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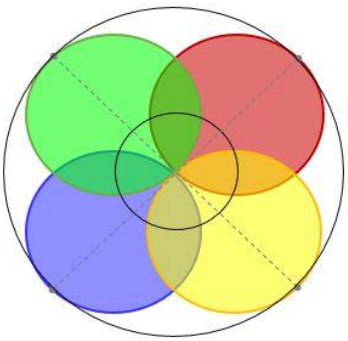


‘An exploration and theoretical schematic of the cognitions and decision-making capacities of expert Strength & Conditioning coaches’ whilst coaching classical weight lifting movements.’

Abstract

An exploration and theoretical schematic of the cognitions and decision making capacities of expert Strength & Conditioning coaches' whilst coaching classical weight lifting movements. Three expert S&C coach's (1 female and 2 males) to stimulate recall watched video footage of athletes performing weightlifting movements immediately after their coaching sessions. Whilst observing the footage they were invited to talk aloud what the ideal technical model of the lift they were observing was, then explain and describe what faults they were trying to effect and how. The interviews (six) were transcribed then analyzed to identify knowledge categories (10) and sub categories (127) that created a skeletal structure for a notational analysis. 201 coaching episodes were observed, a total of 3055 context and technical points and 548 technique errors (total 3603) were coded. A cognitive schematic and hypothetical constellation pattern and error recognition model were built from the analysis. The study found that expert S&C coaches' posses thick deep and rich knowledge content and utilise schema script based mental models in non and semi-deliberative decision making. Coaches rely most heavily on technical model and body part knowledge to identify errors in weightlifting movements. The findings of the study could be used to assist in the development of novice coaches.

Key words:

Coaching; Expert; Strength and Conditioning; Schema; Script; Knowledge; Naturalistic Decision Making; Coach development; Weightlifting; cognitive model;

Introduction

Coaching is idiosyncratic, context determined and hard to research in real world situations (Lyle & Cushion 2010). The 'art' of coaching is also said to be intuitive, tacit or reflexive (Nash & Collins 2006) with some authors describing it as a cognitive activity or decision-making process (Lyle 1999; 2002; 2010) that is difficult to explore or verbalise. Many studies attempting to quantify coaching behaviour have reported that silence, observation and instruction are key behaviours (Becker & Wrisberg 2008; Bloom; Crumpton & Anderson 1999; Claxton 1988) coaches' display in the coaching environment. To gain access and 'unlock' the space that sits between observation (Hars & Calmels 2007) and instruction, we need to reach the cognitions of the coach, by delving into their long and short-term memory, we might be able to understand the expertise of the coach and how they draw upon this in real situations.

The naturalistic decision making (NDM) paradigm (Lyle 1999; 2002; 2010; Lipshitz, Klein, Orasanu and Salas 2001) has been used to good effect to understand the cognitions of expert decision-makers, qualitative research using talk aloud and stimulated recall methods have assisted researchers to better understand the context, environmental factors, processes and knowledge that coaches' use in their domain (e.g. Abraham, Collins & Martindale 2006; Côté, Salmela Trudel; Baria & Russell 1995; Gilbert, Trudel & Haughian 1999; Jones, Armour & Potrac 2003; McCullick, Hsu, Jung, Vickers & Schuknecht 2006; Saury & Durand 1998; Vergeer & Hogg 1999; Voight & Carroll 2006). Expert decision makers appear to make decisions in the moment reflexively, they would describe them as unconscious and would find it hard to verbalise what they did and why

(Nash & Collins 2006). Mixed method approaches (Vergeer & Lyle 2007) are being applied and deployed to study coaching behaviour in coaching domains the findings of which are being used to great effect to inform coach education and development (Abraham & Collins 1998).

Strength and Conditioning (S&C) is considered a science led discipline. As a profession, S&C programmes are underpinned and led by sports science and evidence based practice (Stone, Stone & Sands 2007) but the coaching aspect of our work is poorly researched, badly understood and neglected from a research point of view. S&C coaches' utilise a variety of weightlifting exercises to develop bio-motor qualities in their athletes (Baechle & Earle 2008). These lifts are executed quickly and must be performed technically well to avoid injury and to maximise the load that can be lifted. Our understanding of the knowledge that S&C coaches' posses and how they utilise this in real coaching situations has not, until now been explored. The following study will explore the cognitions and decision-making capacities of expert Strength & Conditioning coaches' whilst coaching classical weight lifting movements. Through our findings, we will attempt to build a cognitive schematic of expert S&C coaches' knowledge and use this to make recommendations for coach education.

Literature review

Understanding coaching behaviour

Research in the domain of coaching has had a chequered but progressive past as academics try to gain insight into the expertise of those who choose to coach (Lyle 2002; 2010). Understanding the skills, knowledge, development paths, experience and expertise of coaches' is no simple task (Côté 2006; Côté & Gilbert 2009; Cushion 2007; Gilbert, Côté & Mallett 2006). In research carried out between 1970 and 2001 there was 1100 published coaching articles reviewed (Gilbert & Trudel 2004a), of the 610 that met inclusion criteria in the study, a significant finding was that across the relatively low spread of output, that a focus primarily on coaching behaviour using quantifiable methodologies has been used.

It has been argued by a number of authors (Abraham & Collins 1998; Cushion, Armour & Jones 2006; Cushion 2007; Lyle, 1999; Potrac, Brewer, Jones, Armour & Hoff 2000) that although significant work has been done in attempt to understand the coaching process and coaching behaviour in coaching situations, the work fails to understand the complexity of coaching practise. Cushion *et al* (2006) discuss research looking at the coaching process in some depth, they argue that research producing idealistic representations (models) 'for' and 'of' coaching fail to account for a number of factors in the coaching domain that 'muddy' these findings. Factors worth consideration and should be accounted for are the personalities and relationships between the athlete and coach (Jones 2006; Jones, Bowes & Kingston 2010), the contexts of the decisions that the

coach makes and the communication that they have with their athletes (Lyle and Cushion 2010) and the environment or socio-cultural back drop in which they deliver. To enhance our understanding of the complexity of coaching it is suggested that 'in-situ' research has much to offer our understanding of coaching (Cushion 2007). This is a view that is echoed in a paper by Potrac *et al* (2000), they argue that to gain a thicker, deeper and broader understanding of the instructional process within coaching, a combination of systematic observation and interpretive interview techniques in the coaching domain is required. They go on to conclude that quantifiable and qualitative research techniques need to be developed to gain greater understanding of the behaviours, actions and motivations of coaching practitioner. The end goal of all this research is to better understand what and why expert coaches do what they do and by doing so, optimise and enhance our coach education and development tools and resources for aspiring and novice coaches (Vergeer & Lyle 2007; Lyle 2010).

Studying behaviour

In systematic observations the researcher attempts to quantify the behaviour of the coach whilst in a coaching situation. Many studies have been carried out across a variety of sports such as tennis and basketball (e.g. Becker & Wrisberg 2008; Bloom *et al* 1999; Claxton 1988). Generally, these studies can tell us much about a coach's idiosyncrasies (Cushion 2007; Lyle 2010; Werthner & Trudel 2006; Potrac *et al* 2000) when coaching but little about what they are trying to achieve or affect by doing it (Lyle 2002). In a study of more or less successful tennis coaches using the Arizona State University Observation Instrument, Claxton (1988) concluded that successful coaches asked more questions than

their less successful counterparts and instruction accounted for the most noted behaviour, perhaps more importantly, management and silence accounted for 75% of all noted intervals. This raises a question of what the tennis coaches were doing whilst silent? If observing, what were they observing and how did this affect their intervention strategies?

Observing expert Basketball coach Jerry Tarkanian using the Revised Coaching Behaviour Recording form, Bloom *et al* (1999) found that tactical (29%), technical (13.9%) and general (12.5%) types of instruction were the most recorded categorised behaviours observed. Becker *et al* (2008) observed basketball coach Pat Summitt using the Arizona State University Observation Assessment and also observed instruction (48%) as the most noted behaviour. It is worth considering what these coaches were trying to achieve in giving their instruction, what had they seen, why where they intervening and what was the change they were trying to effect (Cushion 2010)?

Abraham & Collins (1998) point out that in a quest to better understand coaching expertise, researchers utilise assessments of behaviour and/or coaches' knowledge base and in doing so, fail to answer three significant questions relating to coach education. (1) What knowledge should be taught to novice coaches, (2) What is the optimal method for teaching this knowledge and (3) how should we assess to encourage learning (p59). The critical factor raised in this paper is that the coaches' knowledge is an essential characteristic of expertise and if we are to inform coach education better, we need to better understand this.

It is interesting to note that our understanding of the development paths of expert sports coaches (Gilbert *et al* 2006) and their continuing professional development are immersed in their early athletic and coaching experiences, as they gain coaching experience, it is through trial and error practise, sharing ideas with colleagues, finding solutions to the problems they face from abstract sources and from observation of other coaches (Cushion, Armour and Jones 2003; Schempp, McCullick & Mason 2006). Expert coaches do not spend significant amounts of time on formal CPD but spend significant time thinking and discussing the coaching problems they face (Côté 2006). This again, hints at a cognitive element to coaching (Nash & Collins 2006) and points to coaching knowledge as a critical factor in understanding expertise.

Coaching as a cognitive exercise

Authors argue that coaching is cognitive exercise, that it is fundamentally a decision-making process (Abraham *et al* 2006; Vergeer & Lyle 2007; Lyle 2010) and that much of coaches' behaviour appears to be an automated reaction to what is going on in front of them. Salmela (1995) argues that much of the expert coaches' knowledge base is tacit but he believes that this knowledge can be verbalised and understood, a statement challenged by Nash & Collins (2006) who state that expert coaches struggle to explain their intuitive decision making whilst coaching. Cushion (2010) problematises coaching knowledge further stating that the knowledge of coaches' is sport, level and domain specific, culturally shaped and season dependant whilst Cushion *et al* (2006) argue that more attention to the dynamic, social, inter-personal and situational nature of

coaching is required. Some qualitative, sport specific 'in-situ' studies have been carried out (Abraham *et al* 2006; Côté *et al* 1995; D'Arripe-Longueville, Fournier & Dubois 1998; Gilbert & Trudel 2001; Gilbert & Trudel 2004; Saury & Durand 1998) in an attempt to contextualise and understand the coaching process, coach behaviour and the decisions that coaches' make. It is thought that through this understanding, we will enhance and better inform coach education and significantly contribute to our growing understanding of coaches' knowledge.

Abraham *et al* (2006) developed a schematic using interviews from 16 expert coaches that reflects the coaching process from a content and information-processing stance. Through the interviews 6 general categories were highlighted of which, one was 'required knowledge' that can be further broken down into sport specific, pedagogy and 'ologies', knowledge domains. This was further discussed in Nash and Collins (2006) where coaches' tacit knowledge base and decision making was reviewed, in summary coaches knowledge is hierarchical, nested, interconnected and integrated. In an attempt to conceptualise the knowledge of 17 expert gymnastic coaches, Côté *et al* (1995) used grounded theory (in-situ observation of behaviour with interviews that are coded and then notated) to identify categories that could further be developed into a model representation of the organisation and utilisation of expert gymnastic coaches' knowledge. They found that the coaches' rely on mental models (specific knowledge structures) that are generated in various situations that relate to the development of gymnastic performance. Each mental model draws upon specific knowledge developed over years that is relevant to the specific situation or problem they face.

Gilbert & Trudel (2004) carried out case study interviews of six youth team sports coaches to explore their role frames. Role frames are perceptual filters that influence how practitioners define their role and responsibilities. The study found that environmental conditions and the coach's personal views would influence their coaching and remind us that a coaches knowledge and the decisions they make will be influenced in a multi-factorial way. Gilbert & Trudel (2001) using another multiple case study approach with 6 youth sport coaches found that coaches learnt through varying types of reflection and that the professional knowledge this generates, is largely tacit and difficult to verbalise.

In drawing a thread through these papers, we can see that qualitative research can yield significant and illuminating results enabling us to better understand the backdrop of coaching and this could assist coach development. Coaches contain rich, thick, and deep knowledge acquired and accumulated over many years about specific things, this knowledge is highly individual as it is domain and environment sensitised, it is perceptually filtered by the individuals personal preferences, biases and is shaped by role frame and various types of reflection (Gilbert & Trudel 2001; Gilbert & Trudel 2006). Côté & Gilbert (2009) boil this down nicely stating that understanding expertise is the complex interaction of coaches' knowledge, athletes' outcomes and coaching contexts.

Types of Knowledge

Nash & Collins (2006) and Lyle (1999; 2002) suggest that intuitive or instinctive coaching is wrongly described as the 'art' of coaching, they go on to argue that

research should be directed towards understanding how coaches develop knowledge, how they then access it and how this affects decision making. Côté & Gilbert (2009) state that 'extensive knowledge is considered a primary characteristic of those who become expert coaches and is characterised by its structure and domain content' (p309). This is a view supported by Abraham and Collins (1998) who suggest expertise in cognition is having more expert knowledge to interpret, solve and perform solutions to problems. Schempp and McCullick (2010) point out that there is obvious value in novice and developing coaches learning what expert coaches know in an effort to 'shortcut' their learning.

Declarative and Procedural Knowledge

Knowledge *about* things or particular subjects is declarative (Lyle 2002), it is described as readily available information about concepts, elements, principles and laws (Sternberg 1999) and importantly the relationships between them, it is 'why?' or (Côté & Gilbert 2009) 'understanding' knowledge and can be explained verbally or in written format (Cassidy, Jones & Potrac 2004). Knowing *how to* do something is procedural knowledge (Lyle 2002). This can be thought of as steps or activities required to perform a task or job. Procedural knowledge has also been described as doing knowledge or the implementation of understanding (Abraham & Collins 1998). We can think of declarative knowledge as the compilation of procedural knowledge to a declarative stage (Abraham & Collins 1998). Lyle (1999) observes that it is a mistake for experienced coaches to explain procedural knowledge without allowing for the target audience to reflect on its content. Propositional knowledge (Lyle 2010) is utilised when coaches'

mentally stimulate a course of action and anticipate how it will play out, it describes relationships between things, for example, 'if that happens, do this'. It is this accumulation of knowledge that is difficult to verbalise and an area that coach development has failed to grasp from the research.

