Skill acquisition at British Para Swimming: bridging the gap between research and coaching practice

D R POWELL

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DANNY POWELL

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ABSTRACT

This thesis documents a series of studies which are the first to identify the gaps between skill acquisition research recommendations and applied coaching practice on the British Para Swimming World Class Programme, and to utilise these findings to impact learning design. Specifically, study one and study two examined coaching practices in relation to three key principles in skill acquisition: (i) focus of attention, (ii) contextual interference, and (iii) implicit learning. Using athlete surveys, study one findings revealed no significant difference between coaches' use of internal or external focus cues, that coaches incorporate predominantly blocked practice scheduling, and that training design did not differ as a function of athlete disability. Study two provided a more extensive analysis of coaching practices through the observation of nine senior coaches on the British Para Swimming team, and coach interviews to shed light on the rationale behind their approach. Results indicated that coaches: (i) predominantly emphasise internal focus instruction and feedback cues, (ii) incorporate relatively low levels of between-skill variability and higher levels of within-skill variability and blocked practice, and (iii) apply mostly explicit learning techniques such as part-task training and verbal feedback, but also demonstrate the use of some implicit learning techniques such as analogies and constraints-based learning. Interview data indicated coaches had no knowledge of key skill acquisition principles. In utilising these findings to provide relevance and context to skill acquisition interventions, study three explored the efficacy and impact of an online skill acquisition coach education process with two senior Para swimming coaches with no knowledge of skill acquisition principles. Coaches were observed and interviewed both before and after four development sessions. Findings indicated the intervention was effective in influencing learning design, with coaching practices adapted to align more closely with established lines of inquiry in skill acquisition research. The thesis also describes experiences of a Skill Acquisition Practitioner embedded in the British Para Swimming team, as they attempt to identify and implement techniques which aim to enhance the learning and performance of skills among athletes with a range of disabilities, each with unique learning implications. Overall, the thesis demonstrates the importance of identifying gaps in understanding to provide context, and of harnessing coach experiential knowledge, in attempting to bridge the gap between skill acquisition research and applied coaching practice.

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

Appendix A: athlete survey used to explore perceptions of coaches' use of internal and external focus cues and approach to practice structure.

Appendix B: Extended descriptives for study one.

Appendix C: coach semi-structured interview for rationale and perspectives on coaching practices in relation to focus of attention, contextual interference, and implicit learning.

Appendix D: coach semi-structured interview for rationale and perspectives on coaching practices in relation to focus of attention, contextual interference, and implicit learning following the skill acquisition coach education intervention.

Appendix E: slides used as part of skill acquisition coach education intervention in study three. Base slides were also used as part of 'Key Principles of Skill Acquisition in Swimming' Webinar series.

CHAPTER ONE

1. General Introduction

1.1 Skill Acquisition in sport and Para sport

Skill acquisition is the study of factors which affect the acquisition, performance, and retention of motor skills in both developing and elite level performers or athletes. Research in skill acquisition (SA) has the potential to inform coaching practice and enhance athlete development. More specifically, through developments in research over recent decades, findings have highlighted the potential for SA techniques to enhance athlete learning and performance through various coaching mechanisms, such as the use of coaching cues and language (Winkelman, 2020; Wulf, 2013), the structure and scheduling of training (Magill, 2011; Wright & Kim, 2019), or the design of the athlete practice environment (Pinder et al., 2011; Woods et al., 2020). Despite this, research consistently reports a disconnect between contemporary scientific recommendations for SA and applied coaching practice (Brackley et al., 2020; Buszard et al., 2017; Porter, Wu, & Partridge, 2010; Powell, Wood, Kearney, & Payton, 2021 – chapter four; Williams & Hodges, 2005, 2023). Several researchers have highlighted potential explanations for this, which include a lack of coach access to suitable development opportunities (McMaster, Culver, & Werthner., 2012; Williams & Hodges, 2023), coach dependence on tradition, intuition, and custodial approaches (Dehghansai et al., 2020; Ford, Yates, & Williams., 2010; Moy et al., 2016), and/or de-contextualised research which fails to capture the rationale underpinning coach approaches to learning designs (Kearney et al., 2018; Stodter & Cushion, 2014). Furthermore, in comparison with other sports sciences there is a relative lack of appropriate skill acquisition coach education resources (Müller, Fitzgerald, & Brenton, 2020), and formal education processes which *are* developed, such as coaching workshops, are ineffective in translating knowledge and changing practice (Button & Farrow, 2012; Pinder & Renshaw, 2019; Stodter & Cushion, 2019). Given the nuances associated with the needs of athletes with physical or psychological impairments and the necessity for a more individualised approach to coaching, this has important implications for Para sport[1], where coaches may not be equipped to optimise Para athlete development.

