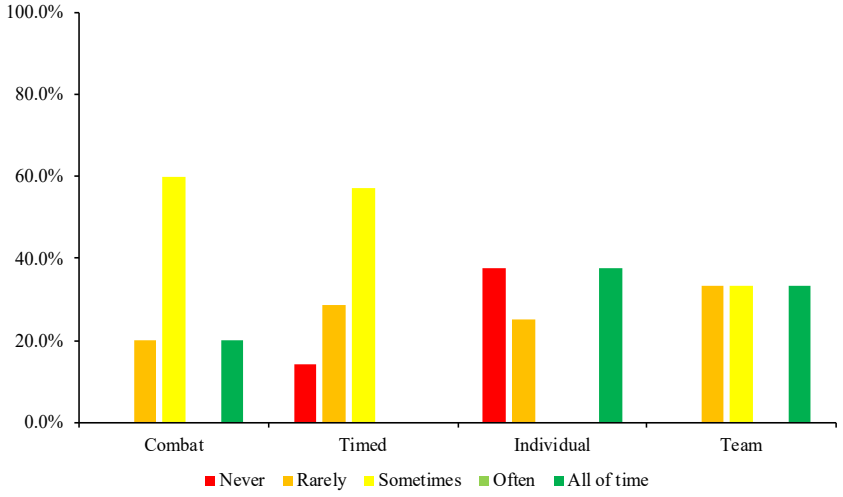
6.3.1 Training – Full Unedited Video

Analysts reported the use of unedited video differed dependent on the type of sport worked for (Kruskal-Wallis H = 4.49, df = 3, p>.05; $eta^2 = 0.03$). Analysts working in team sports tended to report this was used often (33.3%) or all the time (66.7%), whereas analysts within timed (28.6%) and individual (12.5%) sports reported they never used this type of performance analysis technique.



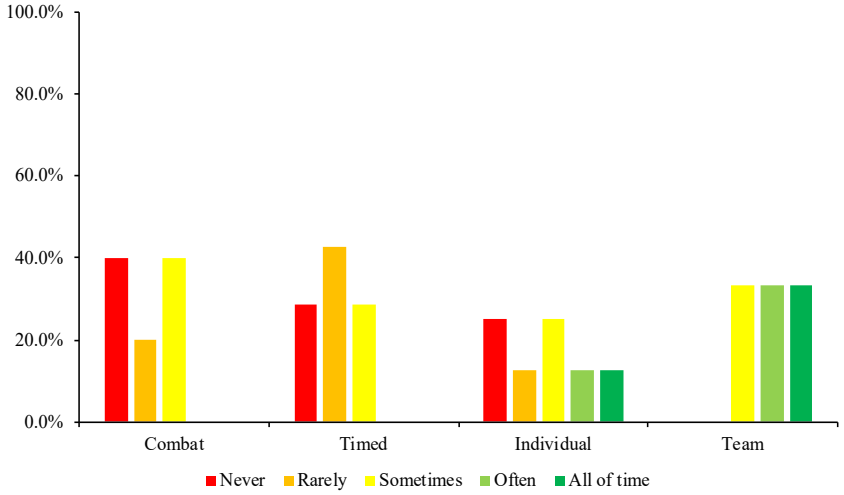
6.3.2 Training – Video of Individual Athletes

Analysts reported the use of individual athlete video differed dependent on the type of sport worked for (Kruskal-Wallis H = 1.63, df = 3, p>.05; $eta^2 = -0.11$). Analysts working in individual (37.5%), team (33.3%), and combat (20%) sports reported this was used all the time.



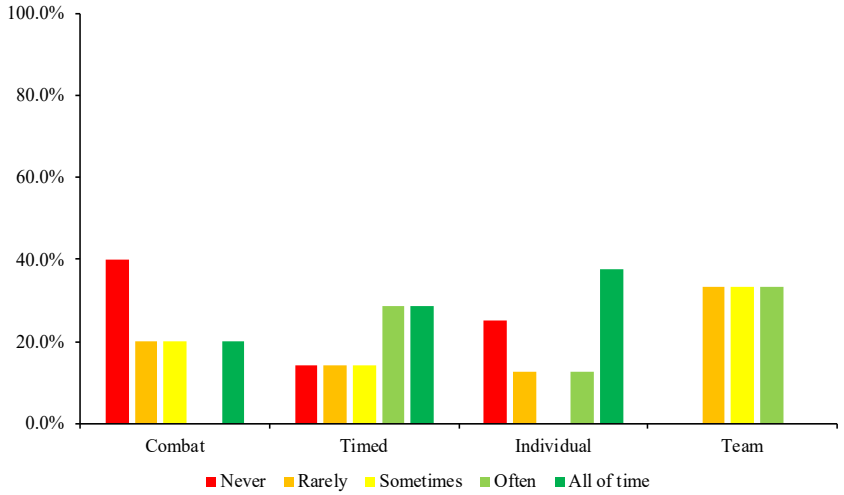
6.3.3 Training – Video of Key Action Points

Analysts reported the use of key action point video differed dependent on the type of sport worked for (Kruskal-Wallis H = 4.99, df = 3, p>.05; $eta^2 = 0.06$). Analysts working in team sports tended to report this was used often or all the time (66.7%), whereas 25% of analysts within individual sports made use of this often or all the time. Comparatively none of the analysts working with combat or timed sports used this technique at that level.



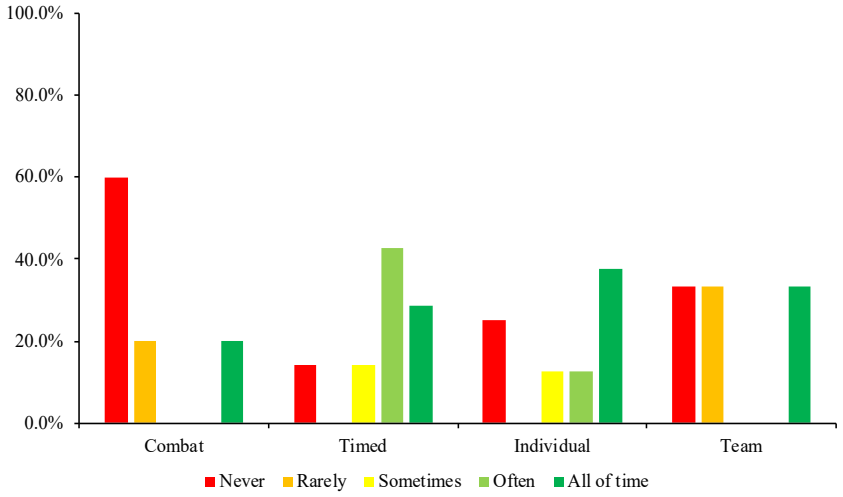
6.3.4 Training – Video of Strengths and Weaknesses

Analysts reported the use of strengths/weakness video differed dependent on the type of sport worked for (Kruskal-Wallis H = 1.06, df = 3, p>.05; $eta^2 = -0.13$). Analysts working in individual (50%) and timed (57.2%) sports tended to report this was used often or all the time, whereas 40% of analysts within combat sports never used this with their athletes.



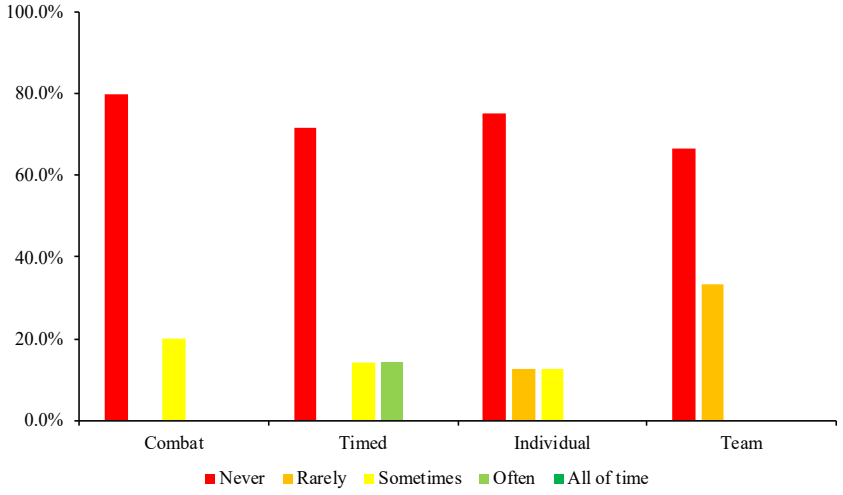
6.3.5 Training – Reports

The majority of analysts reported they either never used or consistently used reports of training with their athletes (Kruskal-Wallis H =1.98, df = 3, p>.05; eta^2 = -0.10). Analysts working in timed (71.5%), individual (50%), and team (33.3%) sports reported this was used often or all the time, whereas 60% of analysts within combat sports never used this.



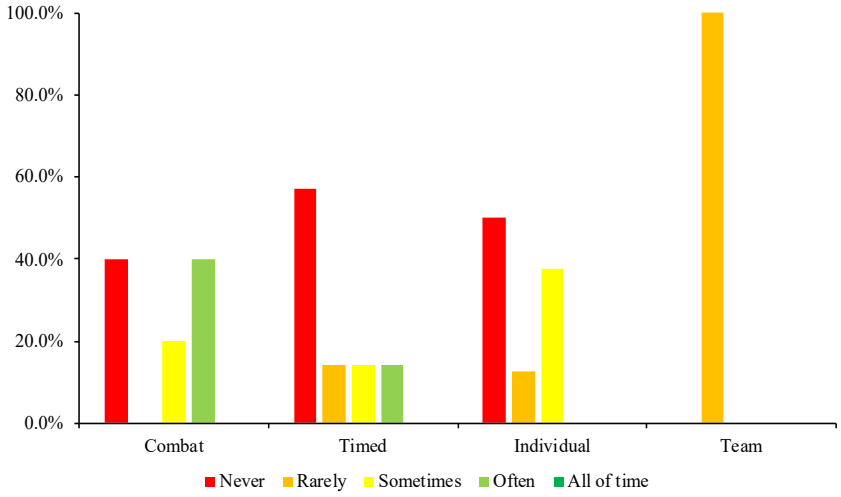
6.3.6 Training – Profiling

The majority of analysts reported they never used profiling of training with their athletes (Kruskal-Wallis H =0.23, df = 3, p>.05; eta^2 = -0.17), however, 14.3% of analysts working in timed sports reported they made use of this often.



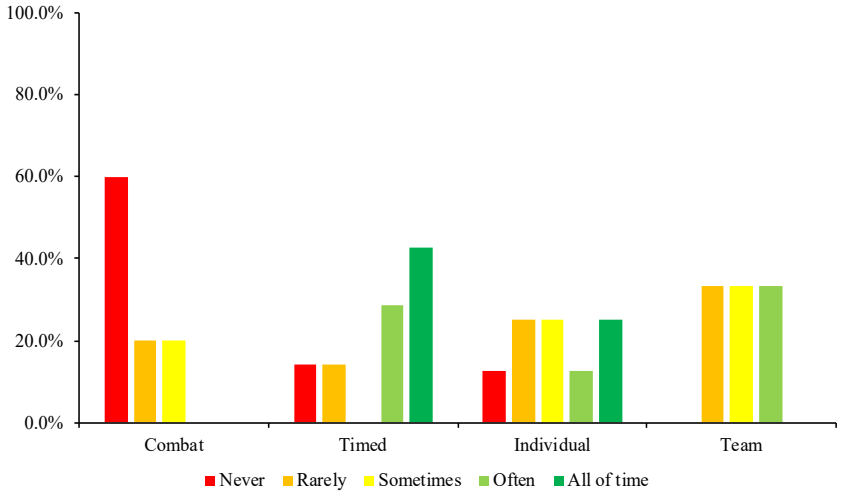
6.3.7 Training – Trend and Data Analysis

The majority of analysts reported they never or rarely made use of trend and data analysis within training (Kruskal-Wallis H =1.32, df = 3, p>.05; eta^2 = -0.12). All team sports analysts reported they rarely utilised this technique, however 40% of combat sports analysts used this often.



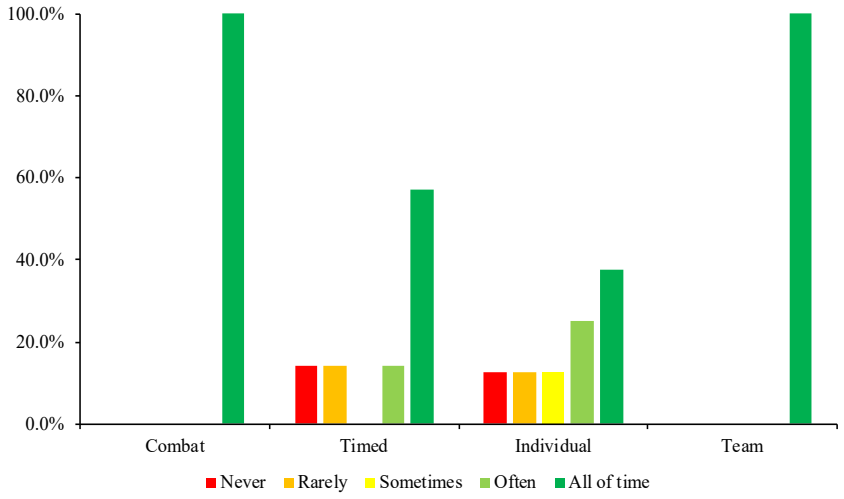
6.3.8 Training – Reports of Strengths and Weaknesses

Analysts reported the use of strengths/weakness reports differed dependent on the type of sport worked for (Kruskal-Wallis H =5.82, df = 3, p>.05; eta^2 = 0.11). Analysts working in combat (60%) sports stated they never made use of this, whereas timed (71.5%), individual (37.5%), and team (33.3%) based sports reported this was used often or all the time.