Cognitive apprenticeships (Erricsson 2009; Nichol & Turner-Bisset 2006), mentoring (Cushion 2006; Jones, Harris & Miles 2009) and reflection (Gilbert & Trudel 2006) are all themes now beginning to be utilised in the sporting context to develop novice coaches' knowledge. Coaches are paired with mentors, these could be highly experienced members of the group or 'master' coaches, and their learning is situated (Cassidy & Rossi 2006; Ericsson & Charness 1994) in real-life situations that are safe. They are then encouraged to reflect on the outcomes of their actions with their mentor to develop and reinforce their procedural, declarative and propositional knowledge thus, enhancing schema and script based memory structures. An interesting side note worthy of mention is that when novice coaches have strong views (knowledge) that are incorrect, it is the coaches' procedural knowledge that must be challenged to change their beliefs. This is because it is the accumulation of procedural knowledge that underpins tacit declarative knowledge; this is why excellent guidance, explanation and discussion are essential from more expert coaches when mentoring (Nash & Collins 2006).

Effective coaches are described as having declarative, procedural and propositional knowledge that is domain specific and is related to the training environment (Lyle 2010; Schempp *et al* 2006). Professional knowledge of this

type contains sport specific elements and scientific and pedagogical principles (Abraham & Collins 1998) and these are characterised through professional application with athletes in different contexts over many years (Côté & Gilbert 2009; Lyle 2002). Nash & Collins (2006) distinguish between tacit and explicit knowledge because coaching is about solving problems in real world situations that are ill defined. It is thought that expert coaches have excellent memory that aids in building a substantial knowledge base. It would appear that experts organise this knowledge in a hierarchical manner and can gain rapid access to it through sequential recall (Ericsson & Charness 1994; McCullick *et al* 2006).

How is knowledge stored?

Schemata are mental models containing clusters of declarative and procedural knowledge that are sculpted, refined and consolidated through a coach's experiences and sit in long term memory. Expert coaches are thought to add to and develop schemas by creating a complex cognitive 'web' linking knowledge structures together, not unlike what Ericsson (2005) describes as 'templates' of associated knowledge. Schema's are domain specific and are activated and pulled into working memory when the coach recognises a familiar pattern 'holistic snapshot or individual frame' that in turn trigger's a solution or recognition primed decision (Lipshitz *et al* 2001; Lyle 2002; Lyle 2010). Utilising feed forward and active reflection strategies the coach can use these schemas to predict events and intervene in situations quickly (Côté *et al* 1995).

'*The coach constantly scans the coaching process-related activity. Situational analysis, based on pattern recognition and key triggers, leads to diagnosis and hypothesising future events*.'

(Lyle 2002, p138)

Hall & Smith (2006), in relation to teachers cognitions when planning, teaching and reflecting on lessons stated that 'spontaneous decisions or improvising requires that a coach [teacher] has an extensive network of interconnected, easily accessible schemata. In addition to this, the coach has to have the ability to select a particular strategy, routine and information from the schemata during coaching instruction' (p431). Schema are developed over time, they are re-enforced by experience and are idiosyncratic. It is therefor vital that in-depth explanations of the relationship between knowledge domains (patterns or webs of knowledge) is offered if we are to better understand the cognitions of expert coaches.

Scripts are memory-based knowledge that is said to be associated with the expert coach (Lyle 1999; Sharp 1992). They are memories of experiences, diagnostic data, consequences and context which when triggered by an event allows the coach to rapidly recall from long term memory, situations that allow rapid recognition of the variables that relate to the unfolding event or process. A threshold of incidents or a particular catalyst will allow the coach to quickly intervene or provide a highly idiosyncratic recipe solution (Lyle 2010) as they have seen the outcome of a similar action before (Lyle 2002; Lyle 2010). Lyle, in research carried out with expert volleyball coaches proposed four models of

non-deliberative decision making utilising schemas and scripts. He found that interactive scripts (61%) accounted most for decision making concluding that coaches attempt to reduce uncertainty by anticipating events and actions by forward modelling (2002, *p135*). Coaches who work in closed skill environments, where the skill is performed rapidly may utilise scripts and schema's differently to identify and decode errors but this has yet to be explored by research.

Triggers, cues and catalysts

Whilst scanning the environment the coach will read triggers and cues within the performance that will rapidly focus their attention from a wide to narrow scope. This can be thought of as the coach instantaneously accessing and calling upon a script or schema and loading the saved memories into their working memory to utilise in the situation. Working memory should be thought of as the structures and processes required for temporary storage and manipulation of information when performing complex cognitive tasks like teaching sport skills (McCullick *et al* 2006, p153). One of the traits of the expert coach is that they have accumulated high volumes of declarative knowledge, this is less tasking on working memory than procedural knowledge allowing them to rapidly attend to relevant stimuli (Ericsson & Charness 1994; Lyle 2002). When the coach does this in a slow, conscious and more deliberative fashion (semi-deliberative decision making), they will be eliminating possible outcomes in the performance observed to ensure they make the correct decision (Lyle 2010). Experts are thought to be able to discern the important from the unimportant (McCullick *et al* 2006). If the intervention is rapid, tacit or intuitive it is likely because the

coach has instantaneously recognised the pattern through a threshold or catalyst of trigger's and cues, narrowed the options sub consciously and can make a decision with immediacy. It is argued that this may be the mark of an expert coach.

Decision Making:

In an effort to understand and explain coaches' mental activity and cognitions such as problem solving, decision-making (action decisions) and judgement researchers have suggested a number of methods and theories. Vergeer & Lyle (2007) suggest that mixing qualitative and quantitative observation methods (mixed method) could prove fruitful in this area providing additional insight into the factors involved in coaches' decision making. There are three types of decision making, deliberative (time to consider options and outcomes), semi-deliberative (decisions where there is limited time to consider outcomes) and non-deliberative (a reaction to what is going on in an intuitive manner). The Naturalistic Decision Making (NDM) paradigm is a vehicle for researchers to observe behaviour in real life settings and has emerged from a number of sub-disciplines that went before it, classical decision-making (CDT), behavioural decision theory (BDT), judgement and decision making (JDM) and organizational decision making (ODM) (Lipschitz *et al* 2001). These methods have been criticised because laboratory settings are too clinical to explore real world decision-making (Gilbert *et al* 1999) and fail to take the characteristics and context of the situation in to account (Côté *et al* 1995).

'*Naturalistic decision making (NDM) is an attempt to understand how people make decisions in real-world contexts that are meaningful and familiar to them*'

(Lipshitz *et al* 2001, p332)

Naturalistic Decision Making (NDM)

NDM has allowed us to explore how non and semi deliberative decisions are made in unpredictable environments where multiple factors, actors and pressure exist (Lyle 1999). One of the strengths of NDM is the emphasis on experience and knowledge that is already present in the subject being observed. It has helped to identify expertise as a key element in sizing up a situation and generating options (Lipshitz *et al* 2001). An essential characteristic of NDM is recognition-primed decision making (RPDM), which is argued to have real relevance in the world of the sports coach. Identifying 'decision errors' is a tool relevant in reflection on past experiences (Gilbert & Trudel 2006) and decision aiding (action reflection) happens with immediacy and can assist in decision-making.

Situation-action matching is the theory that proficient decision making in a situation is matching the unfolding event to a previous similar experience rather than choice. Context-bound informal modelling highlights that decisions are driven by experience-tied knowledge and that the decision is sensitive to extraneous factors from the environment, for this reason NDM models underline what information decision makers attend to and what arguments they use. Finally, empirical based prescription, i.e. deriving prescription from descriptive models of expert performance denotes what 'ought' to happen against what 'is' happening in the situation, a criticism directed at JDM and BDT theories (Lipshitz

et al 2001). These skills are essential to the recognition primed decisions and the NDM paradigm and describe some of the essential characteristics that are argued to cross over into the sporting context (Lyle 2002; 2010).

NDM is a tool for studying behaviour in chaotic or unpredictable environments and has been applied with success to flight controllers, fire fighters and with the army in situations where decisions are made under pressure (Lipshitz *et al* 2001; Lyle 2010). The language and applications of NDM research has been argued to provide a mechanism by which we could better understand the decisions of the team sport's coach (Lyle 2002). In the open and dynamic environment of games its merits are obvious, whether the tool set is applicable to closed skill sports like weightlifting remains to be seen.

How to observe behaviour in 'real life' situations:

Stimulated recall (Lyle 2003; Vergeer & Lyle 2007) has been used in 'in situ' studies to better understand the decision making of expert sailing (Saury & Durand 1998), gymnastics (Côté *et al* 1995) and volleyball coaches (Lyle 1999). The technique involves inviting subjects to recall, when prompted by a video sequence their thinking during the event (Lyle 2003). By interviewing the coach on a particular decision they made (sometimes known as 'hot action' or 'action decisions') we can explore the cognitive activity that sat behind the coaches intervention. Klein's 'Talk aloud' technique (Lyle 2002; Lyle 2010) can be used in this approach allowing the coach to verbalise what they were thinking at the time and provide access to introspective, higher order mental processes (Lyle 2003). Much insight has been gained in the choices and decisions of expert and

novice decision-makers through utilising 'interviews' (e.g. Gilbert *et al* 1999; Jiménez, Lorenzo, & Ibañez 2009; Vergeer & Hogg 1999), stimulated recall and talk aloud techniques however it is not without critics and great care must be taken to avoid biasing the data (Ericsson & Charness 1994; Vergeer & Lyle 2007).

Examples where these techniques have been used to good effect are illustrated below. In a study of 10 elite French gymnasts performances (Hars & Calmels 2007) using a video playback and talk aloud protocol, insight into their observation strategies, how they valued video feedback and how they coded information to retain it was gained. In another landmark study, 16 expert gymnastic coaches were asked to validate their own coaching schematic through interviews (Abraham *et al* 2006). This study gained insight into the coaching processes of expert coaches that was then argued could be used to inform coaching development. Finally, Vergeer & Lyle (2007) interviewed 64 gymnastic coaches to explore deliberations and rationalisations in justifying their decision policies in relation to 16 hypothetical situations in which a gymnast was injured. The research was carried out to validate a 'mixed methods' design of data collection when studying coaches' decision making. The authors concluded that there is clear potential for the method in coaching research.

Strength and Conditioning:

Strength and Conditioning (S&C) is a relatively new discipline that is hugely influenced and dominated by evidence-based practise (Baechle & Earle 2006). There are volumes of literature relating to S&C covering all aspects of sports

science including principles of adaptation, periodization, programming, strength science and energy system training (Bompa & Haff 2009; Cardinale, Newton & Nosaka 2011; Stone, Obryant, Schilling, Johnson, Pierce, Haff, Koch & Stone 1999; 1999a; Zatsiorsky & Kraemer 2006) but until now, S&C has been poorly researched from a coaching perspective. S&C relies on a broad and varied tool kit of weightlifting techniques, jumping activities, throwing type exercises and interval running (to name but a few modalities of training) to physically prepare athletes to cope with the demands of their sport and reduce the incidence of injury (Hedrick & Wada 2008; Stone, Pierce, Sands & Stone 2006). These exercises need to be coached and are required to be executed by athletes with technical proficiency to avoid repetitive, mechanical and loading injuries (Dreschler 1999; Everett 2009; Newton 2002). To coach weightlifting movements S&C coaches are required to understand and be able to convey the extensive technical models of each exercise they use. The techniques are closed skills (clearly defined start and end position) and not unlike gymnastics, diving or trampoline in that with technically able athletes, the coaches ability to observe rapid skill execution, identify and decode subtle errors and coach effectively is a learned but highly skilled and expert behaviour.

There have been very few studies on actual coaching behaviours in S&C, most look at how to break down and coach a lift and the characteristics/bio-motor qualities it develops e.g. force, velocity, rate of force development, coordination, balance, strength (Stone *et al* 2006). In a novel study exploring S&C coaches' behaviour by Massey, Maneval, Phillips, Vincent, White & Zoeller (2002), they found that expert S&C coaches spend 21.9% of time observing/silent monitoring

athletes. If it is the case that coaches spend the majority of their time observing the skills of the athlete, how does this observation inform and translate into coaching interventions and error fixing in skills?

Using unpublished data gathered (Module SPSP54: Assignment 3: submitted on 2nd December 2013) on the behaviours of an experienced S&C coach whilst coaching (appendix A) it was found that of 1110 coaching episodes analysed across two S&C coaching sessions lasting two hours, 28.6% was attributed to observation with a subsequent 34% of the coaches time given to instruction and another 10.4% to feedback. This underlines the point that there is a significant dearth of literature on the cognitions, expertise and decision making capacities of sport and S&C coaches. In developing understanding of what coaches' do, we fail to explain why they did it. It also supports the idea that there is a 'blank space', or a 'vacuum' between a coaching observation and its resultant intervention that we need to fill to better understand coaching practise.

To crystallise the point, what does the knowledge, cognitive processes and expertise of expert S&C coaches look like and how does this apply to the task of identifying and decoding skill execution errors in weightlifting movements? In attempting to understand this complex question researchers have pointed out that there are significant ramifications for coach education and the development of novice coaches (Gilbert *et al* 1999; Jones 2006; Vergeer & Hogg 1999; Lyle & Cushion 2010). An area of research that could prove fruitful in contributing to the body of work around expert S&C coaches' practise is an exploration of a

group of expert S&C coach's interventions whilst observing athletes performing classical weight lifting movement.

Method

Participants

Three expert S&C coaches (1 female, 2 males) agreed to participate in the study. All are working with athletes who would be described as elite high performers. An expert coach is defined as someone with over 10 years experience of coaching in a specific context or domain (Abraham *et al* 2006; Ericsson & Charness 1994; Schempp & McCullick 2010), who has been or is involved in mentoring or teaching novice or developing coaches (Cassidy & Rossi 2006; Jones *et al* 2009) and for the purposes of this study, are active United Kingdom Strength and Conditioning Association (professional body for S&C coaches) Tutor/Assessors.

Each of the coaches who participated has a minimum of 10 years coaching experience (+1-15 years) and has also led national S&C programmes. They have all supported multiple international athletes through numerous Commonwealth and Olympic cycles and supported non 4-year cyclical sports such as rugby, golf and football. Each coach has acted as a mentor for interns, contracted coaches and/or fulltime staff assisting in their development and represents the UKSCA as a tutor delivering coach education and assessing aspiring S&C coaches towards accredited status.

If we are to adopt the criteria suggested by Ericsson (2009), Jiménez *et al* (2009) and Lyle (2002) in identifying expert coaches, then our S&C coaches qualify

within the S&C field. The coaches are all currently working in a multi-sport S&C coaching environment with athletes who are competing at national or international level in a variety of sports. The athletes all had partial or full classical Olympic weightlifting movements, squatting and multi-joint strength based movements in their programmes and varied in ability with novice, intermediate and advanced level lifters attending the sessions.

Procedures

Prior to being recruited for the study, the purpose was fully explained to each S&C coach. The coach gave consent for a number of observations to be carried out using a video recorder and for follow up interviews to be recorded for further analysis. On the observation days, as athletes entered the gym an explanation of the study was given and consent to video record them acquired. All athletes were given the opportunity to opt out of participating in the study prior to commencement. The S&C coach was strongly encouraged to coach as they normally would and pay no attention to the observer or video camera.

Each coach was observed and video-recorded twice in their coaching sessions (total observation time = 14 hours). As each of the coach's observed the athlete performing their sets (Olympic clean/snatch as a partial or full lift, squatting movements or multi-joint assistance movements), the video camera was positioned beside the coach and the repetitions recorded. Each coaching episode across each of the sessions was captured and is summarised in (Table 1).

On completion and directly after the main sessions, the footage was immediately downloaded onto a laptop computer and the video camera then set up to capture the interviews of which there were six. Prior to starting the interview, the observer encouraged the coach to observe the video footage from their session and recollect and recount their thoughts and actions throughout the coaching episodes as freely and honestly as possible by 'talking aloud' (Lyle 2010; Vergeer & Lyle 2007). A list of prompting questions was at hand and offered before starting (e.g. what did you see? Why did you do that? What were you thinking? Can you tell me about…?). Each coaching episode was played back to stimulate recall of the S&C coach's thoughts whilst coaching (Lyle 2003). The S&C coach, on first observation of each exercise was asked to explain their ideal technical model of the lift outlining exactly what they look for before identifying the errors they observed and what aspect of the skill they were trying to effect.

Table 1: *Coaching observation data*

	Coach A		Coach B		Coach C	
Observation	1	2	3	4	5	6
Duration (hrs)	2	2	3	3	2	2
Athlete numbers	6	5	2	3	1	3
Sports	Golf (1) Rugby (3) Swimming (2)	Golf (1) Rugby (2) Swimming (2)	Golf (2)	Golf (2) Rugby (1)	Alpine Skiing (1)	Alpine Skiing (1) Table-tennis (1)
Coaching Episodes	41	29	36	35	20	40
Interview (min)	33	51.55	58.43	61.42	52.28	70:28

A total of 14 hours (6 sessions) of observation was carried out on 3 coaches. 19 athletes were observed from 5 sports and a total of 201 actual coaching episodes were reviewed. The interviews ranged from 33 minutes to 70 minutes and were performed immediately after each coaching session.

Data Collection

The coaching episodes and follow up interviews were recorded using a high definition digital camera (Sony HDR-CX 320e). The data was transferred onto a laptop (MacBook Pro) instantaneously using an SD Card both for the coach to observe their coaching episodes and for the observer to later fully transcribe and analyse the interviews.

Data Analysis

Each interview was fully transcribed (appendix C) and then systematically analysed using a mixed method approach (Vergeer & Lyle 2007). Initially the S&C coach's recollections and thoughts were organised into category/sub category headings, this formed the skeletal structure for the notational analysis that was then completed (appendix B). The interview responses were then coded and the data collated, summed and totalled to build a picture of (a) patterns and trends in expert coaches knowledge and cognitive organisation and then (b), utilised to develop the conceptual model illustrating this. Key quotes have been taken from the interviews to illustrate salient points and used to build the theoretical model for the rapid cognition process that S&C coaches might utilise when identifying pattern errors in the weightlifting movements that they are observing.

Results

The transcribed interviews and raw data from the analysis are presented in appendix B and C. A total of 3055 context and technical points and 548 technique errors (total 3603) were coded relating to the 10 categories and 127

sub categories that were identified and accounted for by the S&C coaches (these can be viewed in appendix B). From the coded transcripts the knowledge headings (Categories) along with the total number of references made are highlighted in table 2.

Table 2: *Identified knowledge headings/categories and the number of references to each (presented as a total, % and group) made by experts S&C coaches when describing the ideal technical model or errors in weightlifting movements*

	A	A-%	B	B-%	C	C-%	Tot	Group %
Context	108	8.3	63	7.7	110	7.4	281	7.8
Coach experience	63	4.8	23	2.8	54	3.7	140	3.9
Body part/ segment	345	26.4	186	22.7	424	28.7	955	26.5
Muscles	108	8.3	42	5.1	91	6.2	241	6.7
Anatomical	107	8.2	76	9.3	188	12.7	371	10.3
Weight bar	122	9.3	74	9.0	104	7.0	300	8.3
Technical model	259	19.8	231	28.2	280	18.9	770	21.4
Kinematics	98	7.5	42	5.1	80	5.4	220	6.1
Motor/movement	96	7.4	82	10.0	147	9.9	325	9.0
	1306		819		1478		3603	

When observing athletes performing weightlifting movements S&C coaches recognise that the context (281/7.8%) in which they observe the lifts is an important factor. Coaches look at and have knowledge relating to segments of the body and part (955/26.5%), the muscles (241/6.7%) and anatomical movements (371/10.3%). They also use specific information relating to the weightlifting bar (300/8.3%), kinematics (220/6.1%) and specific motor/movement qualities (325/9.0%) when observing and coaching athletes.

They have very in-depth specific technical information (770/21.4%) that they use in their coaching.

Expert S&C coaches' knowledge can be clearly divided into kinesiological (anatomical) and kinematic (movement) knowledge bundles. The results are presented in 3 parts, (1) Anatomical (kinesiological) (2), Movement (kinematic) and (3), the conceptual models built from the coded transcripts.

Anatomical References:

Coaches are looking at the human body in movement. Their rich and detailed accounts of the technical models and the errors that they observe in weightlifting movements draw upon knowledge of the anatomical structures of the human body to make sense of what they see.

Figure 1: *References made to body part by expert S&C Coaches when describing the ideal technical model or errors in weightlifting movements*

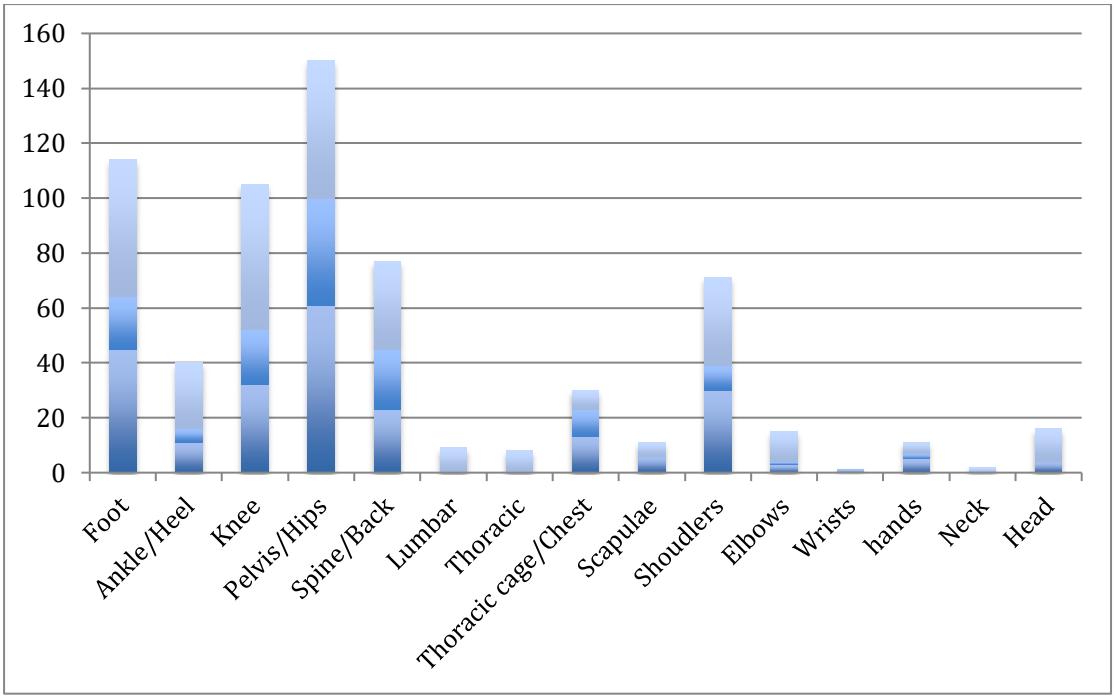


Fig 1 shows that of the 660 references made, hips (150/22.7%), foot (114/17.3%), knees (105/15.9%), spine (77/11.7%) and shoulders (71/10.8%) are significant body part landmarks that S&C coaches use to observe movement. Interestingly, reference to a body part is usually accompanied by 'motor/movement' or 'technical model' information and references to other body parts. An example of this was coach 'C' describing the ideal technical model of the receive position in the snatch '*What I am looking for is her feet going out from a jumping stance which is hip width apart*'. In reference to an error spotted in a front squat technique coach 'C' states '*she has anterior tilt, she is a bit tight through the shoulders, she's got a relatively upright spine*'.

Not only do coaches discuss specific body parts, they use body segments to identify technical errors in weight lifting movements.

Figure 1.1: *References made to anatomical segments of the body by expert S&C coaches when describing the ideal technical model or errors in weightlifting movements*

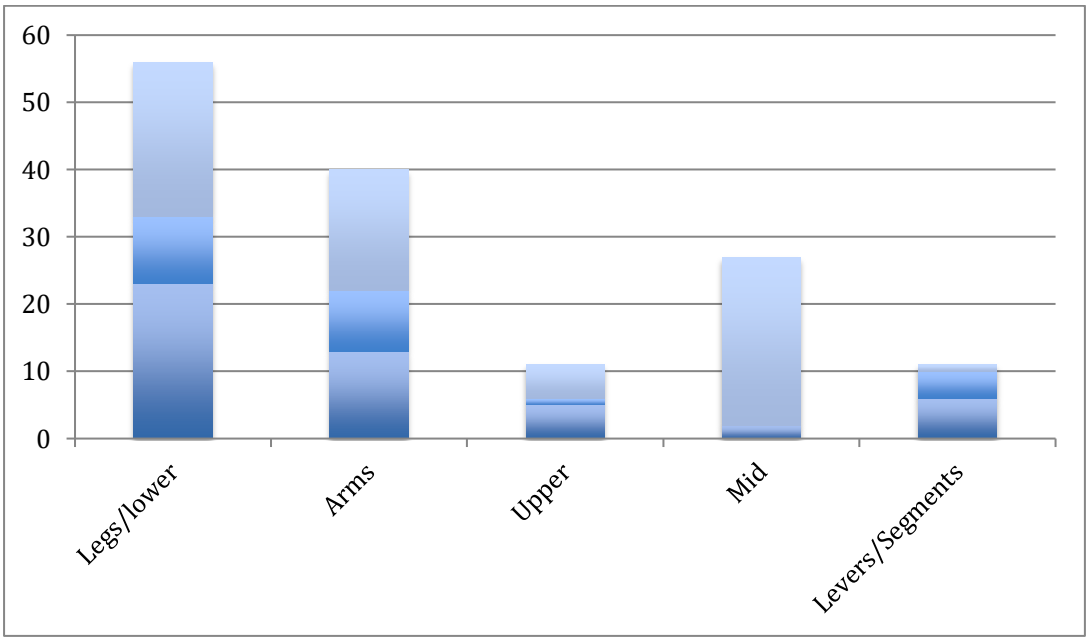
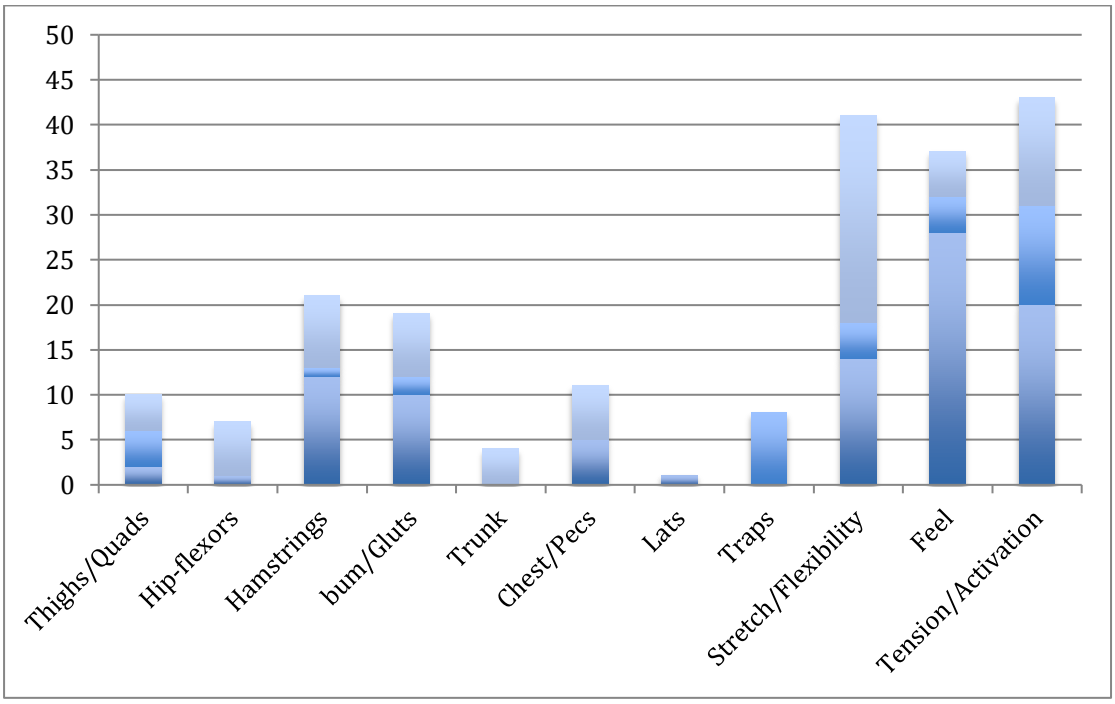


Fig 1.1 illustrates that S&C coaches refer preferentially to the lower body (56/38.6%) followed by the arms (40/27.6%), this makes sense when we consider that in most cases, the appendicular skeleton is moving. The middle of the body (axial skeleton) provides force transfer, stability and is 'stiff', it is also referenced frequently (27/18.6%) when describing and observing weight lifting movements. In relation to the major joints of the body coach 'A' states in reference to good posture that '*all the segments kind of line up'.* Our coach goes on to describe what they are looking for when observing athletes performing warm up sets '*ankle, knee, hip alignment, bar position overhead, I'm thinking about posture, arms and legs'*. Later in the interview, when discussing push press and the set up position the coach says *'I think in the set up I am looking at everything – posture, arms and legs, I think it's the whole thing'.* Coach 'B' when

referencing the optimum position for the overhead squat states **[to achieve it]** *'there will be a bit of forward lean accommodating the levers of the femur by displacing the knees out the way and having the right foot stance to optimise that'*.