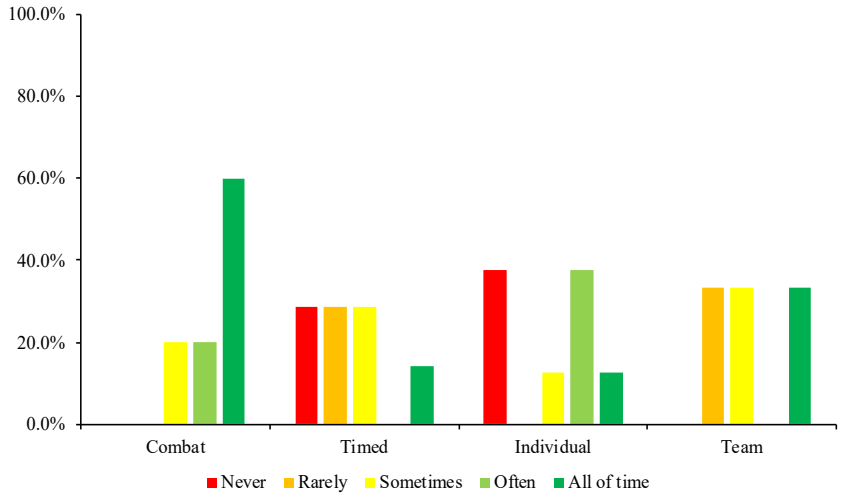
6.3.9 Competition – Full Unedited Video

Analysts reported the use of unedited competition video was mainly provided all the time by the analysts, irrespective of what type of sport worked for (Kruskal-Wallis H = 6.31, df = 3, p>.05; $eta^2 = 0.14$). All analysts (100%) working within combat and team sports, and the majority of analysts within timed (57.1%) and individual (37.5%) sports made use of this all the time.



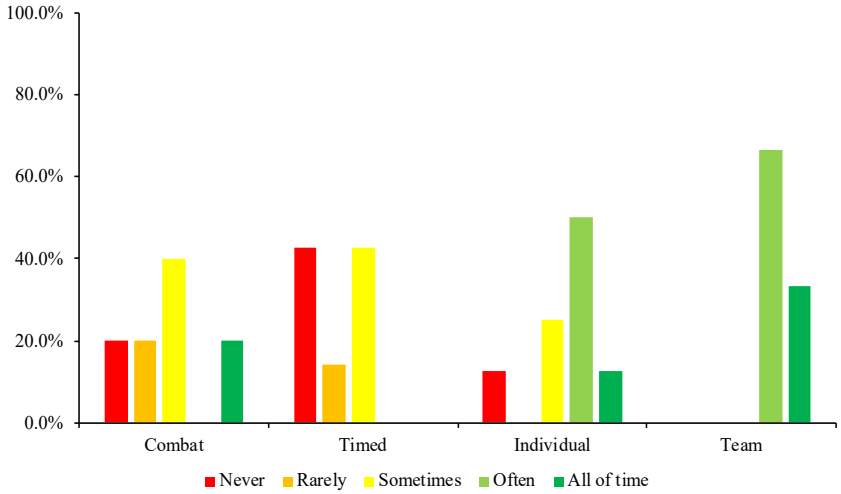
6.3.10 Competition – Video of Individual Athletes

Analysts reported the use of competition individual athlete video differed dependent on the type of sport worked for (Kruskal-Wallis H = 5.35, df = 3, p>.05; $eta^2 = 0.08$). Analysts working in combat (60%) sports reported this was used all the time. Half of analysts within individual sports used this often or all the time, whereas 37.5% also stated they never used this with their athletes.



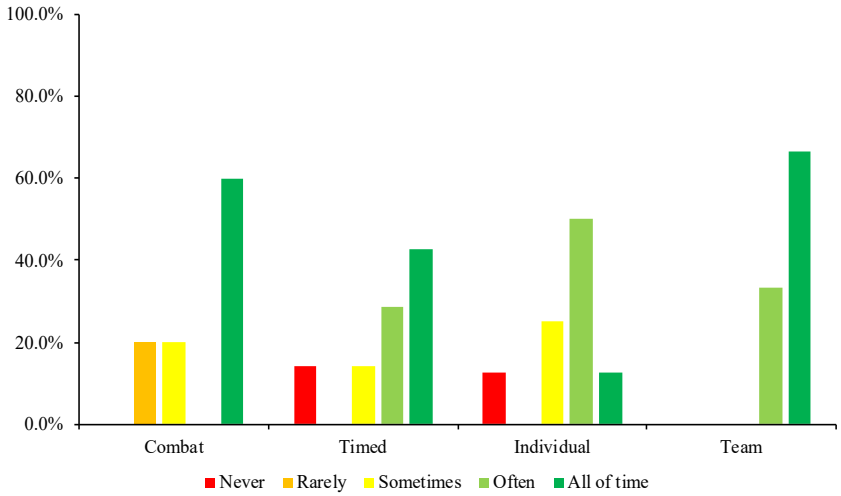
6.3.11 Competition – Video of Key Action Points

Analysts reported the use of competition key action point video differed dependent on the type of sport worked for (Kruskal-Wallis H = 9.00, df = 3, $p<.05$; $eta^2 = 0.36$). Analysts working in team sports tended to report this was used often or all the time (100%), whereas 62.5% of analysts within individual sports made use of this often or all the time. Comparatively none of the analysts working with timed sports used this technique at that level.



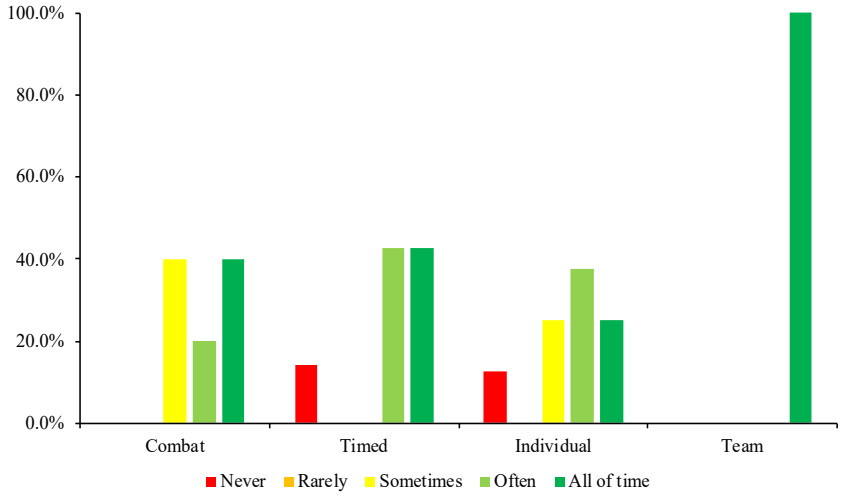
6.3.12 Competition – Video of Strengths and Weaknesses

Analysts tended to report the use of competition strengths/weakness video was used often or all the time across the type of sports assessed (Kruskal-Wallis H = 2.77, df = 3, $p>.05$; $eta^2 = -0.06$). A number of analysts working in individual (12.5%) and timed (14.3%) sports reported this was never used with their athletes.



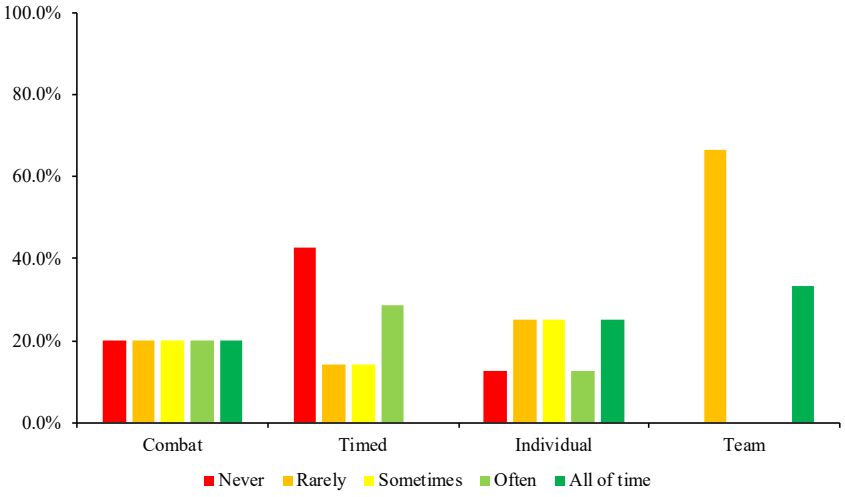
6.3.13 Competition – Reports

The majority of analysts reported they used competition reports often or all the time (Kruskal-Wallis H =4.27, df = 3, p>.05; eta^2 = 0.01). Analysts working in team sports (100%) reported the most consistent approach. A small number of timed (14.3%) and individual (12.5%) sport analysts reported they never used this type of analysis method.



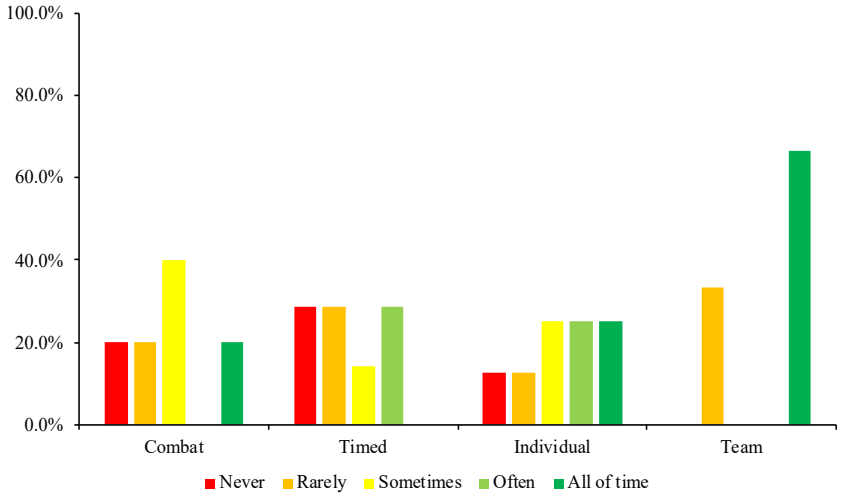
6.3.14 Competition – Profiling

Analysts reported the use of competition profiling differed dependent on the type of sport worked for (Kruskal-Wallis H = 1.55, df = 3, p>.05; eta^2 = -0.11). Analysts working in team (66.7%) sports reported they rarely made use of this, whereas 33.3% of the same sport group stated they used this all the time.



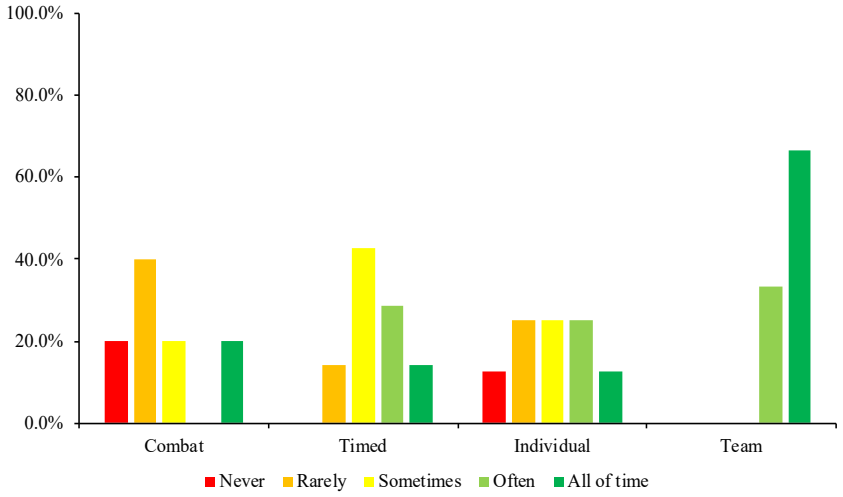
6.3.15 Competition – Trend and Data Analysis

Analysts reported the use of competition trend and data analysis differed dependent on the type of sport worked for (Kruskal-Wallis H = 3.14, df = 3, p>.05; eta^2 = -0.04). Analysts working in team (66.7%) sports reported they used this all the time, whereas 33.3% of the same sport group stated they rarely used this.



6.3.16 Competition – Reports of Strengths and Weaknesses

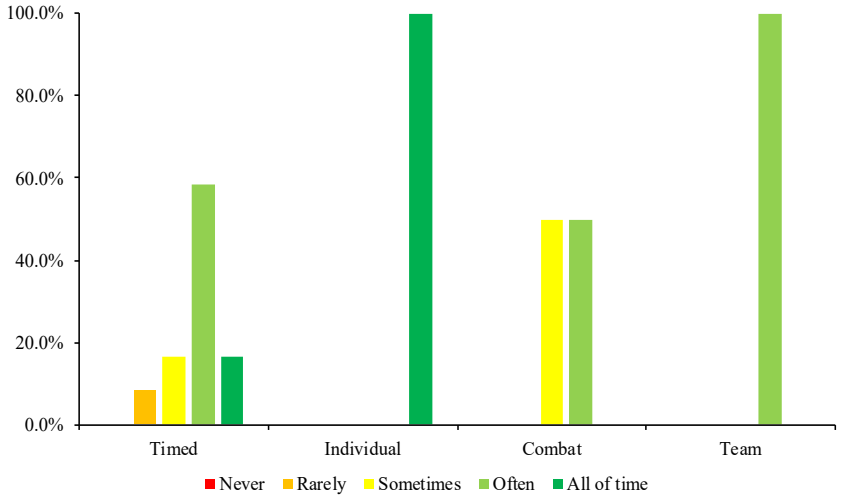
Analysts reported the use of competition strength and weakness reports differed dependent on the type of sport worked for (Kruskal-Wallis H = 5.41, df = 3, p>.05; eta^2 = 0.08). Analysts working in team (100%) sports reported they used this all the time or often, whereas 60% of combat sport analysts never or rarely used this analysis method.