When discussing weightlifting movements it is surprising that muscles are referenced less frequently (241/6.7%) than some of the other anatomical terms used by the S&C coaches. When we consider that it is muscular actions that create the internal and external forces that produce movement we might have speculated that that they would be discussed more. Figure 1.2 shows that stretch, feel and activation are the most referenced terms relating to the muscular system rather than specific muscles.

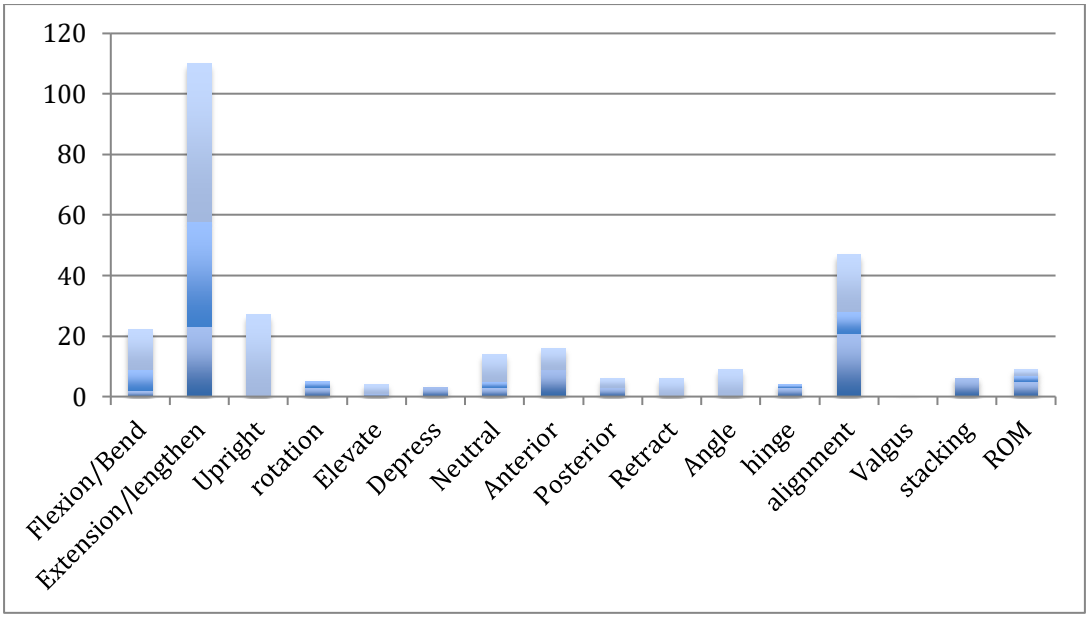
Figure 1.2: *References made to the muscular system by expert S&C coaches when describing the ideal technical model or errors in weightlifting movements*



When referencing muscles, S&C coaches talk more about tension/activation (43/21.3%), stretch/flexibility (41/20.3%) and feel (37/18.3%) rather than referencing specific muscles or muscular actions. *'When I am coaching I'm trying to get them* **[the athlete]** *to feel the right thing... but for me coaching is like, how does that feel to him? Where does he feel stretched? Where does he feel muscles switched on'?* The coach goes on to describe errors they have noted through feel in the push press technique *'I know that he* **[the athlete]** *is challenged with, closed shoulders, tight pecs, I know that he's anterior dominant… he can make that shape look good but actually he really struggles with activating the muscles that control the scapulae'.* In reference to an error in the front squat movement Coach 'C' observes *'you can see her* **[the athlete]** *butt is pushing backwards a little, it's showing that she has got a bit of a lack of flexibility around the hip'.*

The results seem to hint that movement and quality of movement are important aspects of expert S&C coaches' knowledge. Figure 1.3 shows the number of references made to the anatomical movements made by our coaches.

Figure 1.3: *References made to anatomical movement by expert S&C coaches when describing the ideal technical model or errors in weightlifting movements*

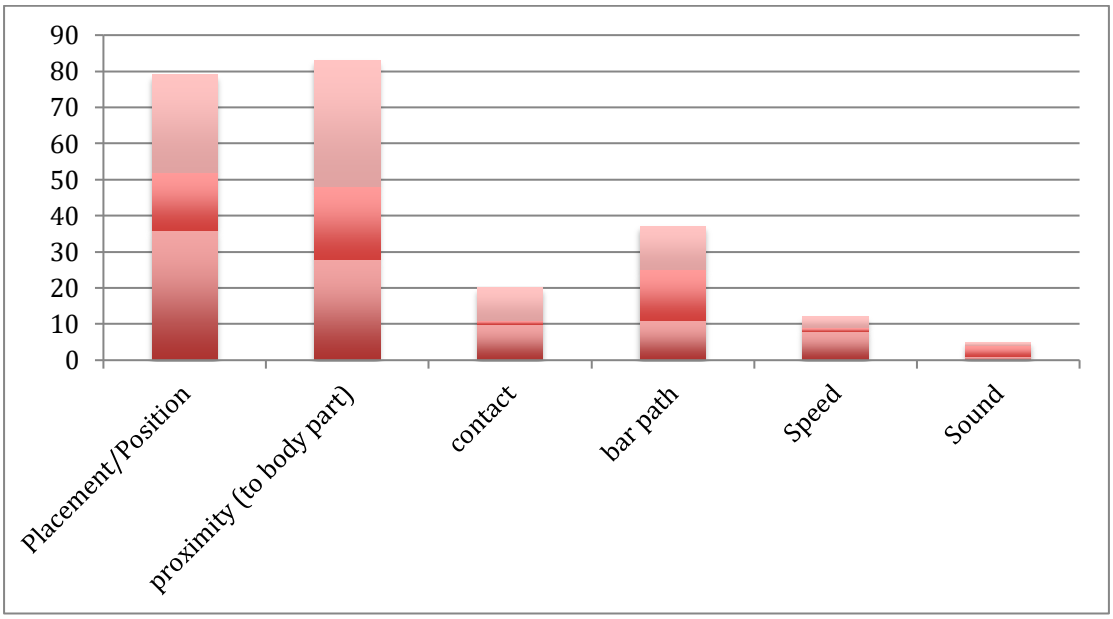


S&C coaches look for and reference most frequently length/extension (110/37.3%) and alignment (47/15.9%) when descrbing movement. They use a wide variety of clinical languague when conveying their technical expertise (16 coded). Coach C talks about athletes maintaing '*femur foot alignment*', the coach goes onto describe posture at length '*so when the human being's standing upright I would be expecting the scapulae to be retracted, the thoracic spine to be moving towards extension. There should be a natural lumar curve in the spine, the pelvis should be neutral, there shouldn't be an emphasised anterior tilt of the pelvis, the legs should be fully extended but the knees soft and she should be in perfect balance, the head should be in alignment with the spine'.* The coach points out that improving posture is why S&C coaches prescribe these movements.

Movement (kinematics):

The athlete and bar work in unison (as one moving unit) when performing weightlifting movements. Expert S&C coaches use the bar as a reference point to spot and fix errors in weightlifting movement.

Figure 2: *References made to the weightlifting bar by expert S&C coaches when describing the ideal technical model or errors in weightlifting movements*

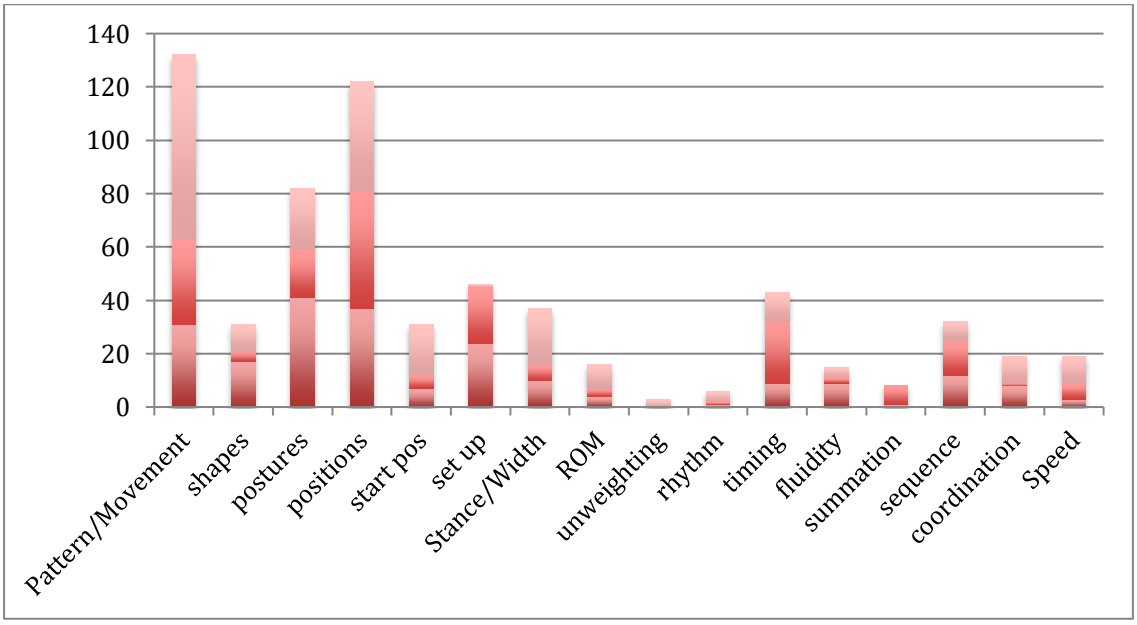


The figure clearly shows that the coaches get information from where the bar is in proximity to a body part (83/35.2%), its placement or position (79/33.5%) and what the trajectory/bar path is (37/15.7%) whilst in motion. Coach 'B' discusses this in reference to the ideal technical model of the clean. '*Once* **[the athlete]** *starts applying force through the floor to lift the bar their weight should be displaced to their heels, they should maintain a constant angle through the first pull, and then if that happens then the bar should move as a unit... and the bar will come past their knees and that will be their first pull position.* Coach 'B' clearly states that bar path is an indicator of errors when lifting. When asked how he spotted an error in the clean the response was *'Bar path and just the action he is doing, I can see that he is not shrugging and the bar path helps to indicate that'.* He goes on to explain the fix for the error, '*I want him to be connected to the bar, and I want him to be fully extended'.* When describing the Overhead squat/snatch

combo Coach 'C' mentions the bar position in relation to the foot, *'I'm looking for the bar to be directly above the malleoli'*, he goes on to say '*when she catches, the bar is going to be above or slightly behind the crown of her head'.*

It is clear from the analysis and frequent references made to technical model information (642 references, 770 including error detection) that the technical knowledge S&C coaches have relating to the weightlifting movements is deep, thick and rich.