Appendix 7.1 Factors influencing analysis direction

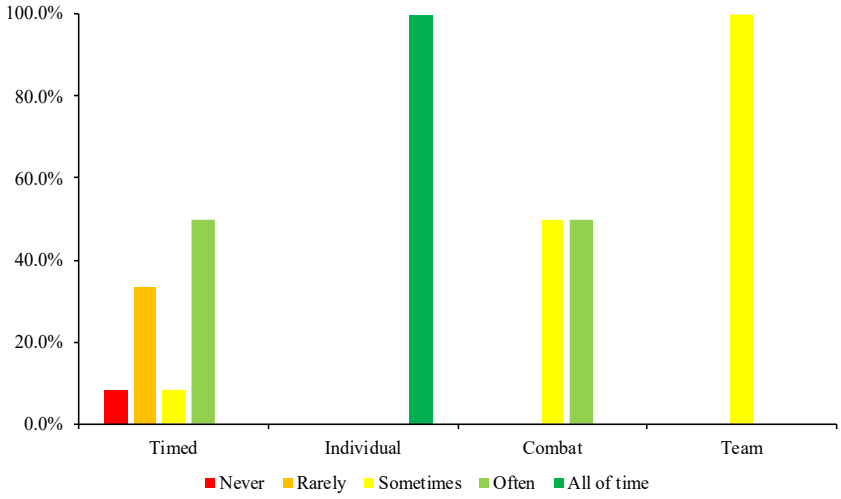
7.1.1 Coaching Experience

Coaches reported the influence of coaching experience differently dependent on the type of sport worked for (Kruskal-Wallis H = 3.55, df = 3, p>.05; eta^2 = -0.02). Coaches working in individual sports tended to report (100%) this influenced them all of the time whereas team (100%), timed (58.3%), and combat (50%) said this occurred often.



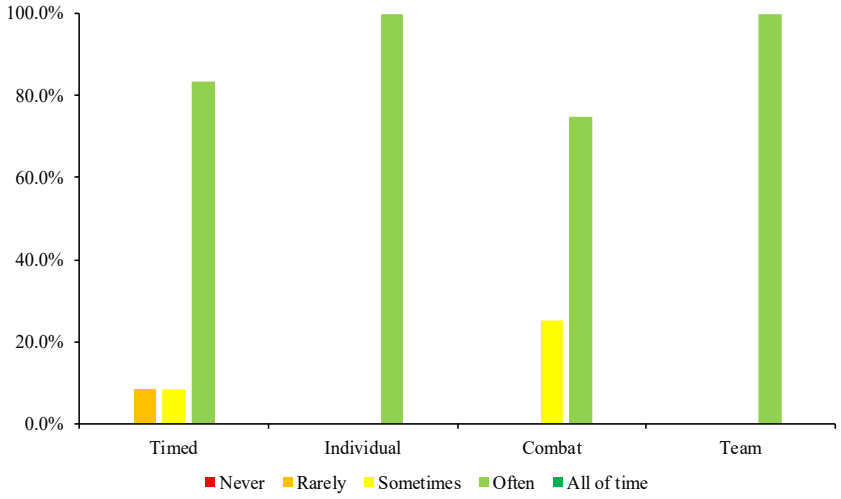
7.1.2 Performance Analyst Experience

Coaches reported the influence of performance analyst experience differently dependent on the type of sport worked for (Kruskal-Wallis H = 3.52, df = 3, p>.05; eta^2 = -0.02). Coaches working in individual sports tended to report (100%) this influenced them all of the time, whereas a mixed response was reported by those working within timed sports.



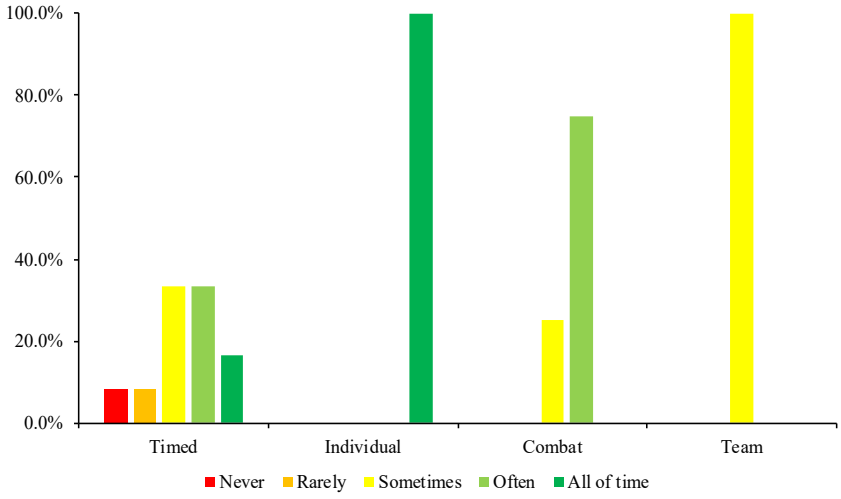
7.1.3 Other Coaches

Coaches reported the influence of other coaches similarly irrespective of the type of sport worked for (Kruskal-Wallis H = 0.51, df = 3, p>.05; eta^2 = -0.16). Over 75% of all coaches questioned within each sport reported that other coaches impacted upon analysis direction often.



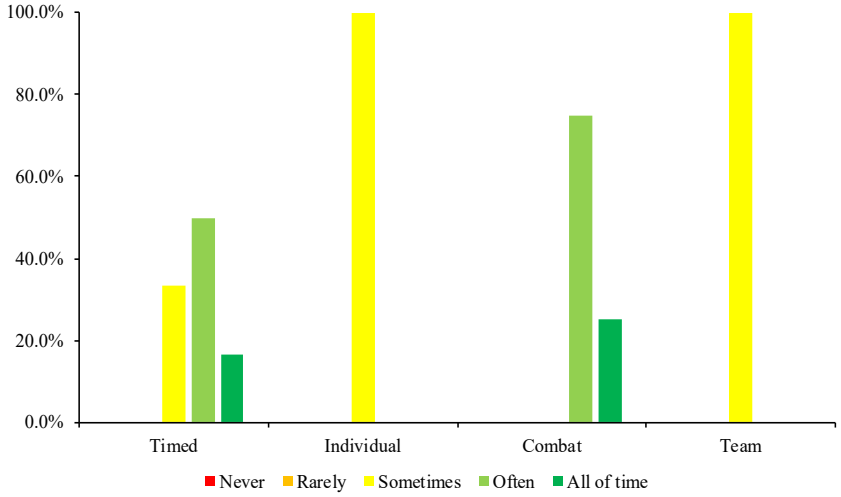
7.1.4 Academic Literature

Coaches reported the influence of academic literature differently dependent on the type of sport worked for (Kruskal-Wallis H = 3.09, df = 3, p>.05; eta^2 = -0.05). Coaches working in individual sports tended to report (100%) this influenced them all of the time, whereas a mixed response was reported by those working within timed sports.



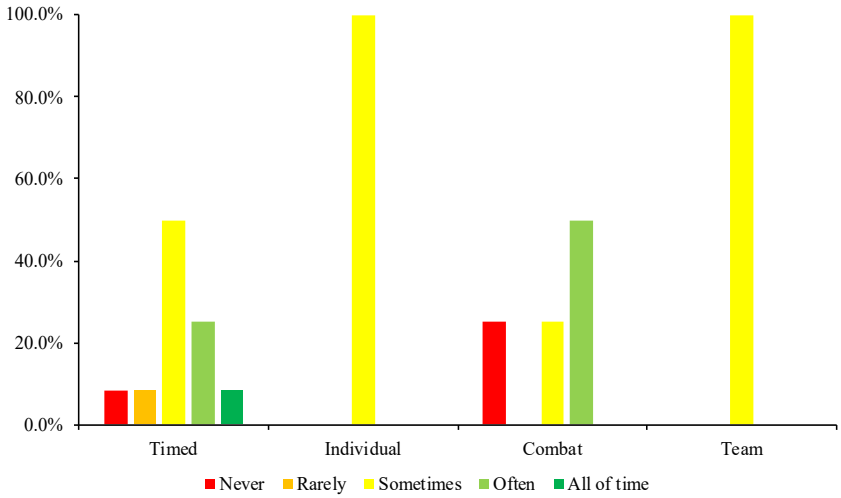
7.1.5 Training Goals

Coaches reported the influence of training goals similarly across two sports groups, timed/combat and individual/team (Kruskal-Wallis H = 4.53, df = 3, p>.05; $eta^2 = 0.03$). Coaches working in individual and team sports tended to report (100%) this influenced them sometimes, whereas 66.7% of coaches within timed and 100% within combat reported this influenced them often or all the time.



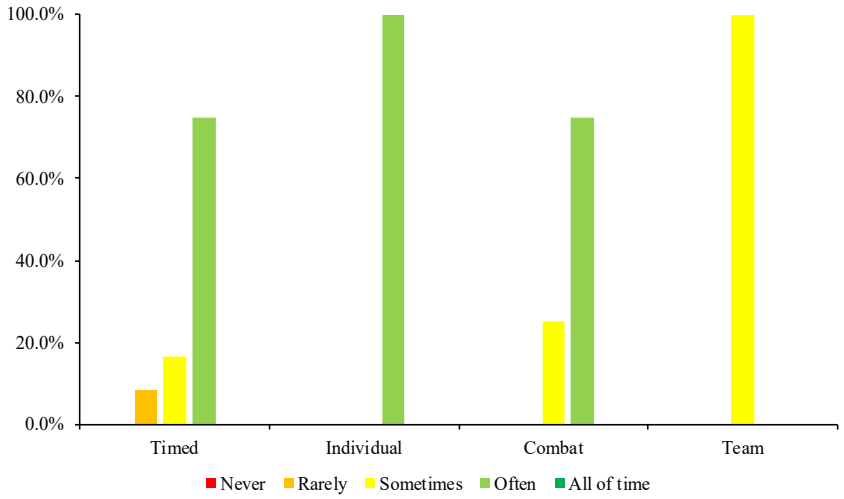
7.1.6 Forthcoming Competition

Coaches reported the influence of forthcoming competition differently dependent on the type of sport worked for (Kruskal-Wallis H = 0.22, df = 3, p>.05; $eta^2 = -0.17$). Coaches working in individual and team sports tended to report (100%) this influenced them sometimes, whereas combat (50%) and timed (33.3%) reported this occurred all the time or often.



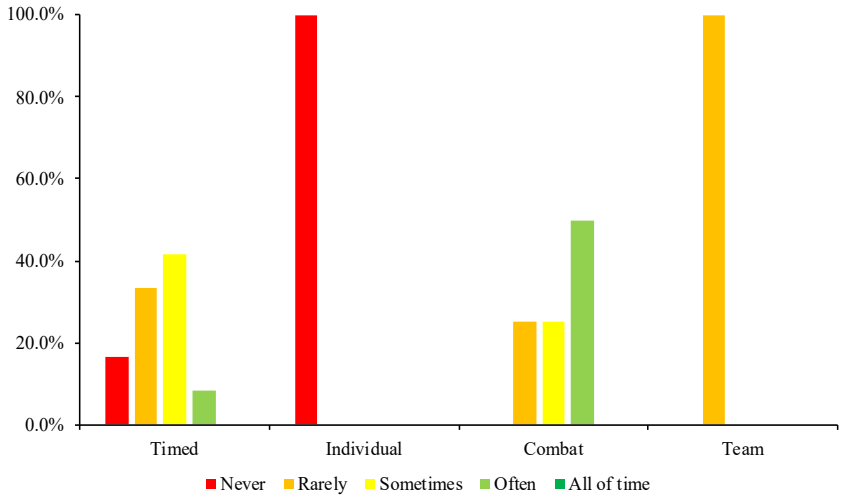
7.1.7 Period within Season

Coaches reported that period with the season influenced analysis direction similarly irrespective of the type of sport worked for (Kruskal-Wallis H = 2.47, df = 3, p>.05; eta^2 = -0.07). Over 75% of coaches within timed, individual and combat sports reported that period within season impacted upon analysis direction often, whereas 100% of those within team sports said this occurred sometimes.



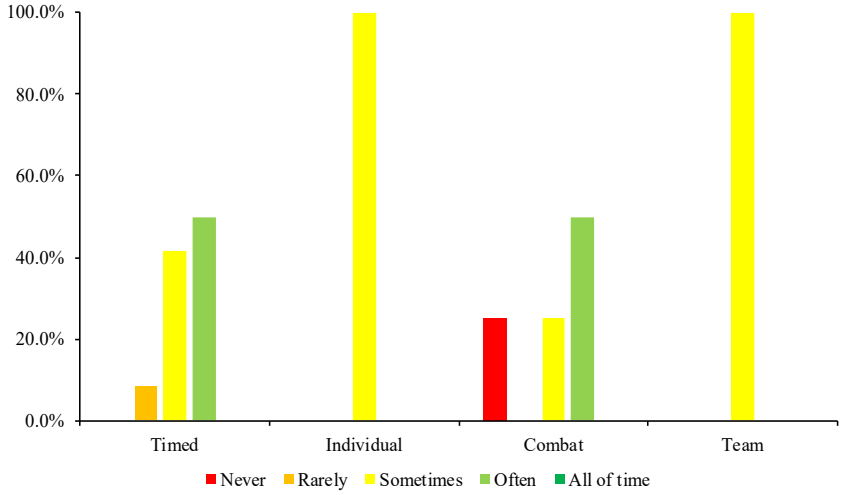
7.1.8 Level / Age of Athlete

Coaches reported that the level or age of athletes they were working with impacted upon analysis direction differently dependent upon the sport worked for (Kruskal-Wallis H = 4.70, df = 3, p>.05; eta^2 = 0.04). A mixed response was reported within timed and combat sports, however, 100% of those working within individual and team sports said this occurred never and rarely respectively.



7.1.9 Discussion with Athletes

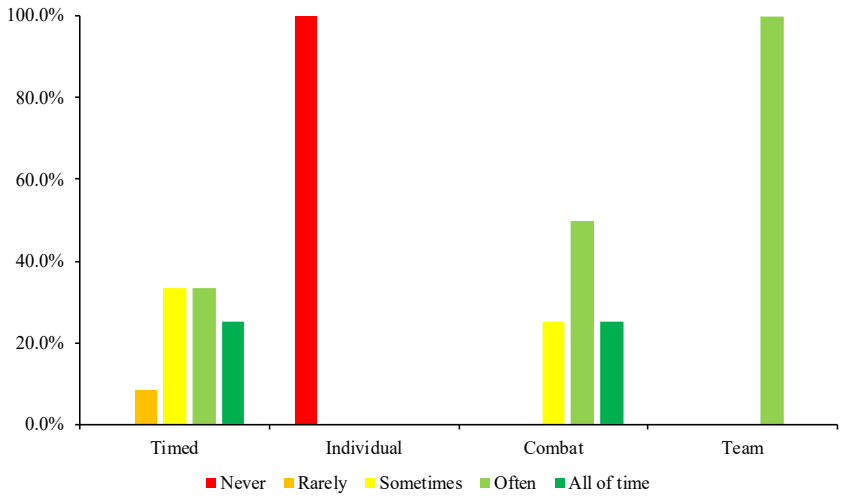
Coaches reported that discussion with athletes influenced analysis direction differently dependent on the type of sport worked for (Kruskal-Wallis H = 0.98, df = 3, p>.05; eta^2 = -0.14). Coaches working in individual and team sports tended to report (100%) this influenced them sometimes, whereas combat (50%) and timed (50%) reported this occurred often.



Appendix 7.2 Factors affecting feedback provision

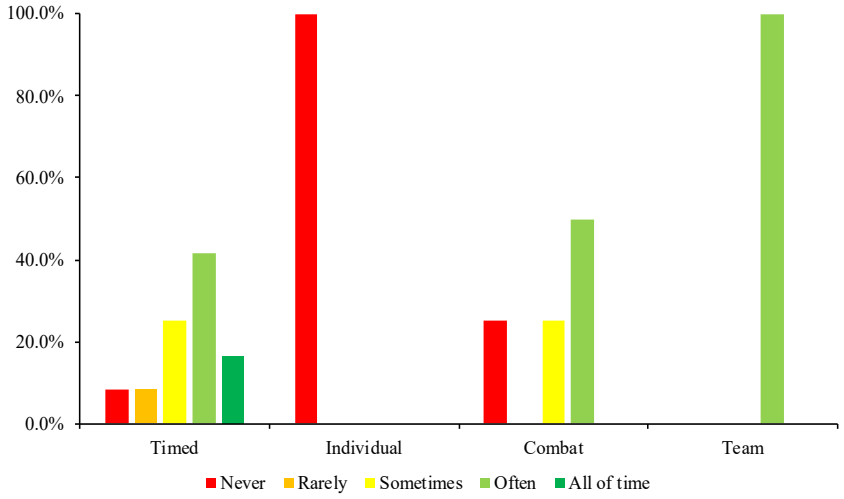
7.2.1 Time Available

Coaches reported that time available affected feedback provision differently dependent on the type of sport worked for (Kruskal-Wallis H = 3.17, df = 3, p>.05; eta^2 = -0.04). Coaches working in individual and team sports tended to report (100%) this influenced them never and often, whereas > 50% of coaches within combat and timed reported this occurred often or all the time.



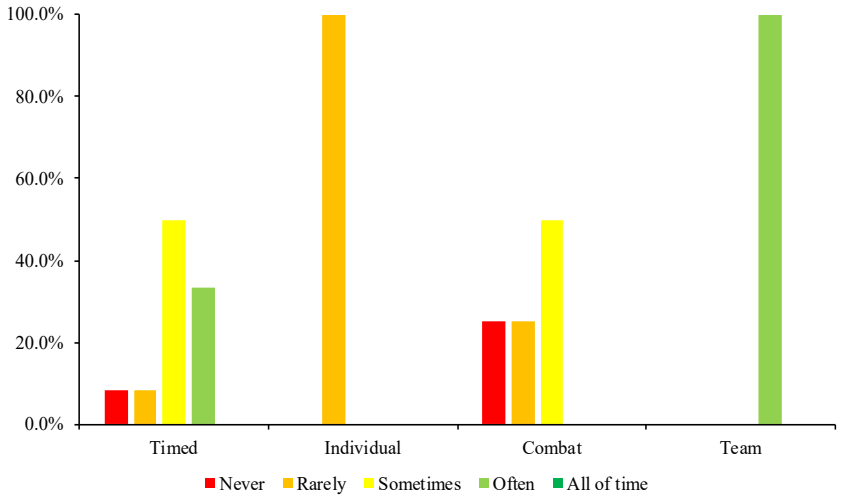
7.2.2 Time Taken

Coaches reported that time taken to complete analysis affected feedback provision differently dependent on the type of sport worked for (Kruskal-Wallis H = 3.01, df = 3, p>.05; eta^2 = -0.05). Coaches working in individual and team sports tended to report (100%) this influenced them never and often, whereas > 50% of coaches within combat and timed reported this occurred often or all the time.



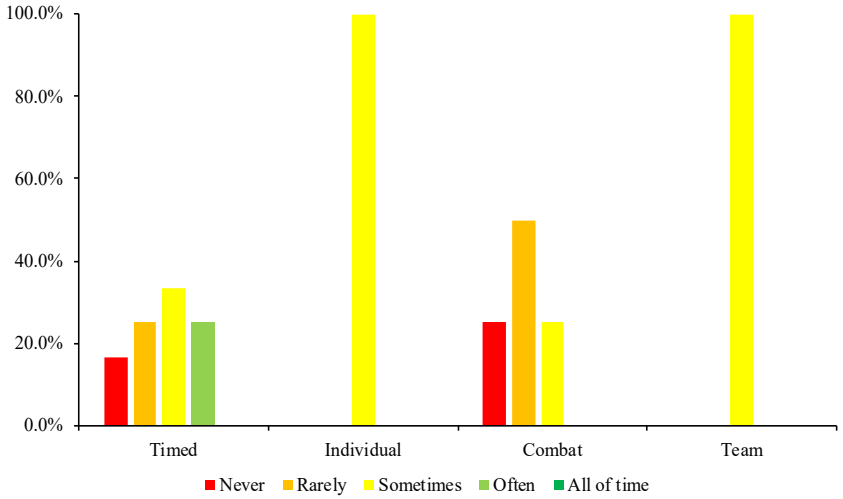
7.2.3 Feedback Quantity Concerns

Coaches reported that concerns over feedback quantity affected feedback provision differently dependent on the type of sport worked for (Kruskal-Wallis H = 5.18, df = 3, p>.05; $eta^2 = 0.07$). All coaches working in team (100%) and individual (100%) reported this occurred often or rarely, whereas 33.3% of coaches within timed sports said this often occurred.



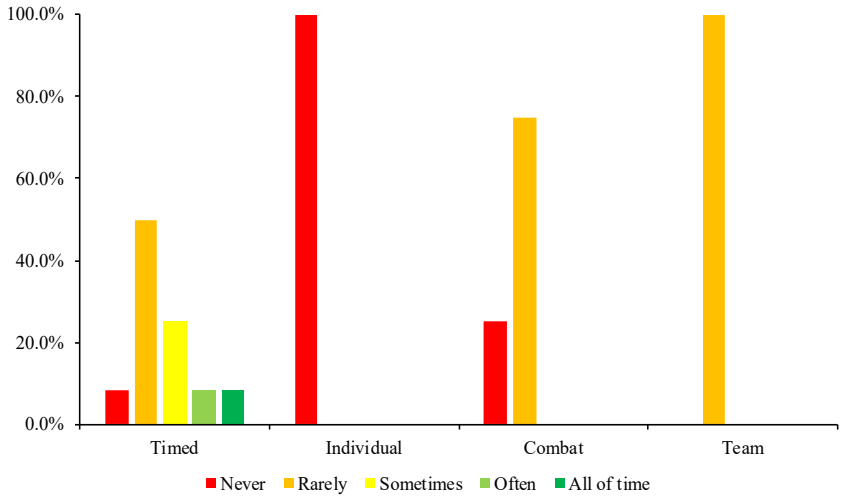
7.2.4 What to Deliver Concerns

Coaches reported that concerns over what to deliver to athletes had limited impacted upon practice (Kruskal-Wallis H = 2.02, df = 3, p>.05; $eta^2 = -0.09$). The majority of coaches reported this impacted them sometimes or less frequently, with only 25% of coaches working within timed sports reporting this occurred often.



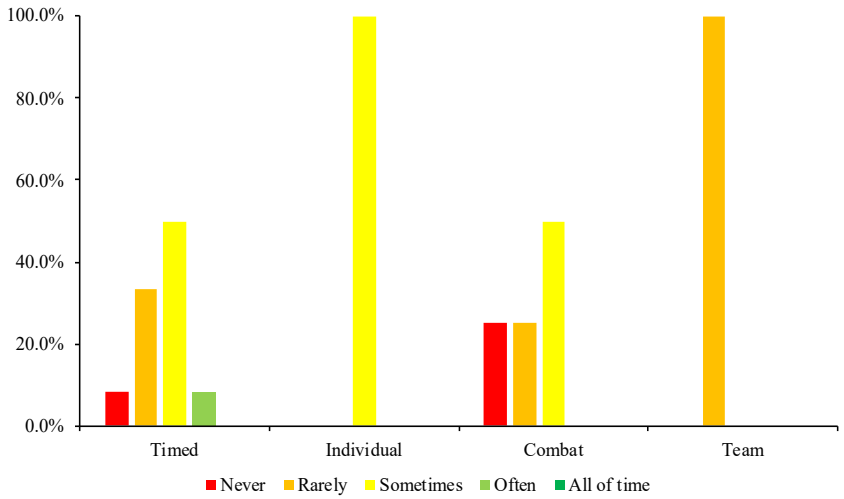
7.2.5 Analysis Reliability

Coaches reported that concerns over what to deliver to athletes had limited impacted upon practice (Kruskal-Wallis H = 4.91, df = 3, p>.05; $eta^2 = 0.05$). The majority of coaches reported this impacted them rarely or never. Only 25% of coaches working within timed sports reported this occurred sometimes, with 16.7% of coaches reporting this occurred often or all the time.



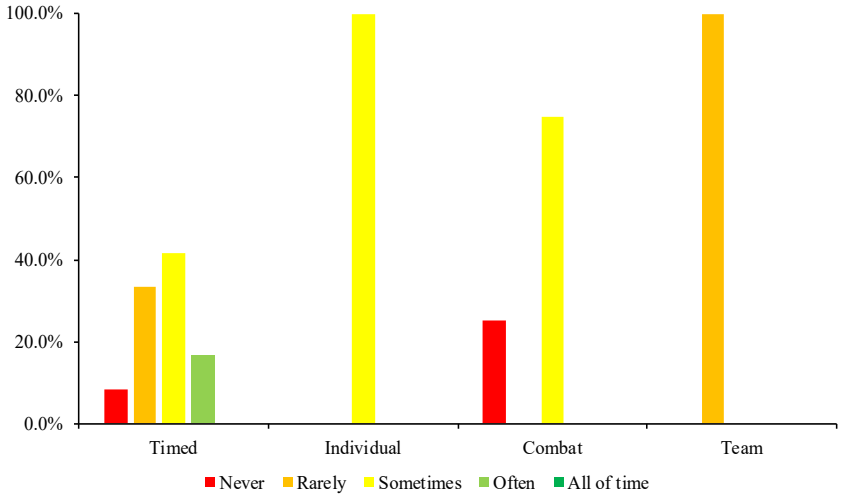
7.2.6 Buy-In to Performance Analysis

Coaches reported that their buy-in to performance analysis had limited impact upon feedback provision (Kruskal-Wallis H = 1.55, df = 3, p>.05; $eta^2 = -0.11$). The majority of coaches reported this impacted them sometimes or less frequently, with only 8.3% of coaches working within timed sports reporting this impacted them often.