Figure 2.1: *References made to specific technical model terms by expert S&C coaches when describing the ideal model or errors in weightlifting movements*

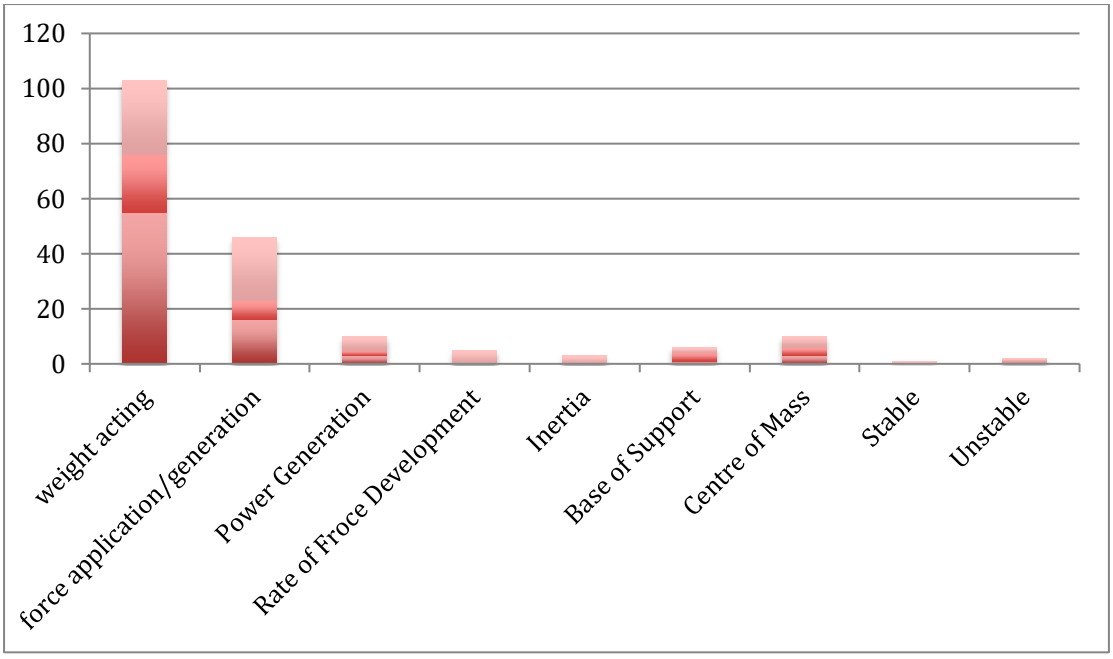


Expert S&C coaches are looking for patterns of movement (132/20.6%); specific body positions (122/19.0%) and postures (82/12.8%) as well as defined set-ups (46/7.2%) for lifts and specific timing (43/6.7%) of movement. These criteria appear to hold key triggers for observation and error detection. Coach 'C' when assessing how well an athlete performed an exercise states *'on a scale of one to*

ten for that combination in terms of movement, in terms of the shape and the positions and the movement, I would be scoring her a seven-and-half to an eight for that'. When describing what an ideal technical model looks like Coach 'C' references mechanical models and states that *'it involves good shapes, positions and postures'.* He goes on '*I'm focusing on posture, correct shapes and positions then the timing or the speed of the rhythm of the movement'.*

Coach 'A' identified 'posture' and the 'set-up position' as being key in '*telling you whether something stands a chance of being relatively close to the technical model'*. The coach goes onto state *'I'm looking at the shapes that the body makes… and the sequence of movement in relation to where the bar is going. I think timing is really important as that's related to the coordination of things as well'.* This quote supports the notion that this coach is framing different parts of the lift and is using shapes and the bar to assess its quality. The statement is reinforced by Coach 'B' who after observing a set of cleans says, '*I was happy with the timing of what she was doing and the positions that she was hitting in terms of second pull and extension in the second pull.'* In another example we can see that this coach uses timing for error detection, '*I'm trying to get him to improve his timing because the timing is not as good as it should be'*.

Figure 2.2: *References made to specific kinematics by expert S&C coaches when describing the ideal technical model or errors in weightlifting movements*

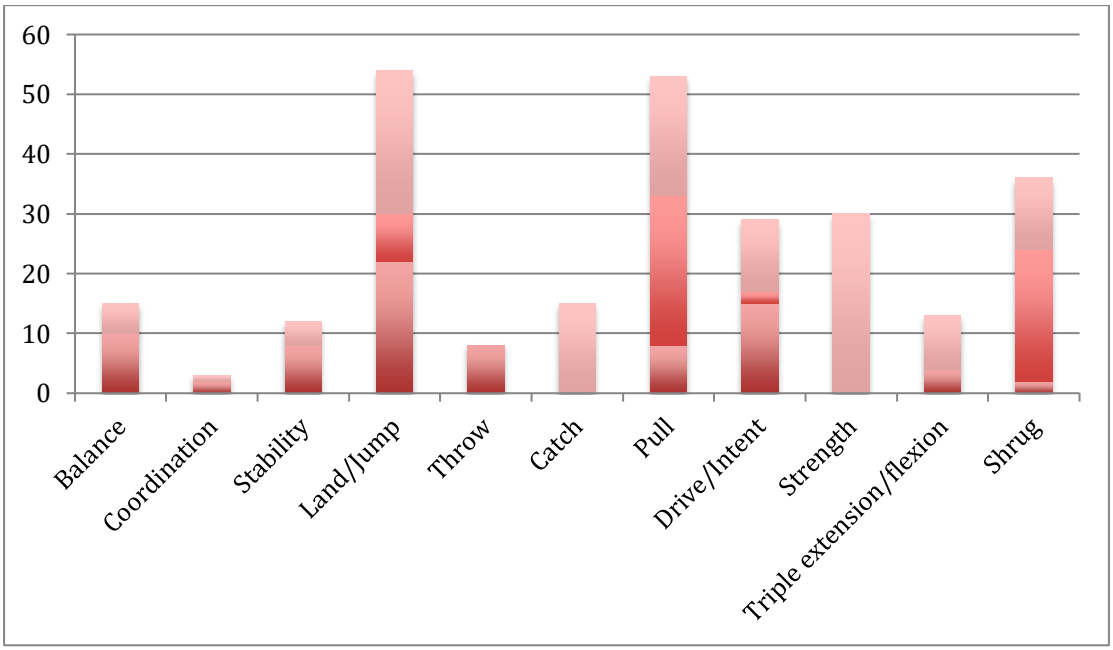


Expert S&C coaches observe how weight is acting through the feet (103/55.4%) and how force is being applied and generated (46/24.7%). The coaches seem to generate a lot of information from this observational cue. Coach 'C' says in relation to an ideal model '*I'm looking for the feet to be flat on the ground and the weight acting through the heels*'. A clue that an error has occurred comes from '*the weight's coming towards the front of the foot,*' which is supported by the observation of a forward lean in the movement. Later in the interview the coach remarks '*Where her weight's acting through her the foot is kind of important, when she picks the bar up off the ground the weight should be coming back into her heels… that's going to enable her not to lift her bum up first'.*

Coach 'A' explains '*a lot of the information that you get in terms of technique is to do with where the weight distribution is in the foot, how that weight changes throughout the lift… if the weight is in the wrong place then something's wrong somewhere else'.* When observing an error in the clean '*he was taking his feet off*

[the ground] *too early, he needed to be driving down, pushing the floor away and driving down into the floor*', this hints at force application. The coach goes on to confirm error detection using a range of different clues '*often if the bar path is wrong the weight distribution in the foot will be in the wrong place because the weight* **[the bar]** *is pulling you off centre'.*

Figure 2.3: *References made to specific motor skills/movement qualities by expert S&C coaches when describing the ideal technical model or errors in weightlifting movements*



It appears that landing and jumping (54/20.1%) are skills that are important for athletes to be able to perform well. In relation to weightlifting movements and postures, the shrug (36/13.4%) and pull (53/19.8%) are critical terms. Expert S&C coaches make reference to strength (30/11.2%) and athletes displaying drive and intent (29/10.8%) when performing weightlifting exercise.

Coach 'A' explains an issue that an athlete is having *'Something's are really obvious to me from a physical literacy point of view* **[jumping]**, *everyone can jump – and he* **[the athlete]** *can jump. And its almost like when there's a bar he cant jump… its just a jump'.* A key quote illustrating our coaches thinking on jumping with intent is *'he doesn't seem to be able to drive with the same intensity [under load] so my thinking about the jump was, jump as high as you can, get the feeling from that and what that feels like'.* In reference to the jumping action of the clean, our coach conveys some critical information *'***[the athlete]** *needs to be driving down into the floor and I was trying to get him to…* (as the coach watches the video) *there wasn't really any shrug happening either. So I was just trying to get him to pull the bar up as fast as he can'.* Interestingly both Coach 'B' and 'C' spot errors by watching whether the athlete jumps backwards or forwards. A forward jump is a trigger that an error has occurred.

Coach 'B' explains the importance of the pull '*I know that in order to apply a summation of forces that there should be a pulling action and I think that's pretty crucial; it is a jumping action but it's really a pull'.* He goes on '*Setting yourself up to that pulling position is crucial… so that you can apply force through shrugging the bar'.* When trying to correct an athletes clean '*what I am trying to get them to do, like, ritually, is pulling… doing shrugs off the box and try to get the timing right'.* Our coaches appear to use the jump and shrug movements to detect errors, they also recognise that the load on the bar, the intent to move it fast is important.

Error identification in weightlifting techniques

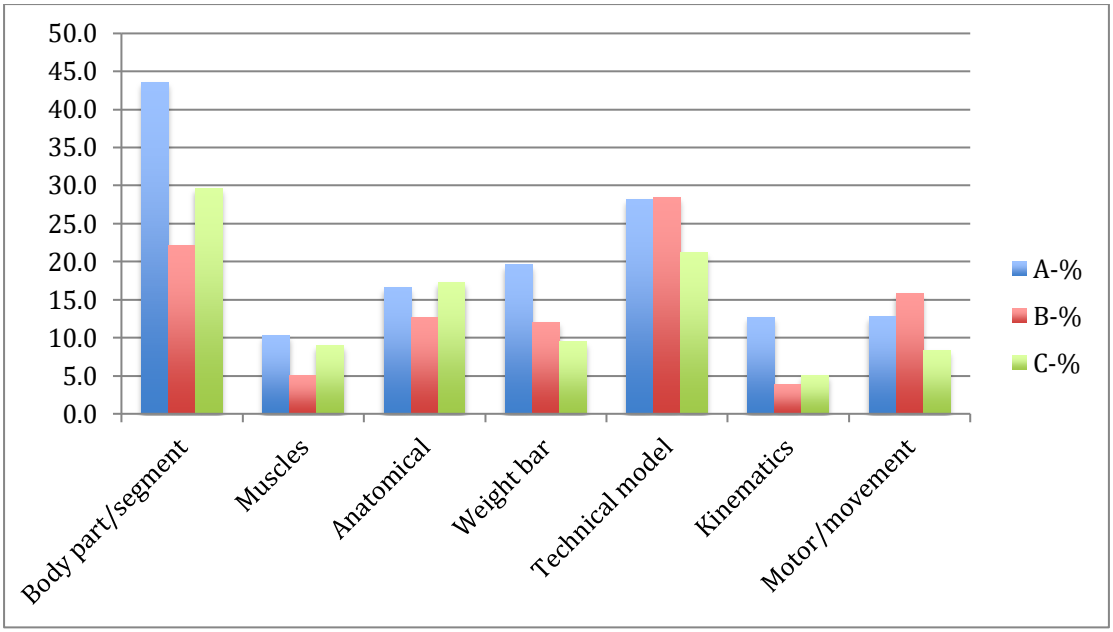
Table 3 and figure 3 reflect the number of coded errors captured by each S&C coach by category type and are summed and averaged.

Table 3: *The total number of errors referenced by each expert S&C coach (and the group) by knowledge category displayed per session, totalled and as a percentage % for each individual.*

	Coach A				Coach B				Coach C				
	1	2	Tot	A-%	1	2	Tot	B-%	1	2	Tot	C-%	Tot
Body part/segment	27	35	62	43.6	7	28	35	22.2	22	31	53	29.6	150
Muscles	6	9	15	10.3	1	7	8	5.1	4	12	16	8.9	39
Anatomical	9	16	25	16.6	8	12	20	12.7	11	20	31	17.3	76
Weight bar	12	16	28	19.6	7	12	19	12.0	7	10	17	9.5	64
Technical model	13	32	45	28.2	13	32	45	28.5	16	22	38	21.2	128
Kinematics	7	12	19	12.7	3	3	6	3.8	3	6	9	5.0	34
Motor/ movement	9	8	17	12.8	7	18	25	15.8	6	9	15	8.4	57
Total	83	128	211		46	112	158		69	110	179		

The table shows that there is a small variance in the number of coded responses by each coach (A= 211, B=158, C=179) by variable type. Technical model errors and body part/segment errors (150) are the most referenced by individual and the group. The frequency of errors captured between observation 1 and 2 for each coach increased.

Figure 3: *Total errors observed by S&C coaches whilst observing athletes perform weight lifting movements shown as a percentage of total errors observed for each S&C coach*



This figure shows how the 548 coded errors across our categories of knowledge domains break down across our coaches. The expert S&C coaches' dominant observable error was body part/segment error (150/27.4%). The technical model (128/23.4%) is the next highest reported error detection source. Coach A (43.6%) and C (29.6%) both favoured body part/segment error detection where as Coach B (28.5%) relied more on technical model errors.

Conceptual model of expert S&C coaches' knowledge and cognitive organisation

Figure 4 shows a hypothetical model of the cognitive organisation of the knowledge that expert S&C coaches' possess. The model has been built from the framework that was developed through the coding of the 3 expert S&C coaches interviews and subsequent notational analysis. All of the variables referenced are reflected in the model, it is worth highlighting that the anatomical knowledge bundles have been condensed into the knowledge content headings, as there were too many to reflect in the model.