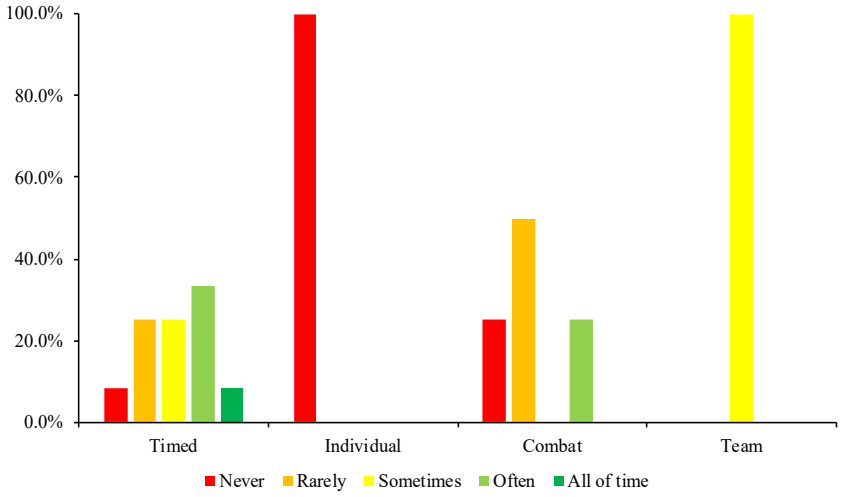
7.2.7 Buy-In to Feedback

Coaches reported that their buy-in to feedback had limited impact upon feedback provision (Kruskal-Wallis H = 1.11, df = 3, p>.05; eta^2 = -0.13). The majority of coaches reported this impacted them sometimes or less frequently, with only 16.7% of coaches working within timed sports reporting this impacted them often.



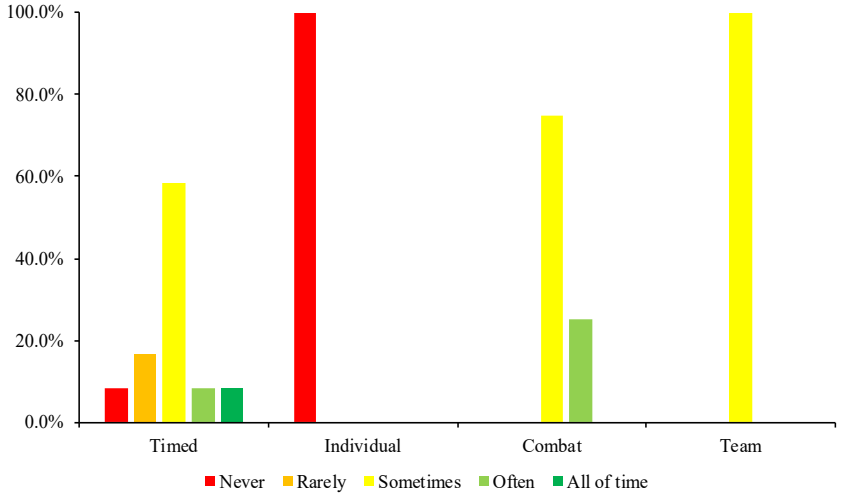
7.2.8 Equipment Availability

Coaches reported that equipment availability affected feedback provision differently dependent on the type of sport worked for (Kruskal-Wallis H = 3.62, df = 3, p>.05; eta^2 = -0.02). All coaches working in team (100%) and individual (100%) reported this occurred sometimes or never, whereas 41.6% and 25% of coaches within timed and combat sports said this occurred often or all the time.



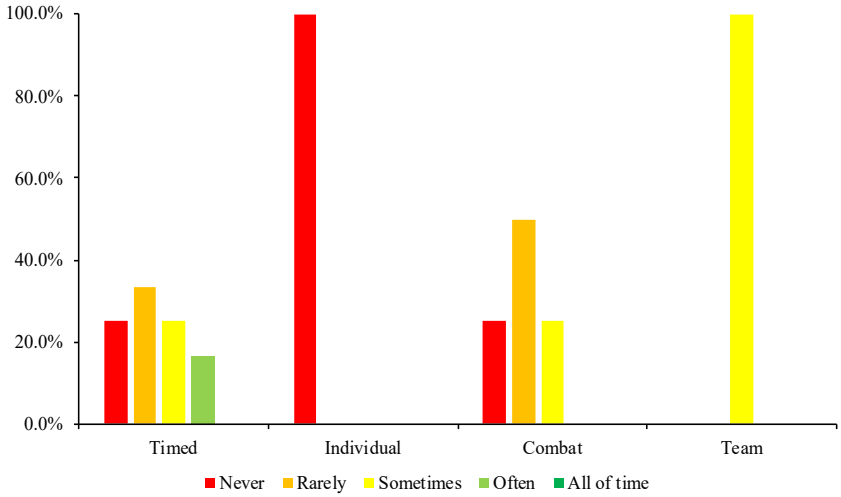
7.2.9 Training Time

Coaches reported that conflict between training time and feedback had limited impact upon feedback provision (Kruskal-Wallis H = 3.76, df = 3, p>.05; eta^2 = -0.01). The majority of coaches reported this impacted them sometimes or less frequently, with only 25% and 16.7% of coaches working within combat and timed sports respectively reporting this impacted them often or all the time.



7.2.10 Other Staff Sessions

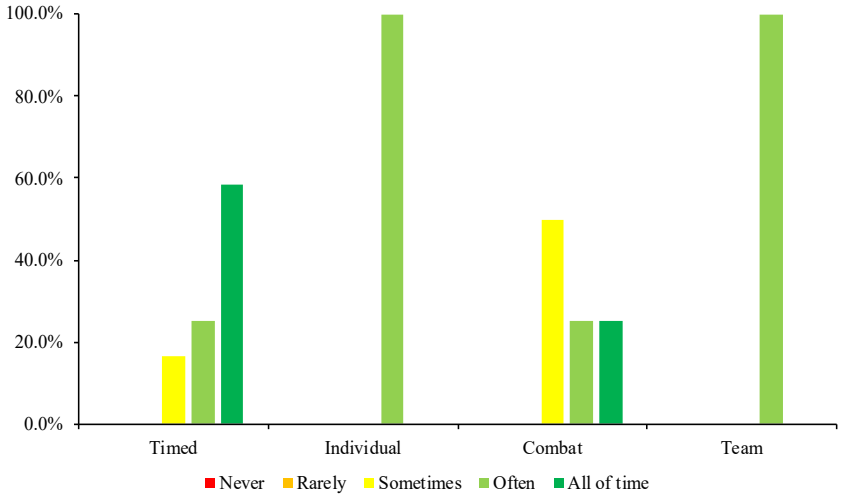
Coaches reported that other staff sessions had limited impact upon feedback provision (Kruskal-Wallis H = 2.65, df = 3, p>.05; eta^2 = -0.07). The majority of coaches reported this impacted them sometimes or less frequently, with only 16.7% of coaches working within timed sports reporting this impacted them often.



Appendix 7.3 Type of performance analysis provided

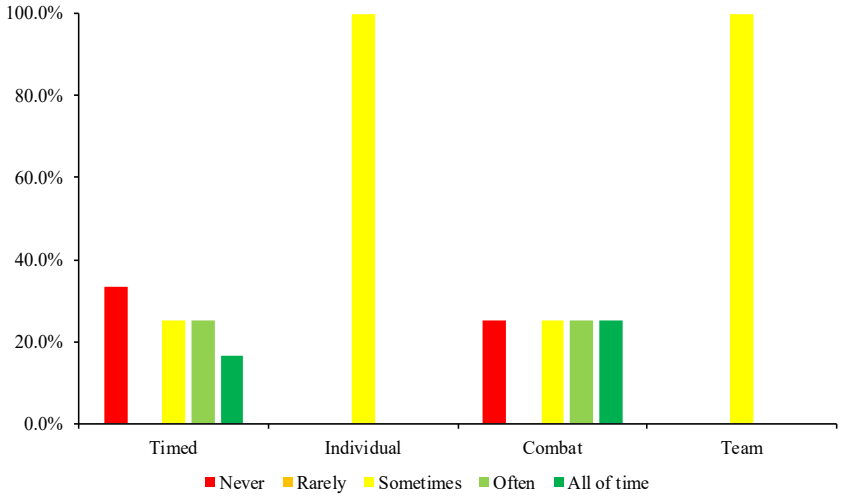
7.3.1 Competition – Full Video

Coaches reported the consistent use of full video within competition irrespective of the type of sport worked for (Kruskal-Wallis H = 2.31, df = 3, p>.05; eta^2 = -0.08). The majority of coaches within all sports reported this was used often or all the time, however, 50% and 16.7% of coaches within combat and timed sports respectively said they only sometimes made use of full performance video.



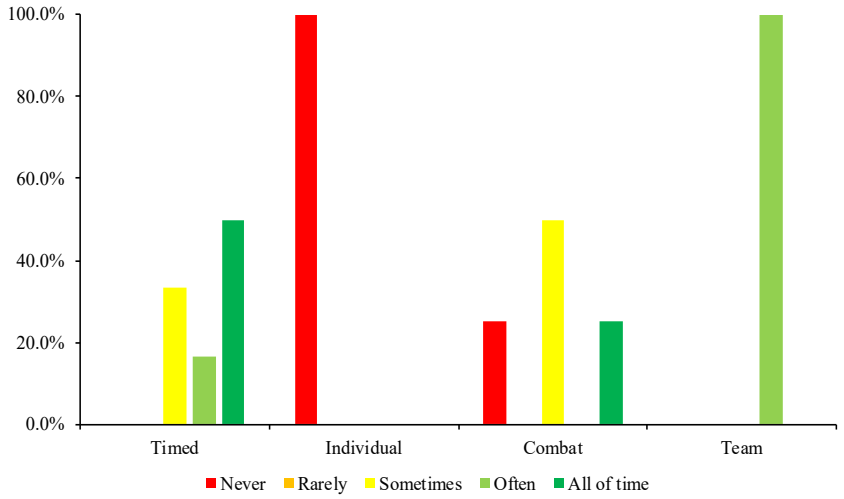
7.3.2 Competition – Edited Video

Coaches reported the use of edited video within two main patterns dependent upon sport worked for (Kruskal-Wallis H = 0.24, df = 3, p>.05; eta^2 = -0.17). All coaches within individual and team sports reported they used edited video sometimes, whereas a varied use was reported by those working within timed and combat sports.



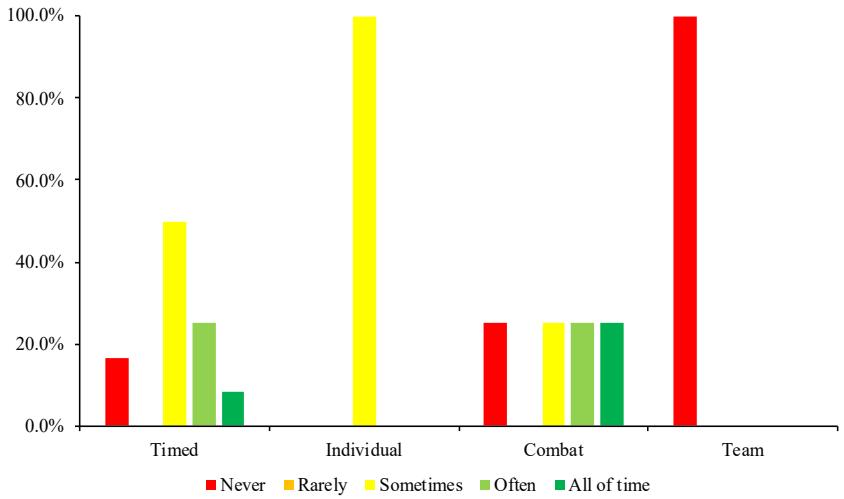
7.3.3 Competition – Performance Reports

Coaches reported the use of performance reports differed dependent upon the type of sport worked for (Kruskal-Wallis H = 4.63, df = 3, p>.05; $eta^2 = 0.03$). All coaches within individual sports reported they never used this, whereas all coaches within team sports reported they often requested performance reports. Half (50%) of coaches within timed sports, and 25% of combat sports coaches requested performance reports all the time.



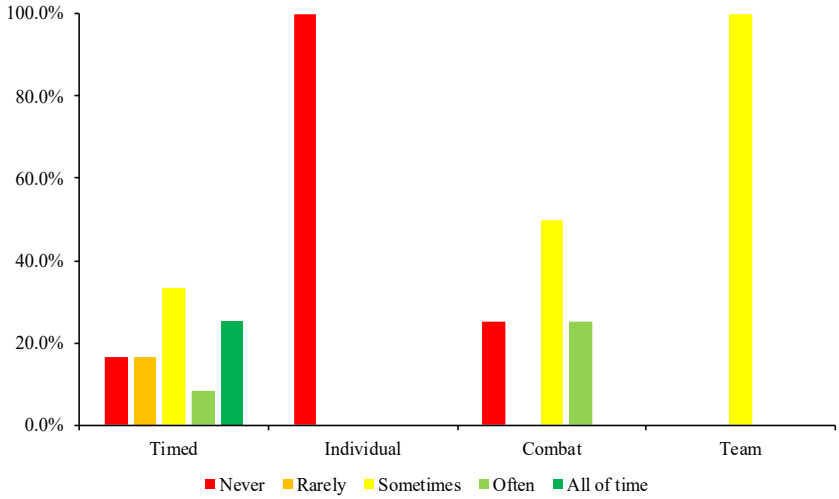
7.3.4 Competition – Profiling

Coaches reported the use of performance reports differed dependent upon the type of sport worked for (Kruskal-Wallis H = 2.24, df = 3, p>.05; $eta^2 = -0.08$). All coaches within team sports reported they never used this, whereas all coaches within individual sports reported they sometimes requested profiling.



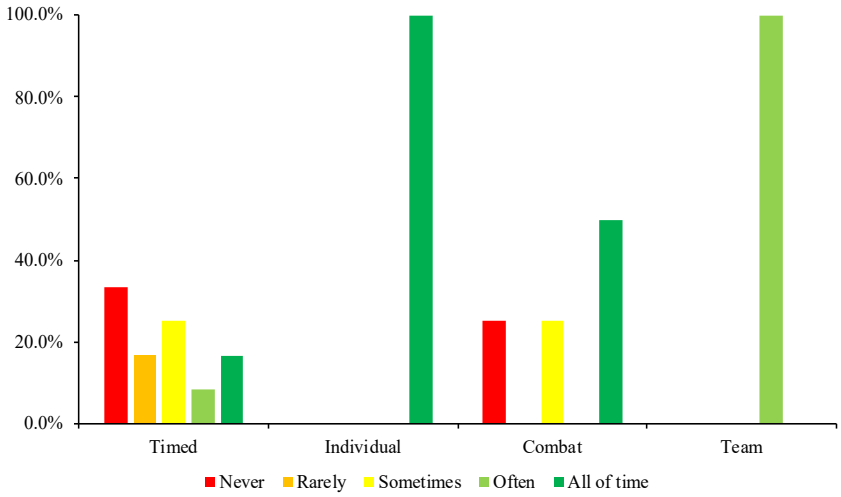
7.3.5 Competition – Live Coding

Coaches reported the use of performance reports differed dependent upon the type of sport worked for (Kruskal-Wallis H = 2.05, df = 3, p>.05; eta^2 = -0.09). All coaches within individual sports reported they never used this, whereas all coaches within team sports reported they sometimes used live coding information.



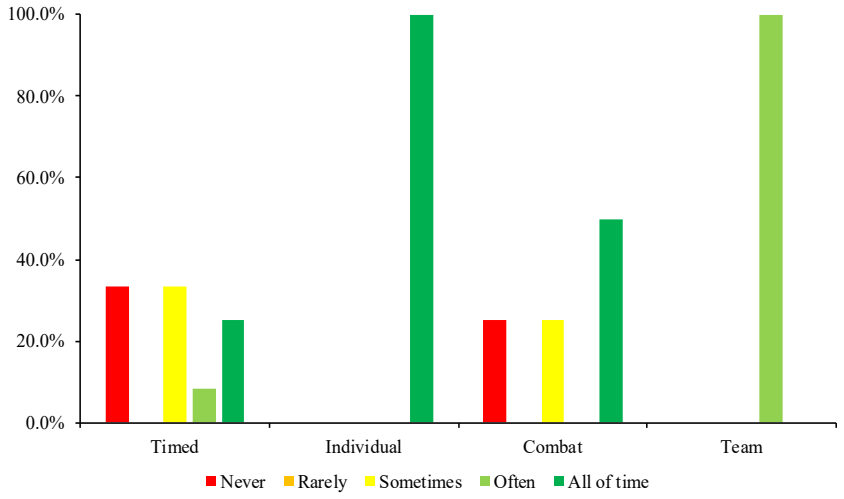
7.3.6 Competition – Opposition Strengths and Weakness Reports

Coaches reported the use of opposition strengths and weakness reports differed dependent upon the type of sport worked for (Kruskal-Wallis H = 3.08, df = 3, p>.05; eta^2 = -0.05). All coaches within individual and team sports reported they used this all the time or often, whereas 33.3% and 25% of coaches within timed and combats sports reported they never used this.



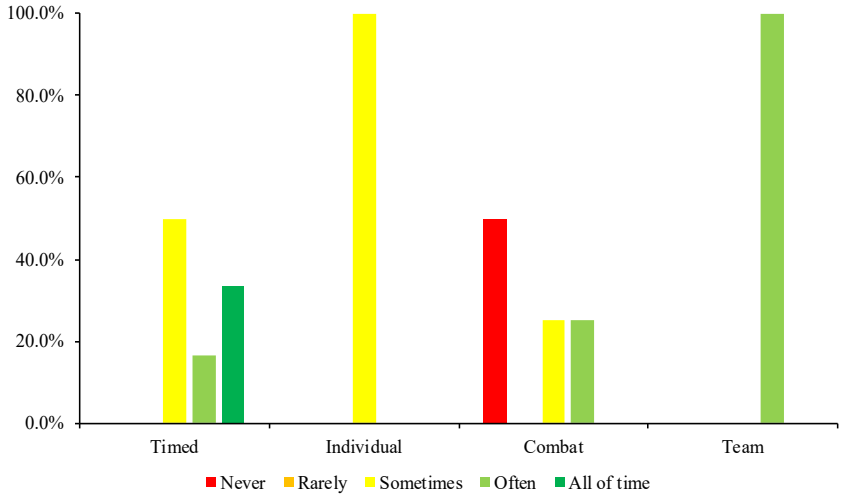
7.3.7 Competition – Opposition Strengths and Weakness Video

Coaches reported the use of opposition strengths and weakness video differed dependent upon the type of sport worked for (Kruskal-Wallis H = 2.13, df = 3, p>.05; eta^2 = -0.09). All coaches within individual and team sports reported they used this all the time or often, whereas 33.3% and 25% of coaches within timed and combats sports reported they never used this.



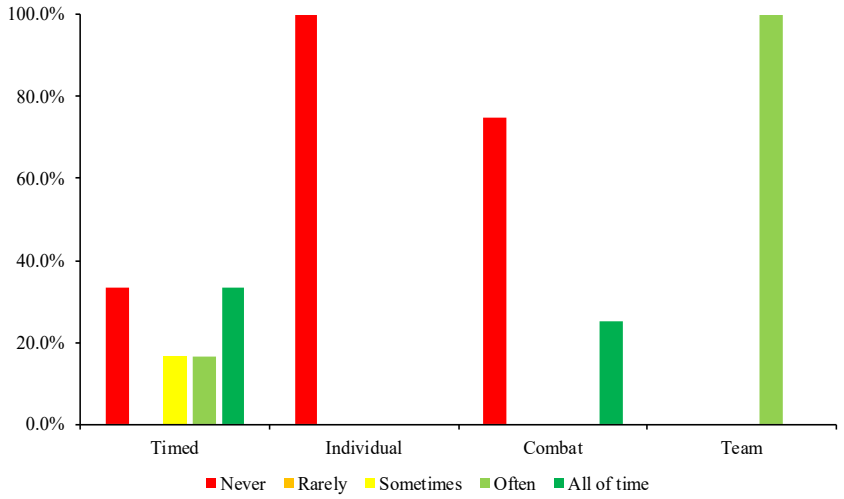
7.3.8 Competition – Trend and Data Analysis

Coaches reported the use of trend and data analysis within competition differed dependent upon the type of sport worked for (Kruskal-Wallis H = 4.07, df = 3, p>.05; eta^2 = 0.00). All coaches within team sports stated they often used this, whereas 50% of coaches within combat sports stated they never used this aspect.



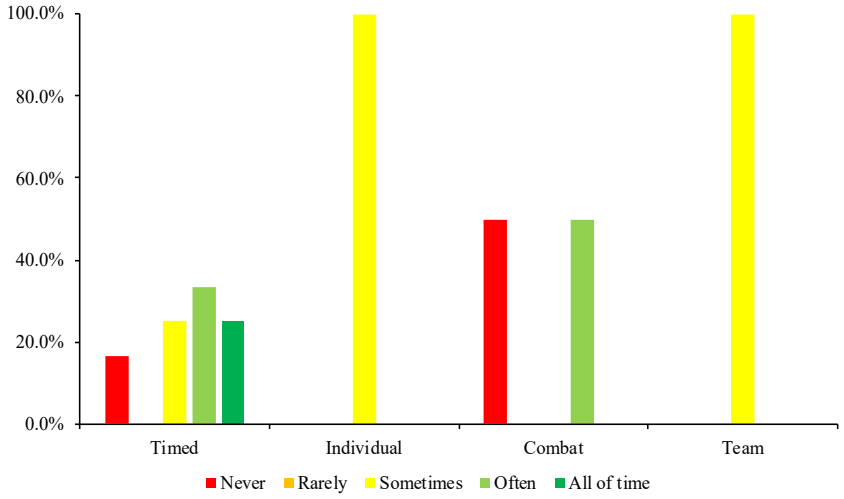
7.3.9 Training – Full Video

Coaches tended to report they either used full video of training either never or often dependent on the type of sport worked for (Kruskal-Wallis H = 2.35, df = 3, p>.05; eta^2 = -0.08). All coaches within team sports used this often, whereas coaches within individual sports reported they never used this. Combat sports coaches were split between using full video all the time (25%) and never (75%).



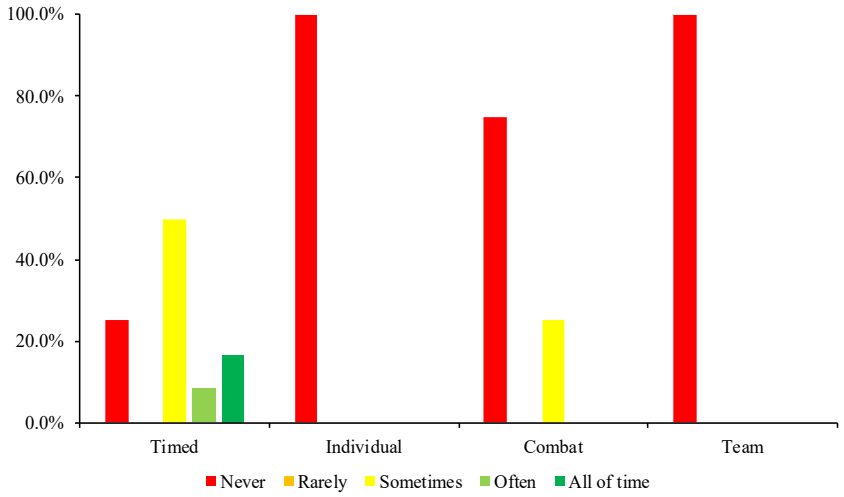
7.3.10 Training – Edited Video

Coaches reported edited video was used differently dependent on the type of sport worked for (Kruskal-Wallis H = 1.61, df = 3, p>.05; eta^2 = -0.11). All coaches within team and individual sports used this sometimes, whereas combat sports coaches were split between using edited video all the often (50%) and never (50%).



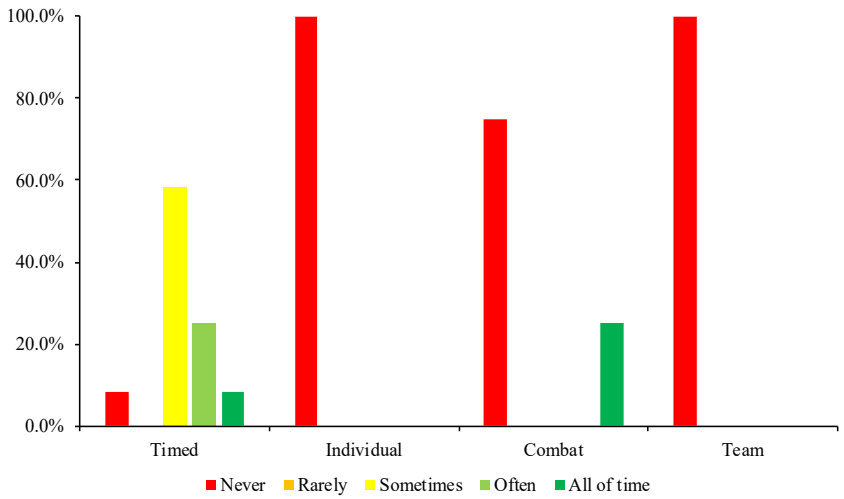
7.3.11 Training – Performance Reports

Coaches tended to report that training reports were seldom requested irrespective of the type of sport worked for (Kruskal-Wallis H = 5.39, df = 3, p>.05; $eta^2 = 0.08$). Over 75% of coaches within individual, combat, and team sports reported they never used these, whereas 25% of coaches within timed sports reported they made use of these reports often or all the time.



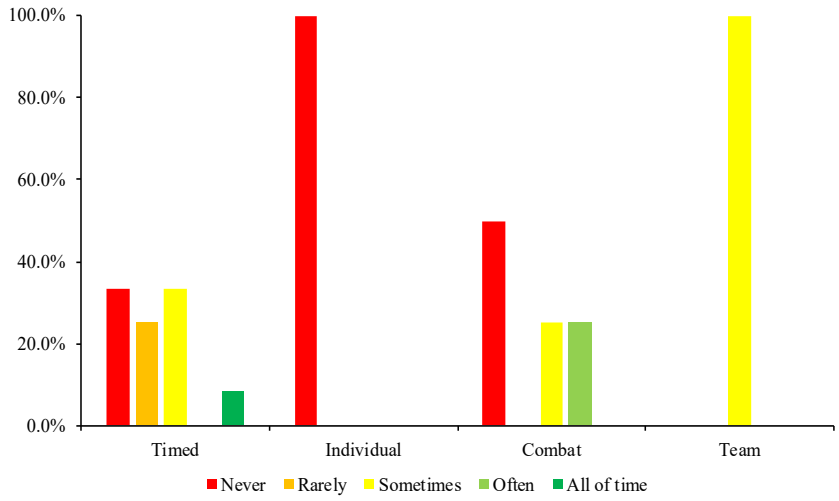
7.3.12 Training – Profiling

Coaches tended to report that training profiling was seldom requested irrespective of the type of sport worked for (Kruskal-Wallis H = 5.35, df = 3, p>.05; $eta^2 = 0.08$). Over 75% of coaches within individual, combat, and team sports reported they never used these, whereas 33.3% of coaches within timed sports reported they made use of these reports often or all the time.