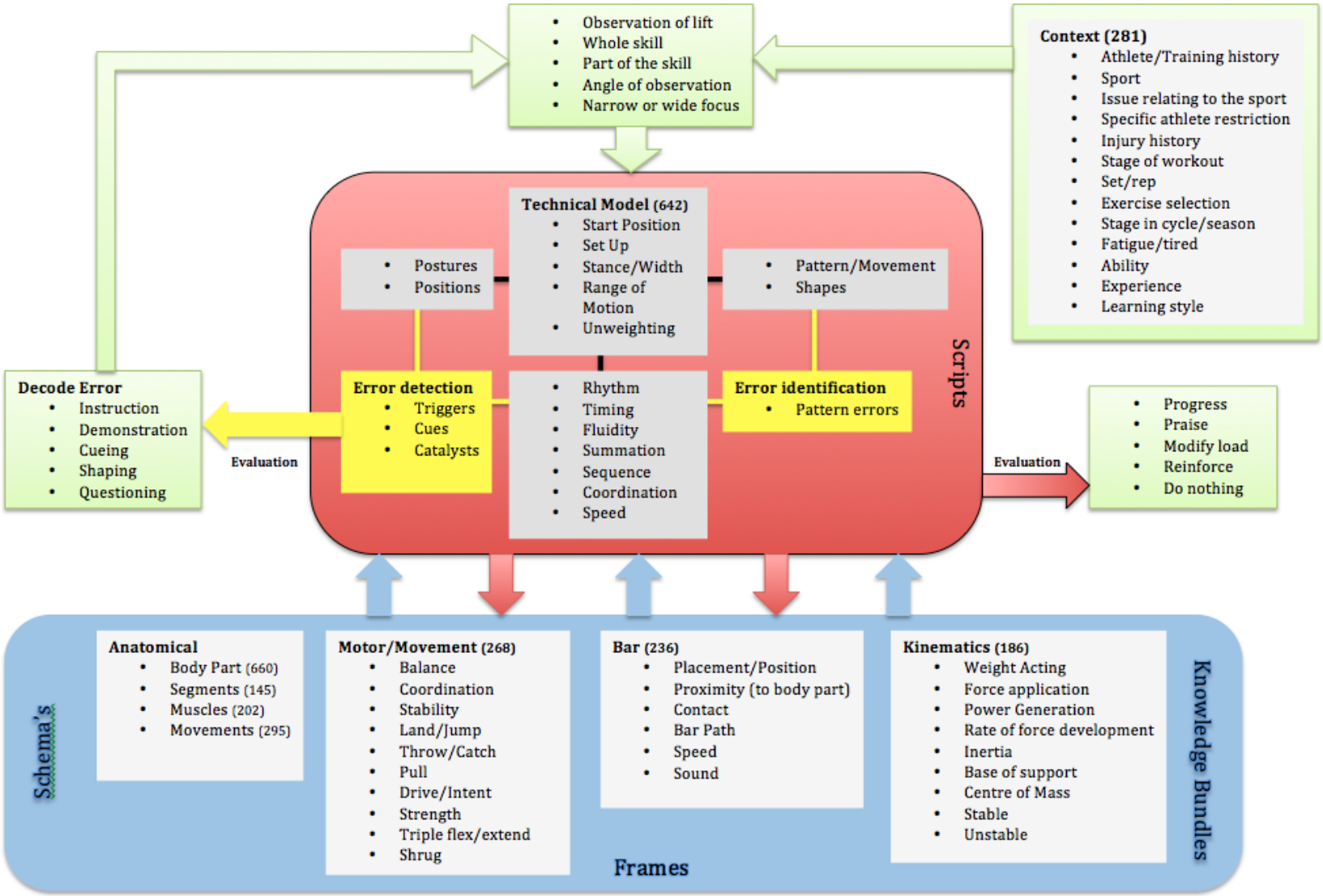


Figure 4: *A model of the cognitive organization and inter-connected knowledge of expert S&C coaches*

When S&C coaches observe athletes performing weightlifting movements (at the top of the model) they always account for a range of context determined variables (top right box) (Saury & Durand 1998). The load that is on the bar and the stage of the workout are the dominant factors that affect the coach's account for what they see however there are a significant amount of factors that effect the judgements that coach makes. When observing the weightlifting movements the S&C coach is utilising complex script-based knowledge pertaining to the particular lift being observed, it is through these familiar movements, shapes, postures and patterns that error detection occurs. It appears that there is a level of tolerance for what constitutes a good lift when coaches evaluate what they have observed, when happy, the coach praises and progresses as opposed to correcting.

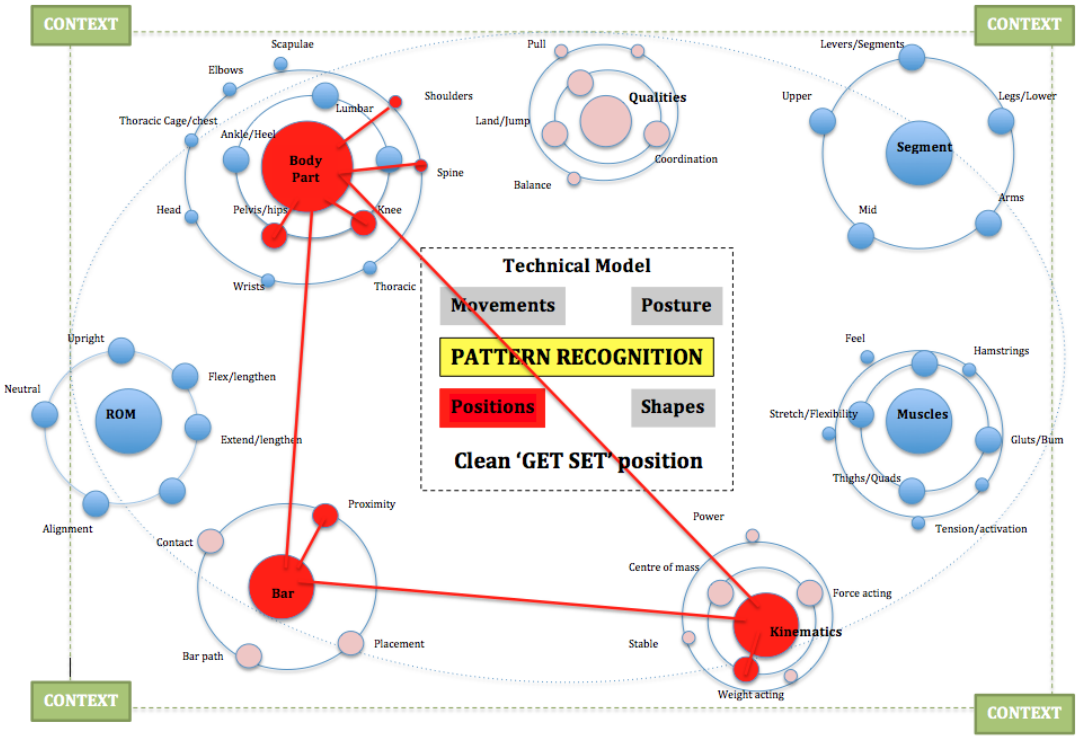
Under-pinning the script-based knowledge is a series of specific specialist knowledge bundles (schemas) that are deep, thick and rich and interconnected (Abraham & Collins 1998; Ericsson 2005; Nash & Collins 2006). These knowledge bundles can be viewed in isolation or as part of an integrated knowledge mesh (Lyle 2010) that is rapidly accessed when the coach observes the athlete move. The rapid assessment of what the coach is observing leads to the recognition of specific triggers, cues and catalysts (context determined frames) that allow the coach to deploy a strategy for improving the technique or giving the athlete feedback.

Figure 4.1, 4.2 and 4.3 is a high concept constellation model of how S&C coaches rapidly access schema and script based knowledge through inter-connected

knowledge frames to identify and decode errors in weightlifting movements. The examples are taken from the transcripts and illustrate how coaches recognise a familiar shape (frame) in their deeply engrained integrated knowledge mesh (constellation) that allows them to intervene with a coaching strategy.

Figure 4.1: *High concept constellation pattern and error recognition (Coach A)*

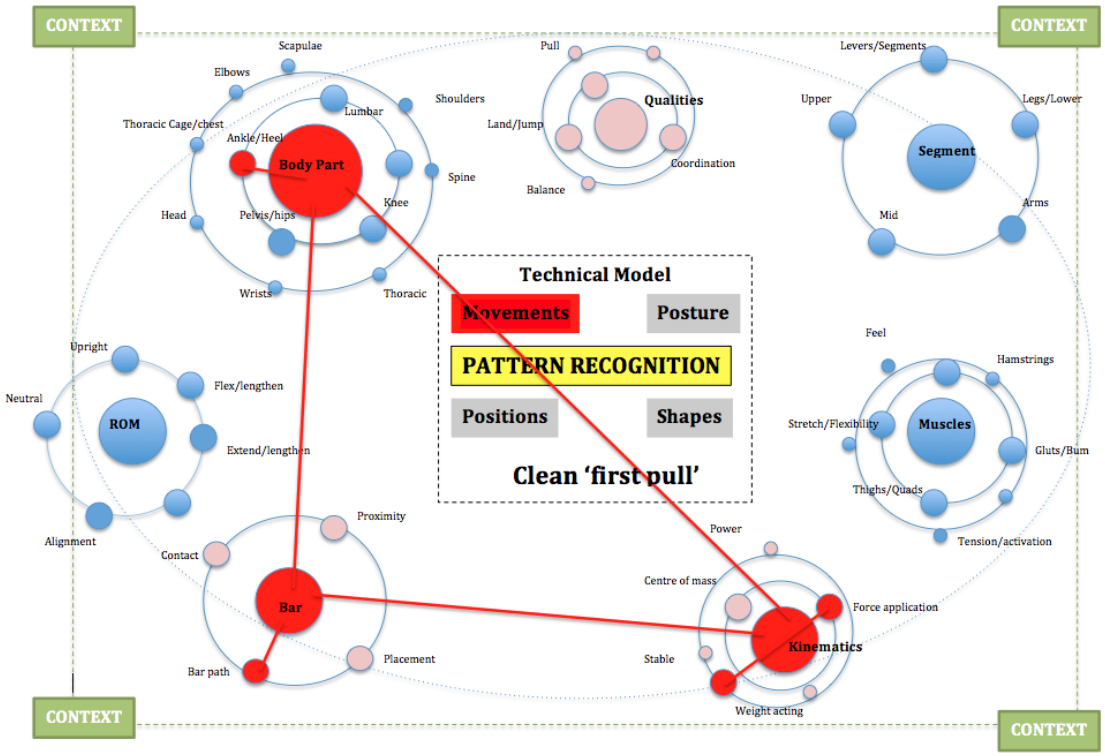
In reference to the set up Coach A said the following '*so I was looking for things like where all the joints were in relation to the bar, where the weight distribution was in the foot, shapes through the spine, so just making sure everything from setup was correct*'.



The constellation shape can be thought of as the pattern that the S&C coach sees when assessing the 'get set' position of the clean. This could be likened to a cognitive 'observation frame' or 'template' that has been rapidly captured by the S&C coach whilst observing the lift being performed. It illustrates the integrated and interactive domains of knowledge that the S&C coach draws upon. If the S&C coach had observed an error in the 'get set' position, we might have seen a different constellation shape, a broken connection between knowledge domains or a different configuration of knowledge activated in our knowledge network.

Figure 4.2: *High concept constellation pattern and error recognition (Coach B)*

In reference to the movement of the 'first pull' of the clean Coach B discusses what they are looking for *'Once they start applying force through the floor to lift the bar it should encourage the weight to shift towards their heels'*. The model shows a hypothetical 'shape' in their integrated mesh of knowledge that links the script bundles with the dense schema based information.

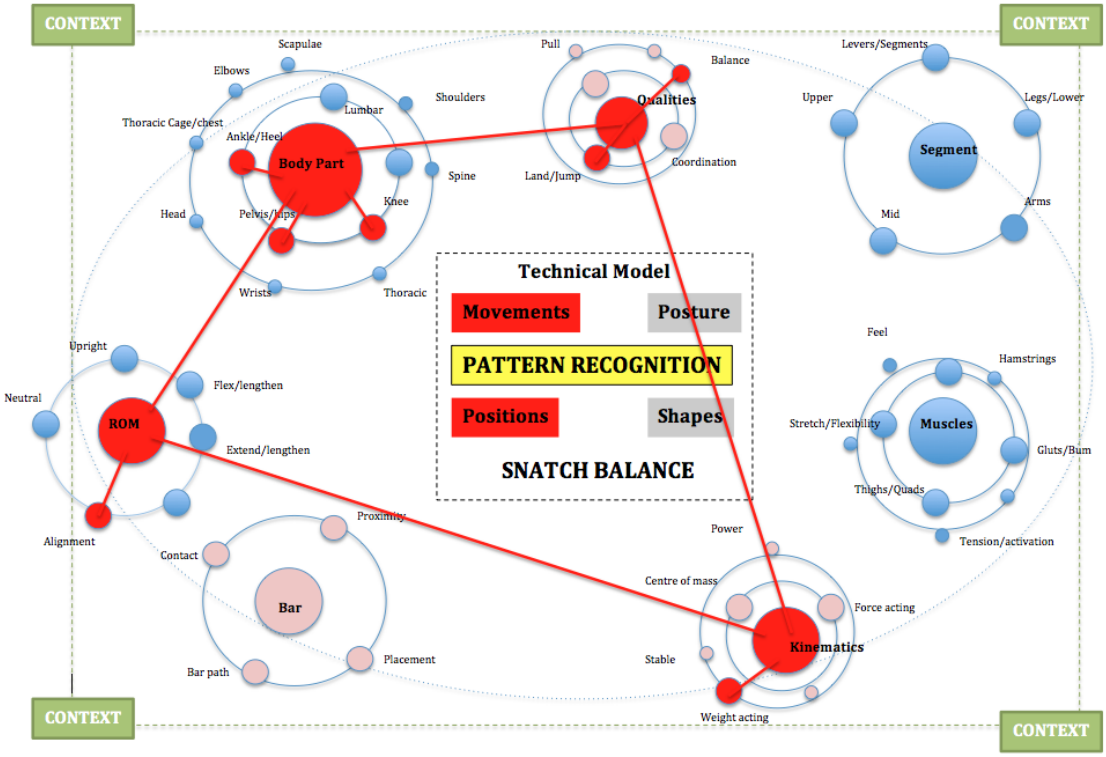


Whilst the athlete performs the first pull of the clean the coach is accessing sensitive 'movement based' scripts. From the coach's description, you can see that they are anticipating where the force should be acting and how force transfer will happen across the movement. If the movement had been incorrect, the coach would have rapidly noticed this through specific triggers that were

saved in long-term memory from previous experience. It is likely that the coach already had solutions to fix the problem.

Figure 4.3: *High concept constellation pattern and error recognition (Coach C)*

Coach C articulates some insight as to why he is happy with an athlete's catch position at the bottom of a drop snatch '*I was quite happy with how she was landing, I was happy with her alignment, I was happy with where the weight was acting through the foot, it was acting through the heels, she was well balanced*'.



Our coach makes reference to specific 'movement and position scripts' relating to snatch balance. There is declarative, procedural and propositional schema knowledge underpinning the coach's judgements, The constellation knowledge web is intricate but the movements and positions are clearly within a level of

tolerance that error detection triggers have not activated to a threshold that the coach feels they need to intervene.

Discussion

Our cognitive schematic and constellation pattern error recognition model provide a framework from which, we can begin to understand Coach C's following statement.