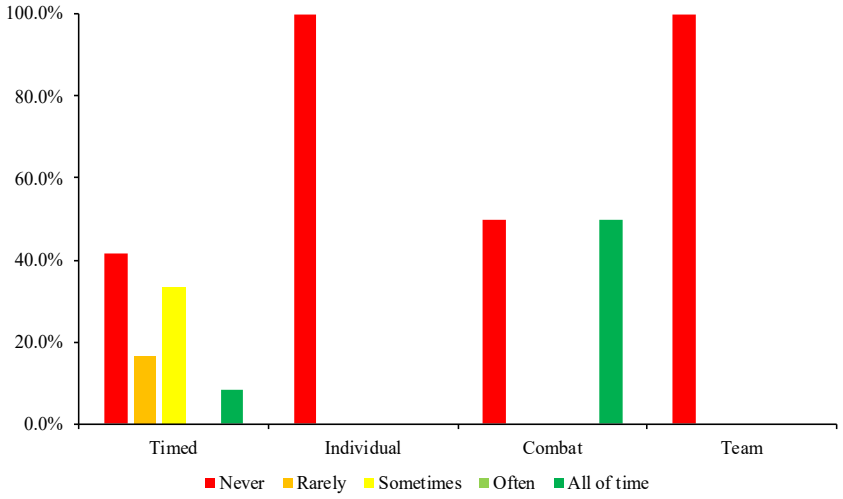
7.3.13 Training – Live Coding

Coaches reported live coding within training was seldom requested irrespective of the type of sport worked for (Kruskal-Wallis H = 1.81, df = 3, p>.05; eta^2 = -0.10). All coaches within individual and team sports reported they never or sometimes used this aspect of analysis, whereas, 25% of combat sports coaches used this often.



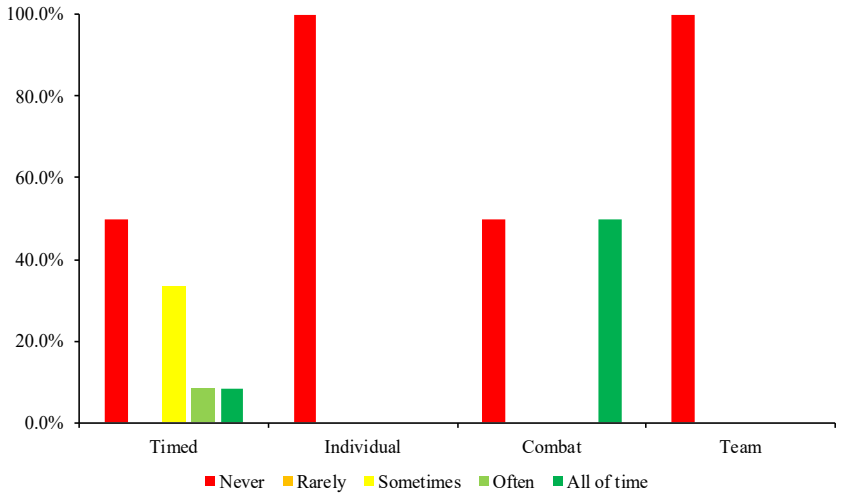
7.3.14 Training – Opposition Strengths and Weakness Reports

Coaches stated opposition reports were generally never used within training irrespective of the type of sport worked for (Kruskal-Wallis H = 2.05, df = 3, p>.05; eta^2 = -0.09). All coaches within individual and team sports reported they never used this aspect of analysis, whereas an even split was reported by combat sports coaches between never being used and being used all the time.



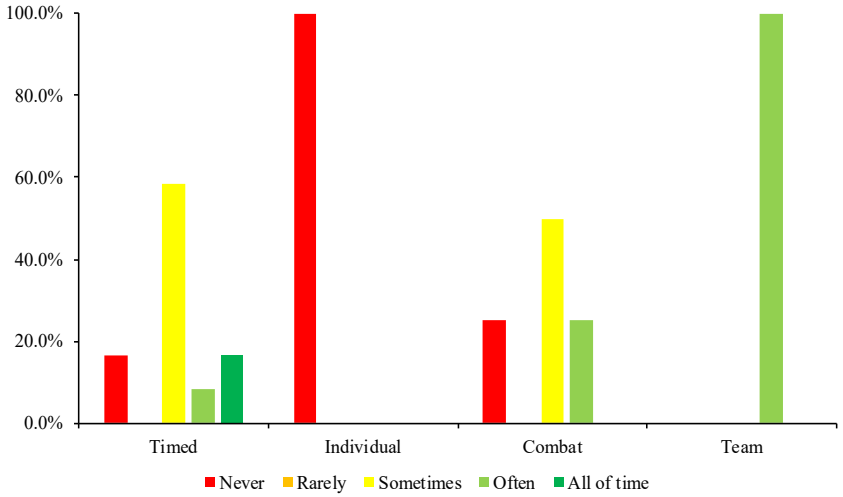
7.3.15 Training – Opposition Strengths and Weakness Video

Coaches stated opposition video were generally never used within training irrespective of the type of sport worked for (Kruskal-Wallis H = 1.91, df = 3, p>.05; eta^2 = -0.10). All coaches within individual and team sports reported they never used this aspect of analysis, whereas an even split was reported by combat sports coaches between never being used and being used all the time.



7.3.16 Training – Trend and Data Analysis

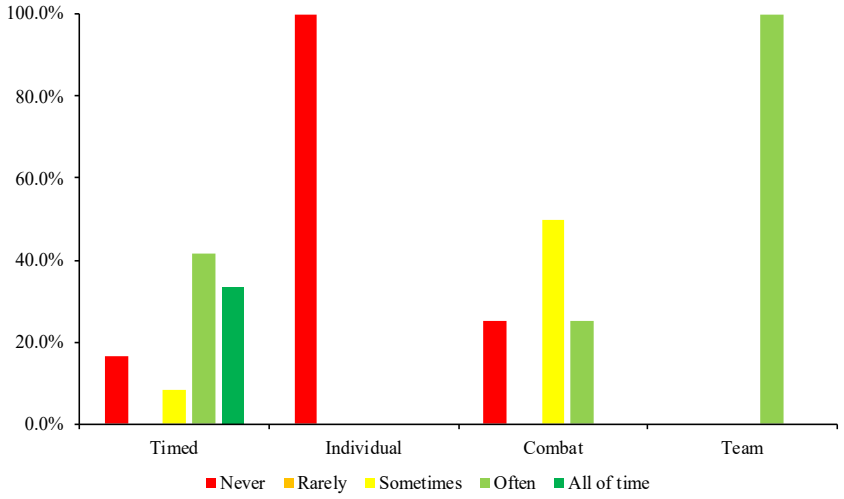
Coaches tended to report a mixed use of trend and data analysis within training dependent on the type of sport worked for (Kruskal-Wallis H = 3.35, df = 3, p>.05; eta^2 = -0.03). All coaches within individual and team sports reported they never used this, where all team sports coaches said they used this often.



Appendix 7.4 Feedback delivery structure

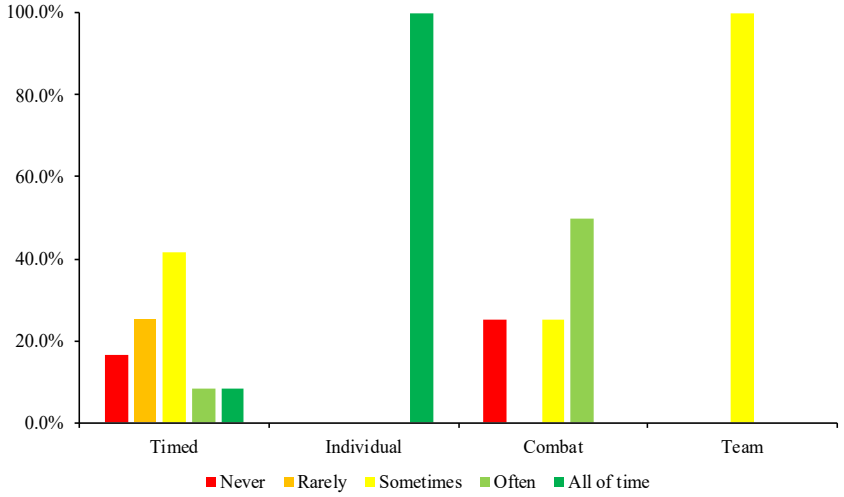
7.4.1 Consistent Approach

Coaches reported the use of a consistent feedback approach differed dependent on the type of sport worked for (Kruskal-Wallis H = 4.49, df = 3, p>.05; $eta^2 = 0.03$). All coaches working within team sports, and the majority of those within timed sports (75%) used a consistent approach often or all the time within their feedback, whereas 100% of coaches within individual sports never used this approach.



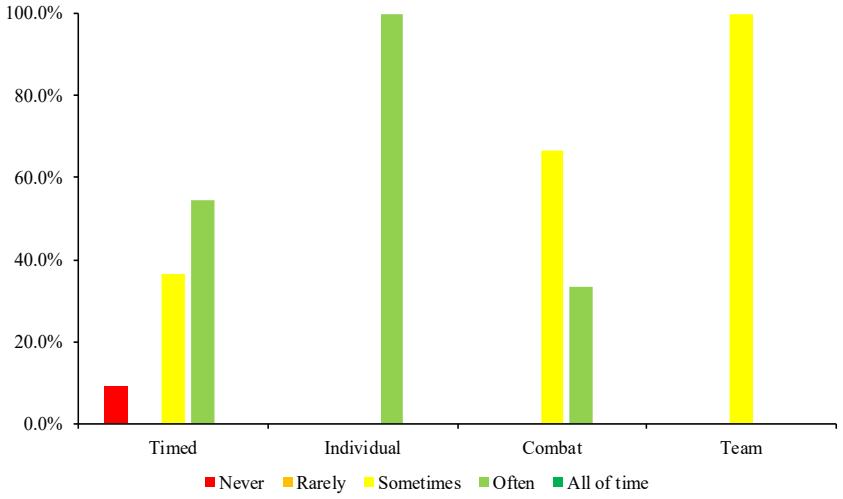
7.4.2 Varied Approach

Coaches reported the use of a varied feedback approach differed dependent on the type of sport worked for (Kruskal-Wallis H = 3.07, df = 3, p>.05; $eta^2 = -0.05$). All coaches working within individual sports used a varied approach, whereas this was used sometimes by those working within team sports.



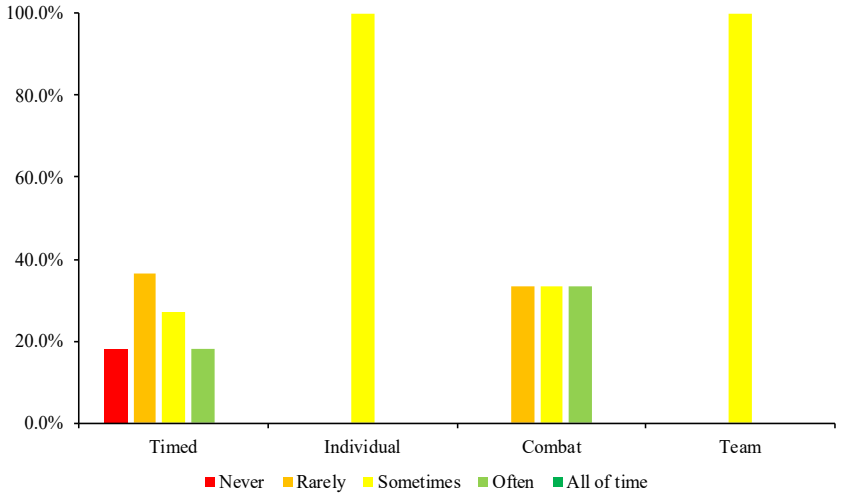
7.4.3 Coach Led Approach

Coaches reported the use of a coach led approach was generally used often or sometimes across all sport types (Kruskal-Wallis H = 1.77, df = 3, p>.05; eta^2 = -0.11). All coaches working within individual, 54.5% within time, and 33.3% within combat sports used this often.



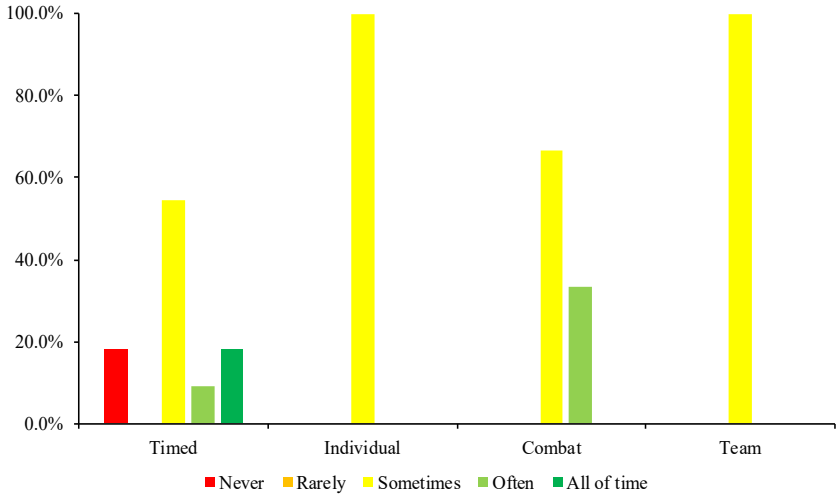
7.4.4 Analyst Led Approach

Coaches reported the use of an analyst led approach was seldom used irrespective of the type of sport worked for (Kruskal-Wallis H = 1.15, df = 3, p>.05; eta^2 = -0.13). All coaches working within individual and team sports used this sometimes, whereas only 33.3% of combat and 18.2% of timed sports coaches employed this approach often.



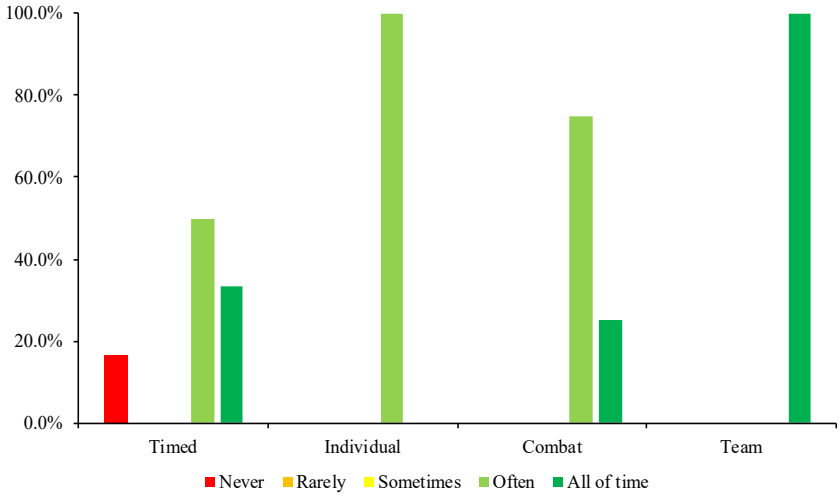
7.4.5 Combined Approach

Coaches reported the use of a combined approach was generally only used sometimes across all sport types (Kruskal-Wallis H = 0.30, df = 3, p>.05; eta^2 = -0.16). All coaches working within individual and team sports used this sometimes, whereas only 33.3% of combat and 27.3% of timed sports coaches employed this approach often or all the time.



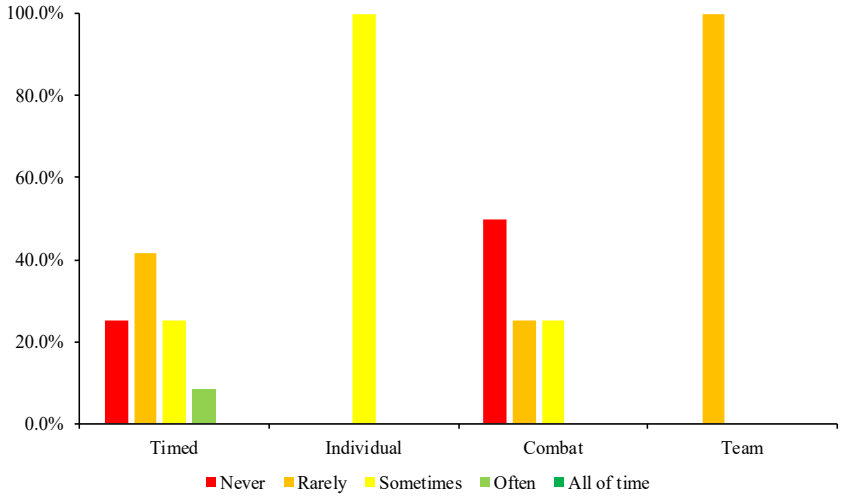
7.4.6 Face-to-Face Delivery

Coaches reported the use of a face-to-face delivery method was generally used irrespective of the type of sport worked for (Kruskal-Wallis H = 1.83, df = 3, p>.05; eta^2 = -0.10). Only 16.7% of coaches working within timed sports reported that they never used this approach, compared to being used often or all the time by the remaining coaches and sports.



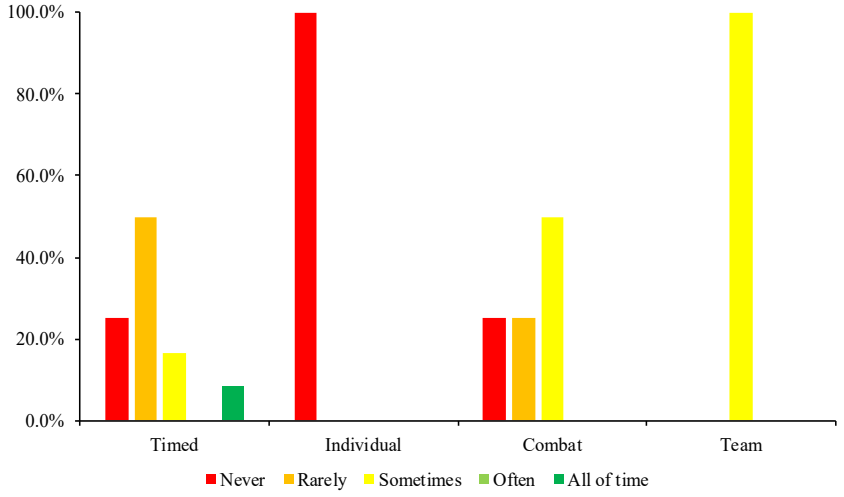
7.4.7 Video / Phone Delivery

Coaches reported the use of a video or phone delivery method was seldom used irrespective of the type of sport worked for (Kruskal-Wallis H = 1.84, df = 3, p>.05; eta^2 = -0.10). Only 8.3% of coaches working within timed sports reported that they used this approach often.



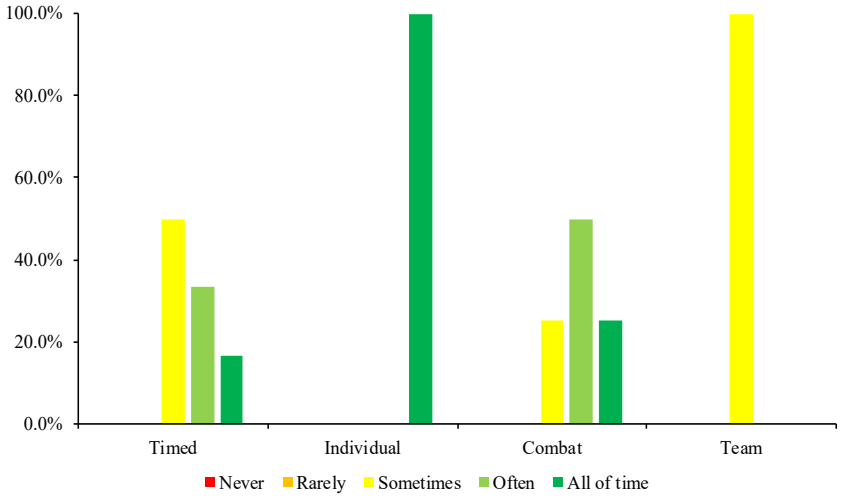
7.4.8 Online Delivery

Coaches reported the use of online delivery methods was seldom used irrespective of the type of sport worked for (Kruskal-Wallis H = 3.01, df = 3, p>.05; eta^2 = -0.05). Only 8.3% of coaches working within timed sports reported that they used this approach all the time.



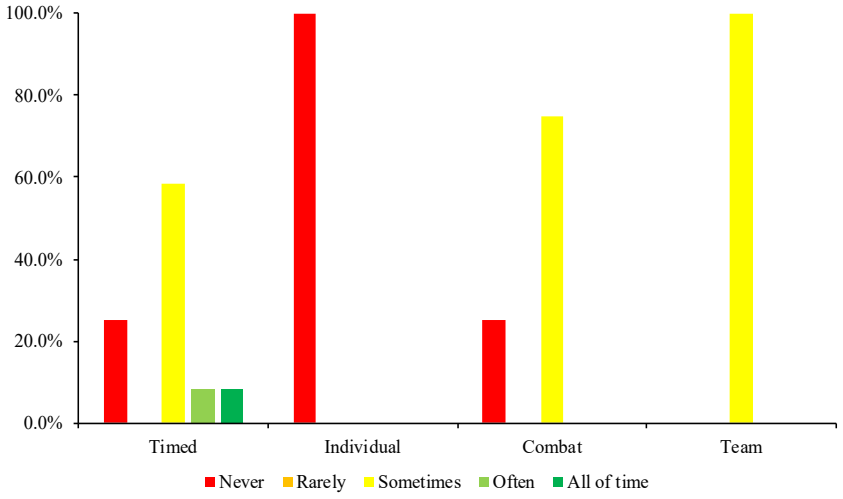
7.4.9 Individual Delivery

Coaches reported the use of an individual delivery method was generally used irrespective of the type of sport worked for (Kruskal-Wallis H = 3.58, df = 3, p>.05; eta^2 = -0.02). All coaches within individual sports used this approach all the time, whereas all coaches within team sports used this approach sometimes.



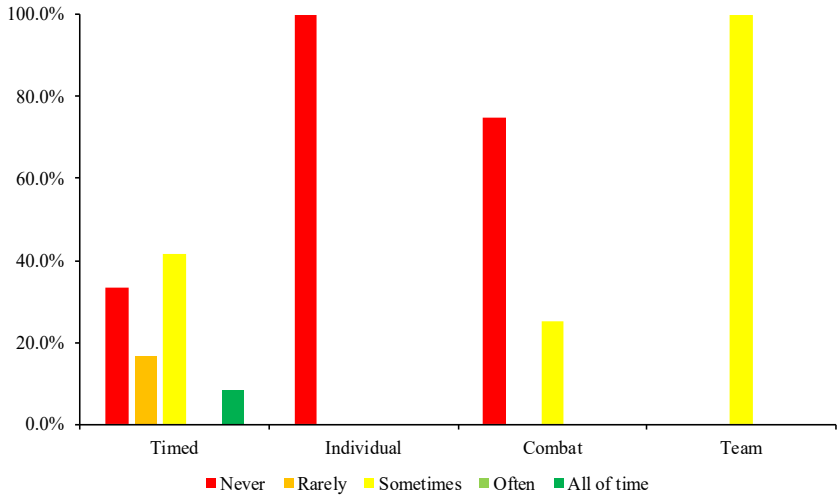
7.4.10 Small Group Delivery

Coaches reported the use of small group feedback sessions were seldom used irrespective of the type of sport worked for (Kruskal-Wallis H = 2.31, df = 3, p>.05; eta^2 = -0.08). Only 16.6% of coaches working within timed sports reported that they used this approach all the time (8.3%) or often (8.3%).



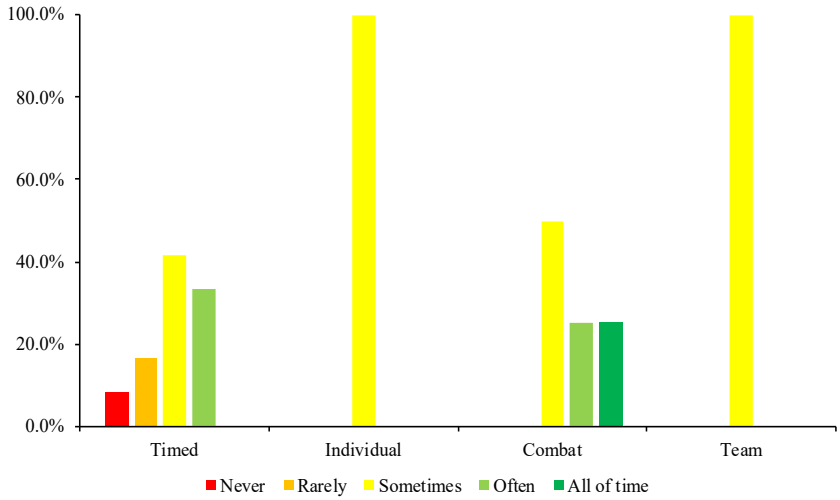
7.4.11 Team / Squad Delivery

Coaches reported the use of team or squad feedback sessions were seldom used irrespective of the type of sport worked for (Kruskal-Wallis H = 3.40, df = 3, p>.05; eta^2 = -0.03). Only 8.3% of coaches working within timed sports reported that they used this approach all the time, with 100% and 75% of coaches within individual and combat respectively reporting they never used this approach.



7.4.12 Video Delivered Before Data

Coaches reported the use of video before data within feedback sessions differed dependent on the type of sport worked within (Kruskal-Wallis H = 1.65, df = 3, p>.05; eta^2 = -0.11). All coaches within individual and team sports used this approach sometimes. Whereas, 50% within combat, and 33.3% within timed sports reported they took this approach all the time or often.



7.4.13 Data Delivered Before Video

Coaches reported the use of data before video within feedback sessions differed dependent on the type of sport worked within (Kruskal-Wallis H = 2.74, df = 3, p>.05; eta^2 = -0.06). All coaches within individual sports reported they never used this approach, whereas all coaches within team sports used this approach sometimes. Only 25% of coaches within combat sports and 16.7% of coaches within timed sports reported they took this approach often.