'What I have in my head is a technical checklist and I guess what I've also got in my head is a picture of watching experts doing this… I think there's some constant evaluation going on, so from **[observation]** *lift to lift there are different things that are coming up. I guess maybe I see one or two things, so while you're seeing the bigger picture I guess I'm focusing on the major things and I'm coming to some sort of evaluation of that. I guess I'm prioritising but I don't know how! I'm prioritising in terms of what I think the most important things are at that particular moment in time and giving feedback'.*

Weightlifting

It is well documented that the key technical elements of interest to an S&C coach whilst observing and teaching classical and strength based weightlifting movements is static and dynamic postural points, how the bar is moving in relation to the body and how the weight is acting through the feet (Baechle & Earle 2008; Brewer 2005; Drechler 1998; Everett 2009; Newton 2002). Coach A sums this up nicely '*I'm looking at the shapes that the body makes and the*

sequence of those in relation to where the bar path is going'. Our study has accounted for how this technical information is stored and accessed.

If we pick a classical weightlifting movement to illustrate the point, we know that the athlete is connected to the bar through their hands (and therefor are in unison and move as a single unit). The connection between athlete and bar changes the centre of mass and base of support of the athlete in the 'get set' position. Internally, muscular contractions pull on their associated tendons that cross-joints and attach to neighbouring bones producing external forces through the athlete's feet (which are on to the floor) eventually, overcoming the bars inertia thus moving it. Overcoming the bars inertia will be determined by the amount of force applied to the bar, this is the product of mass multiplied by acceleration (F=MxA). The bar is positioned in front of the athlete, the weight, along with gravity is pulling them forwards so they have to attempt to maintain postures and shapes across the key positions as they execute the movement. It is said that experts posses a quality of analysis and 'recognise patterns that allow them to extract meaningful chunks of information from often confusing and complex activity' (McCullick *et al* 2006, p161). This is nicely illustrated by coach C who states '*I think with this kind of lift where it's done quickly, I tend to take a global view of it, I take an overall view of it, but then what I will do is focus in on certain aspects*'. Through the study, we are in a better place to understand how coaches can perform this task.

Expert S&C Coaches knowledge

We can see that our expert S&C coaches' possess declarative, procedural and propositional knowledge relating to the weightlifting movements. As illustrated in our example above, it is the inter-related aspects of this knowledge that is going to assist them in identifying and decoding errors (Lyle 2002; 2010). McCullick *et al* (2006) state that experts have a large library of domain related information and point out that the ability to grasp and retain new information depends on the existing knowledge base. The account of the technical model of 'front squat' recited by Coach C shows excellent recall and a dominant order (Schempp *et al* 2006; Sidentop & Eldar 1989) illustrating this point nicely, '*I'm looking for her elbows to be high, chest to be high, thoracic spine to be extended, for a natural lumbar curve in the spine to be evident and I'm looking for tracking her knees tracking out along her toes. I'm also looking for her coming to a pelvic neutral position before she descends and also I'm looking that her trunk is as upright as possible. I'm looking for her feet being flat on the ground and the weight acting through her heels. So what I'm seeing is a wee bit of slackness round about the pelvis, I'm seeing some anterior tilt there and at the bottom I see that she's not tightening up as much as she could do. I'm seeing a little bit of flexion in the thoracic spine and because of that possibly, and because of other things, she's losing a little bit of control in her lumbar spine'.*

The accumulation of procedural knowledge (e.g. physics, muscular system, skeletal system, anatomy) that underpins the declarative knowledge (e.g. the snatch, clean, squatting) is tacit (Nash & Collins 2006) and has not been verbalised strongly by our coaches. For example, how does coach C know what

the technical model should look like and how are they able to describe in depth the anatomical language associated with the front squat? Expertise is said to be highly specific to content and subject matter that is performance orientated (Siedentop & Eldar 1989). It is clear that the group have an excellent understanding of how the human body moves and how this relates to the weightlifting movements. When coaching, it appears that propositional and declarative knowledge is important. The technical models of the weightlifting movements and what these look like is declarative knowledge that has become tacit, probably through coaching, experience and reflection (see appendix B for our expert coaches references to coaching experience) (Cushion *et al* 2003). When an error has been detected, the propositional knowledge utilised to correct it may well be borne out of previous trial and error practise (Schempp *et al* 2006; Schempp & McCullick 2010).

If we relate our knowledge domains to our cognitive schematic, we can see that the underpinning schema knowledge is highly intricate and complex. Knowledge in one domain can be very thick and rich, that is, the coach has a significant amount of knowledge or a specialism in an area (e.g. body parts, bio-energetics, bio-mechanics), when this domain is linked with another thick knowledge domain (e.g. anatomy of joints) and then practically applied to create breadth of knowledge, a number of strong links or bonds in the cognitive web are formed as the outcomes of an intervention are realised (Ericsson 2005; Ericsson & Charness 1994; McCullick *et al* 2006).

If we consider the following statement made by coach A '*So I was looking for things like where all the joints were in relation to the bar, where the weight distribution was in the foot, shapes through the spine, making sure set up was correct*'. Our coach mentions, joints, shapes, weight application and references the bar. It would appear that for novice coaches wishing to develop the underpinning knowledge that will form later expertise, they should concentrate on the technical models of the weightlifting movements and all the appropriate associated knowledge as well as on excellent applied anatomy. It was these two knowledge categories that our expert coaches utilised most when observing athletes performing weight lifting movements. By teaching the novice to understand and see the patterns, connections and integrated 'links' in this knowledge, we will have 'shortcut' their learning.

Expert knowledge is said to be highly integrated, organised and hierarchical (Ericsson 2005; McCullick *et al* 2006; Nash & Collins 2006). Through the study we have identified 8 categories in which coaches posses knowledge and all the sub-categories that relate to these. In Abraham *et al's* (2006) study validating the gymnastic coaching schematic, they identified first, second and third order themes that allowed them to have sight of the tacit knowledge underpinning their practise and represent this in a hierarchical manner. Côt**é** *et al* (1995) adopting a grounded theory method and utilising meaning units were able to identify properties, categories and components of gymnastic coaches' knowledge. The method utilised in our study allowed us to (1) systematically identify knowledge that expert S&C coaches posses, (2) suggest what knowledge coaches use to identify errors and (3) how they access this knowledge when

observing weightlifting sessions. Perhaps further research of expert coaches utilising different research methods might gain even greater understanding of the integration (between knowledge domains) and hierarchy (get sight of deep tacit knowledge) of the knowledge that S&C coaches possess.

Experts are said to gain and utilise knowledge from different domains (McCullick *et al* 2006), if we consider the fact that in an Institute environment our S&C coaches are exposed to physiotherapists and are expected to carry out shared musco-skeletal and dynamic profiles, we can see that acquisition of new domain sensitised knowledge relating to movement dysfunction and restriction will be formed. For example, coach A mentions '*Gluts switching off to extend*', coach B states that '*there shouldn't be any imbalances or a-symmeteries*' in the squat and Coach C talks about '*ACL injury control exercises*'. The literature says that experts seek out information that will enhance their ability to understand the problems they face (Côté 2006; Ericsson & Charness 1994) and that this new knowledge is integrated into the expert's cognitive web. This raises a question of how information 'creeps' across professional domains (Errricson 2009) and how it might potentially positively or negatively influence and affect practise, is physiotherapy language useful or relevant in weightlifting? Some thought should be given to a coaches significant influences (Lyle & Cushion 2010), for example, if they are heavily influenced by a physiologist or a particular method of training, this will shape their knowledge in a particular way as they capture and assimilate shared expertise. Again, it is hard to account for these random interactions, perhaps conceptually; the cognitive knowledge schematic and

constellation webs need to reflect the idiosyncratic and personal beliefs (Cushion 2010) of expert coaches.

Script based error detection

Error detection occurs mainly through body part/segment and technical model faults, it would appear that our coaches utilise a script based error detection strategy as they watch the athlete performing each lift. Scripts can relate to a specific phase of the lift for example, the 'get set', first pull, transition, second pull, the catch, or the whole lift. As the athlete executes the skill, the coach is scanning the coaching related activity for triggers or cues that will flag an error (Lyle 2002; 2010). Coach A states that error detection starts in the 'get set' position of each lift '*I find that when I'm looking at a lot of lifts, where the weight distribution is in the foot tells me a lot of information… in almost any kind of exercise in terms of clean or snatch derivatives, squatting patterns, push press, I'm always thinking about setup because, for me it's crucial, a lot of the information that you get in terms of technique is to do with where the weight distribution is in the foot, how that weight distribution changes throughout the lift… for example, if the weight's in the wrong place then something's wrong somewhere else'.*

Expert coaches tend to correctly identify a problem rather than attempt a range of solutions, a trait of the more novice coach (Schempp *et al* 2006; Schempp & McCullick 2010). Experts are also said to be able to sift through large amounts of data and distinguish the important from irrelevant (McCullick *et al* 2006). If we think of the interaction between the rich, thick, deep and wide schema knowledge structures of our expert coaches' and how these relate to each of the

multiple phase and lift 'scripts' they posses, it seems clear that they will rapidly recognise error and have solutions to correct them.

As the coach observes each part of the lift they are taking a 'holistic snapshot' or 'frame' that they can compare with their 'template' ideal model (Lipschitz *et al* 2001; Lyle 2002). The ideal model can be thought of as a distinct pattern (constellation web) or collection of schema based knowledge relating to the full lift (or phases) that is stored in long-term memory and can be updated with new detail as coaching experience increases (Ericsson 2004; Lyle 2010). McCullick *et al* (2006) refer to a hierarchical 'inter-related schema' that are stored in a logical way and therefore readily accessible to the expert. The ideal technical model is stored as a series of schema scripts relating to the movement, positions, shapes and postures of each lift. Coach B describes this '*understanding of the technical model – what the ideal technical model should be. And then in terms of what those positions they should be hitting, and then I am trying to get them to do the same*'.

Whilst performing the repetition, the athlete transitions through the phases of the lift (as the bar moves through the sequence) and the coach scans for movement errors (incorrect bar path, incorrect movement at knee, pelvis, back) by rapid cognitive matching of what they are witnessing with script based knowledge that is instantaneously being pulled into working memory (Lyle 2010). The coach is constantly unconsciously performing this mental task allowing them to intervene with immediacy to provide necessary feedback. It is said that experts are able to see things that non-experts don't see and had have strong metacognitive capabilities (Siedentop & Eldar 1989), perhaps this

description of error detection provides a vehicle for better understanding this statement.

Through this description, we begin to better understand how experts observe faults in weightlifting movements. The simultaneous interaction between an error trigger and the recognition of a familiar pattern or fault through a 'scripts' stored in long-term memory, the retrieval of this 'template' into working memory and the subsequent coaching episode happens instantaneously. It is thought that experts appear to operate with automaticity and intuitively in their domain (Lyle 2002; McCullick *et al* 2006; Schempp *et al* 2006; Schempp & McCullick 2010) but in actual fact, rapid cognitive processes are at work, the experience underpinning this is shaped over many thousands of hours of practise (Côt**é** 2006; Cushion *et al* 2003; Gilbert *et al* 2006).

Linking this to the language of NDM:

There is no doubt that our coaches face problems in their everyday coaching environments (Cushion 2007) and therefore supports the idea that coaching is a problem-solving task. When we are faced with problems it is inevitable that we must make decisions about how best to rectify them. The decisions of S&C coaches would appear to be non-or semi-deliberative (Lyle 2002). Deliberate decisions are classified as those when the decision maker has time to consider all options without time pressure. Our coaches give feedback with relative immediacy to skills that are executed in under 3 seconds however, they are not the reflexive or intuitive decisions associated with life or death (Lyle 2010). Semi-deliberative decisions are those where the decision maker can benefit from

time, it is argues that if a coach can delay intervening, they can narrow alternative options by dismissing relevant informational cues therefor making better decisions (Lyle 2010).

Our expert coach performs rapid situational assessment whilst observing the athlete prepare to lift; there is immediate recognition of key attractors. These attractors are the mental 'templates' outlined above and assist the coach in assessing the unfolding situation. Whilst assessing the situation, the coach is performing diagnostic hypothesising, this can be thought of as them comparing what is unfolding in front of them with past experiences enabling them to predict potential outcomes, also considered a trait of expert coaches (Lyle 2010; Schempp *et al* 2010). Recognition of pattern faults trigger a range of appropriate solutions allowing the coach to intervene in an appropriate fashion.

Heuristics or 'speedy heuristics' are cognitive shortcuts that allow coaches to intervene with a solution to what is going on with immediacy (Lyle 2002; Lipshitz *et al* 2001). An example of this might be the athlete always losing the bar in a snatch to the front of the body. The heuristic they might deploy to fix the problem could be to state 'keep the shoulders over the bar for longer' or 'pull the knees further back through the first pull'. Both solutions could potentially fix the problem but (due to a range of attractors and cues) the coach automatically deploys the correct heuristic to fix the problem.

Context as a significant factor in coaching

From our interviews, context was identified as a significant category influencing the decisions of our coaches. Of relevance were factors such as past experience and athlete ability whilst in the session, the load on the bar, stage of workout and exercise selection. We know that research studies fail to contextualise the coaching interaction they observe (Cushion *et al* 2006; Cushion 2007; Cushion 2010) and that through interviews, it is possible to give more clarity to what is going on (Vergeer & Lyle 2007). We highlight some considerations that expert S&C coaches have whilst coaching however, shining a spot light on the coach-athlete interaction (Wikeley & Bullock 2006; Jones *et al* 2010) is critical if we are to fully understand the deliberations of the coach on each of their interventions. Our coaches do make reference to a range of contextual and inter-personal components relating to athlete understanding, learning style, level of analytical ability and mood all of which underpin the coaching episode observed. Our context box in figure 4 depicts a range of contextual factors that influence the coaching episode, in figure 4.1-4.3, the constellation maps are set within a context determined frame that is supposed to illustrate how context effects how the situation is observed. It is clear that further research is required to better develop understanding of how context effects the inter-personal and decision making component of the coaching process.

Another point of note relating to context is whether the findings of the study would have been different if we had observed expert S&C coaches from another environment or domain? For example, rather than observing the Institute multi-sport environment, what would we have found if we had observed S&C delivery

within a specific sport (Judo, cycling rugby or football), in another service area (other home nation Institute, higher education, professional sport, another country), or in a different part of the pathway (grass roots, youth, disability, schools), would the skills, knowledge domains and expertise schematic take on the same shape? We need to acknowledge that expertise is idiosyncratic (Lyle 2010) and that culture (Cushion *et al* 2006) influences it, all of our coaches have been heavily influenced by Scotland's S&C community and the philosophies and working practices of the **sport**scotland Institute of Sport, it would be interesting to review the findings of this study in different environment with other coaches to see whether they look different.

How this study could help novice coaches:

If we review the three questions that Abraham *et al* (1998) asked of coach development, (1) What knowledge should be taught to novice coaches, (2) What is the optimal method for teaching this knowledge and (3) how should we assess knowledge to encourage learning (p59), we are perhaps in a better place to answer this in relation to developing S&C Coaches.

We have identified the relevant knowledge that underpins our expert coaches decision-making whilst coaching. Developing coaches usually have a tertiary education and have spent time in the domain as an athlete (Gilbert *et al* 2006), this has given them skills and a basic understanding of the vocabulary they will need to engage with when coaching, knowledge at this stage is often presented in a modular 'silo' format (Jones 2006) and therefor, we need to help connect the knowledge bundles together in a meaningful way. Our expert coaches constantly

referred to the interaction between declarative and propositional knowledge for example, the bar moving away from the shins as the result of the hips rising to early or the athlete not shrugging and jumping resulting in them pulling the bar too early. We need to assist novice coaches in developing their cognitive knowledge webs so that they better understand the interaction *between* and integration *of* their knowledge. If we can help them to recognise triggers and cues and develop heuristic 'cognitive shortcuts' for spotting errors and appropriate solutions to them, we will have moved our coach education along.

By exploring how knowledge is stored and accessed in schema and script memory models we have a better understanding of what we might need to teach more novice coaches. Research has taught us that scripts and schema's are developed through experience (Ericsson 2005; Nash & Collins 2006), this experience cannot simply be downloaded into developing coaches however, we can orchestrate the forming of intricate cognitive 'constellation' webs by teaching coaches how to see what the exert coaches see (Cushion *et al* 2003; Gilbert & Trudel 2001; Nichol & Turner-Bisset 2006). We now know that a major source of error detection for S&C coaches is in technical model faults within the lifts and body part movement errors. If we provide formal training (Trudel, Gilbert & Werthner 2010) where we situate novice coaches in practical situation where they are encouraged to coach under the tutelage of more experienced coaches (Cassidy & Rossi 2006; Cushion 2006; Jones *et al* 2009), the practical forming of schema and script mental models can be developed in real situations. There are some critical points to be made here (1), the mentor has to encourage learning by initiating reflection in the novice, this should be done by

asking them to verbalise what they were thinking when coaching (Gilbert & Trudel 2006; Werthner & Trudel 2006), (2), Trial and error practise is critical to the novice, they need to make mistakes and then be given the opportunity to learn from them. (3) Mentor's must not simply provide the solutions, they must assist in developing understanding in the novice by adopting a questioning approach (Cassidy & Rossi 2006; Werthner & Trudel 2006) and finally (4), the novice must be able to practise their newly found knowledge in different situations, contexts and environments to reinforce the learning (Cushion *et al* 2003).

Critique of the study:

The study has given us novel access to the cognitions and decision-making capacities of expert S&C coaches. Our talk aloud (Lyle 2010) and stimulated recall (Lyle 2003) method gave us a significant amount of data to analyse however, care must be taken with this type of study (Lyle 2003; Vergeer & Lyle 2007). It is very challenging in the interviews for the interviewer not to share their ideas and opinions. This has obvious implications in that this can shape the interviewees responses skewing the results. Only one researcher has carried out the coding of the interview transcripts leaving it open to interpretation, this again has the potential to skew the findings of the study, as what is perceived to be meaningful to one person may be insignificant to another. There is also the potential for personal bias in the development of the categories, sub categories and subsequent coding. To reduce this, it is recommended that a team of researchers develop the coding from the interviews and that the analysis be verified through inter-test reliability.

An attempt was made to explore the coaches' knowledge and decision-making in and through their actual practise. Perhaps another approach would have been to present standard video footage of athletes carrying out weightlifting movements to our coaching group. By providing non-descript footage with deliberate faults, it would have been interesting to see how the coaches would interpret the athlete and lifts without context, how they would identify errors and what questions and assumptions about the lift they make. The control provided would allow us to compare knowledge between coaches and observe and explore how this would be applied to the same coaching episode.

To enhance the findings of the study, a re-coding of the interview transcripts to capture (1) interconnection and integration of knowledge areas and (2) actual errors by sub category would give us further data to understand how coaches cognitive webs are devised. It would also be interesting to attempt to further unpick the underpinning tacit knowledge (Nash & Collins 2006) of the coaches through follow up interviews. This study is certainly a 'first toe in the water' in exploring S&C coaches' expert knowledge but this is an early attempt and refinement and improvements will be needed to evolve our understanding of this interesting domain.

Conclusions

Utilising the language of NDM and a stimulated recall method we can conclude that expert S&C coaches utilise schema script based mental models when coaching weightlifting movements. Although still somewhat 'tacit' and idiosyncratic their declarative and propositional knowledge is deep, thick and rich, has a dominant order and is integrated and interconnected. We have proposed a 'cognitive schematic' and 'constellation pattern recognition' model to illustrate the cognitions of expert S&C coaches and suggested how they identify and decode errors in weightlifting movements. It would appear that expert S&C coaches' use non, and semi-deliberative decision-making when in coaching situations and that these are context determined. The findings of this study can assist in coach education and development by (1), identifying the relevant knowledge that novice coaches' will require to be effective when coaching, (2) offering an explanation of how knowledge integrates and inter-connects to, (i) identify coaching errors and (ii), provide appropriate solutions to fix them and finally (3). We suggest that these theoretical models are applied in practical situations to build novice coaches' own applied 'context related' experience under the tutelage of more experienced coaches'.

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Appendix A: *Unpublished data from coaching observation carried out for SPSP54*

Table 1: *Overview and summary of sessions*

	Session 1	Session 2	In Total
Duration	2 hrs	2 hrs	4 hrs
Athletes	8	12	20
Coach Episodes	488	622	1110

Table 2: *Overview and summary of coaching episodes*

	4th Nov	(%)	8th Nov	(%)	Total	Totals%
Observe	143	29.3	174	28.0	317	28.6
Demonstrate	35	7.2	51	8.2	86	7.7
Instruction	153	31.4	224	36.0	377	34.0
Feedback	64	13.1	53	8.5	117	10.5
Reinforce	70	14.3	73	11.7	143	12.9
Manage	23	4.7	47	7.6	70	6.3
Total	**488**		**622**		**1110**	

Table 3: *Breakdown of coaching interventions*

		4th Nov	8th Nov	Totals	%
Observe	Whole gym	3	37	40	3.6
	Individual Athlete	110	112	222	20.0
	Multiple Views	30	25	55	5.0
Demonstrate	Visual Demo - Positive	24	37	61	5.5
	Visual Demo - Negative	11	14	25	2.3
Instruction	Verbal education (Why's)	17	20	37	3.3
	Static cues	35	91	126	11.4
	Dynamic Cues	80	93	173	15.6
	Positive - non verbal	1	8	9	0.8
	Negative - non verbal	1	0	1	0.1
	Physical Manipulation	19	12	31	2.8
Feedback	Open Questions	44	42	86	7.7
	Closed statements	20	11	31	2.8
Reinforce	Positive reinforcement	41	59	100	9.0
	Negative reinforcement	5	6	11	1.0
	Hustle	21	7	28	2.5
	Scold	3	1	4	0.4
Manage	Meet/greet	8	12	20	1.8
	Platform allocation	4	10	14	1.3
	Space allocation	1	2	3	0.3
	Load assignments	5	14	19	1.7
	Review	5	9	14	1.3

Appendix B: Categories/sub categories identified and coded from the transcribed interviews

		Coach A		Coach B		Coach C		
		1	2	1	2	1	2	
	Athlete/Coach							Totals
Context	Athlete History	5	4	0	3	0	1	13
	Training History	10	5	0	1	1	2	19
	Sport	4	1	0	0	3	6	14
	Issue relating to sport	5	1	0	0	3	5	14
	Specific athlete restrictions	8	10	0	2	3	3	26
	Injury history	1	1	5	2	1	0	10
	Stage of workout	2	5	5	10	1	3	26
	Set/Rep					3	8	11
	Exercise selection					13	9	22
	Stage in cycle/season	2	1	1	3	1	1	9
	Load on the bar	6	16	4	14	8	14	62
	Fatigue/Tired					0	8	8
	Ability	2	4	2	1	2	2	13
	Experience	3	3	3	2	3	1	15
	Learning style	4	5	3	2	2	3	19
coach expertise	Coaching experience	6	5	0	1	5	1	18
	Watching others	1	0	3	1	3	1	9
	Professional body	1	0	0	0	0	0	1
	Coaching	12	8	5	2	15	10	52
	Making mistakes	2	0	0	0	2	0	4
	Formal training	2	0	0	0	1	0	3
	Reading	0	1	4	0	0	0	5
	Significant others	3	2	1	1	4	1	12
	Lifting experience	5	0	1	2	1	2	11
	General experience	1	1	0	0	4	0	6
	Reflection	7	6	0	2	1	3	19

Anatomical

		Coach A		Coach B		Coach C		
		1	2	1	2	1	2	
	Kinesiology							
Body part	Foot	23	22	15	4	28	22	114
	Ankle/Heel	5	6	3	2	15	9	40
	Knee	12	20	15	5	21	32	105
	Pelvis/Hips	27	34	13	26	25	25	150
	Spine/Back	9	14	5	17	11	21	77

	Lumbar					3	6	9
	Thoracic					1	7	8
	Thoracic cage/Chest	5	8	2	8	2	5	30
	Scapulae	5	1	0	0	1	4	11
	Shoulders	18	12	6	3	15	17	71
	Elbows	2	1	0	1	2	9	15
	Wrists	0	1	0	0	0	0	1
	hands	1	4	0	2	4	0	11
	Neck	0	0	0	0	2	0	2
	Head	0	4	0	0	4	8	16
Segments	Legs/lower	10	13	3	7	14	9	56
	Arms	9	4	3	6	6	12	40
	Upper	2	3	0	1	2	3	11
	Mid	0	2	0	0	16	9	27
	Levers/Segments	2	4	3	1	0	1	11
	ERROR	27	35	7	28	22	31	150
Muscles	Thighs/Quads	0	2	3	1	1	3	10
	Hip-flexors	0	1	0	0	3	3	7
	Hamstrings	7	5	1	0	4	4	21
	bum/Gluts	2	8	2	0	1	6	19
	Trunk	0	0	0	0	3	1	4
	Chest/Pecs	3	2	0	0	0	6	11
	Lats	0	1	0	0	0	0	1
	Traps	0	0	0	8	0	0	8
	Stretch/Flexibility	4	10	2	2	11	12	41
	Feel	21	7	2	2	2	3	37
	Tension/Activation	9	11	2	9	4	8	43
	ERROR	6	9	1	7	4	12	39
Anatomical	Flexion/Bend	2	0	2	5	8	5	22
	Extension/lengthen	8	15	7	28	26	26	110
	Upright					12	15	27
	rotation	3	0	1	1	0	0	5
	Elevate	1	0	0	0	2	1	4
	Depress	2	1	0	0	0	0	3
	Neutral	0	3	2	0	1	8	14
	Anterior	1	8	0	0	1	6	16
	Posterior	1	2	0	0	2	1	6
	Retract					3	3	6
	Angle					5	4	9
	hinge	2	1	1	0	0	0	4
	alignment	6	15	5	2	7	12	47
	Valgus						7	7
	stacking	4	2	0	0	0	0	6

	ROM	1	4	0	2	2	0	9
	ERROR	9	16	8	12	11	20	76

Technical

		Coach A		Coach B		Coach C		
		1	2	1	2	1	2	
	The Lift							
Weight Bar	Placement/Position	20	16	10	6	13	14	79
	proximity (to body part)	17	11	12	8	21	14	83
	contact	6	4	0	1	4	5	20
	bar path	7	4	4	10	8	4	37
	Speed	4	4	0	1	0	3	12
	Sound	0	1	0	3	0	1	5
	ERROR	12	16	7	12	7	10	64
Technical Model	Pattern/Movement	12	19	9	23	21	48	132
	shapes	6	11	1	3	4	6	31
	postures	24	17	3	15	6	17	82
	positions	15	22	21	23	28	13	122
	start pos	2	5	1	4	14	5	31
	set up	14	10	5	16	1	0	46
	Stance/Width	4	6	6	0	12	9	37
	ROM	3	1	3	0	7	2	16
	unweighting					2	1	3
	rhythm	1	0	0	1	0	4	6
	timing	4	5	1	22	2	9	43
	fluidity	3	6	1	1	1	3	15
	summation	1	0	1	6	0	0	8
	sequence	6	6	4	9	4	3	32
	coordination	5	3	0	1	8	2	19
	Speed	0	3	1	5	6	4	19
	Error	13	32	13	32	16	22	128
Kinematics	weight acting	26	29	16	5	20	7	103
	force application/generation	9	7	4	3	12	11	46
	Power Generation	3	0	0	2	3	2	10
	Rate of Force Development	0	0	0	0	2	3	5
	Inertia					1	2	3
	Base of Support	1	0	3	0	1	1	6
	Centre of Mass	2	1	3	0	1	3	10
	Stable	0	0	0	0	1	0	1
	Unstable	0	1	0	0	0	1	2
	ERROR	7	12	3	3	3	6	34
ent/Mo	Balance	3	7	0	0	3	2	15
	Coordination	1	1	0	0	1	0	3

	Stability	2	6	0	0	4	0	12
	Land/Jump	15	7	6	2	11	13	54
	Throw	2	6	0	0	0	0	8
	Catch					9	6	15
	Pull	7	1	8	17	10	10	53
	Drive/Intent	6	9	0	2	7	5	29
	Strength					15	15	30
	Triple extension/flexion	4	0	0	0	5	4	13
	Shrug	2	0	1	21	5	7	36
	ERROR	9	8	7	18	6	9	57

Appendix C: Interviews

COACH A – Interview 1