Although public interest in Paralympic sport has grown, along with an increase in research into the physical preparation of elite Para athletes (e.g., Leprêtre et al. 2016), applied SA research in Para sport has been severely lacking - due in part to concerns over population validity and/or research settings which are unrepresentative of performance contexts (Churton and Keogh 2013; Pinder, Headrick, & Oudejans 2015). To illustrate this, a recent systematic review (Dehghansai et al. 2017) reported only one research study investigating learning in a Paralympic cohort (see Oudejans et al. 2012). A significant challenge for SA research in Para sport in particular is low levels of funding for sport science support, which results in practice interventions often limited to 'a theory transfer' from non-disabled contexts (see Paulson and Goosey-Tolfrey 2017). While this may be effective in some instances, there is ongoing debate about the usefulness of this approach across a range of disciplines (Hutzler, Higgs, & Legg 2016; Dehghansai et al. 2017). For the coaches of Para athletes, where a wide range of athlete disabilities each present unique implications for learning, this could lead to significant challenges (Fairhurst, Bloom, & Harvey 2017), particularly when aiming to optimise learning environments and integrate recommendations from scientific research (Pinder & Renshaw, 2019).

1.2 *The Skill Acquisition Practitioner*

The skill acquisition (SA) practitioner has been described as a sport scientist who examines the theories and processes underpinning motor learning and control and works closely with coaches and athletes to help translate research into practice (Steel et al., 2014; Williams & Ford, 2009; Williams et al., 2012). In collaboration with coaches and athletes, the SA practitioner often acts as a 'mediator' - transferring and translating relevant knowledge and theory into more accessible mediums (Dehghansai et al., 2020). Through working to understand and improve how athletes or teams make

[1] 'Para sport' is synonymous with disability sport, and comprises all sports involving individuals with physical, vision, and intellectual impairments, regardless of whether the sport is included in the Paralympic Games programme. 'Paralympic' is reserved exclusively for sports and athletes competing at the Paralympic Games (see Patatas, De Bosscher, & Legg 2018).

decisions, source information, and develop complex motor skills, the SA practitioner carries out a number of tasks, including:

- Designing and implementing skill training sessions for individuals or teams.
- Providing guidance to coaches and support staff on the use of effective instructions and feedback.
- Facilitating a greater awareness and understanding among coaches and support staff of the learning-performance distinction; how this distinction can underpin training design, and the development of appropriate methods of assessment for both.
- Delivering workshops/seminars/presentations to educate coaches, athletes, and support staff on key principles of skill acquisition.
- Collaborating with other sports scientists (e.g., strength and conditioning coaches) to improve athlete technique, measure performance, or design appropriate training activities.
- Conducting research to explore key questions of interest pertaining to the application of skill acquisition techniques.

In line with the gap between skill acquisition research recommendations and applied coaching practice described above, there remain very few acting SA practitioners in the applied/elite sport setting (Dehghansai et al., 2020; Williams & Hodges, 2023). This could in part be explained by the historical perception that skill acquisition is exclusively the domain of the coach (Steel et al., 2012), or the misperception that coaches are in fact skill acquisition practitioners and vice versa (Williams and Hodges, 2023). Nevertheless, researchers have called for more examples of successful collaborations between coaches and skill acquisition practitioners (e.g., Williams and Hodges, 2023) both to provide frameworks to guide future collaborations and help to demonstrate the value of the discipline in sport.

1.3 Swimming fundamentals

Long Course and Short Course

Swimming competitions take place in pools with standardised lengths. Long course (LC) events are held in 50 m pools and short course (SC) are held in 25 m pools. The Olympic and Paralympic Games take place in 50m pools but there are international events in both LC and SC. The primary difference between LC and SC is that a swimmer will turn more often in SC competitions and consequently will create more momentum from powering off the wall of the pool.

Competition Events

A variety of events are contested at major international swimming competitions like the World Championships and the Olympic and Paralympic Games. Typically, this will include the 50 m, 100 m, and 200 m races in each of the four strokes (breaststroke, backstroke, butterfly, and freestyle). For the freestyle there is also the 400 m event, and for women the 800 m, and the men the 1500 m freestyle. However, for Para swimming, event lengths do not go beyond 400 m. There are also the 200 m and 400 m individual medley events for both men and women, where swimmers complete lengths using backstroke, breaststroke, butterfly, and freestyle strokes (in that order). The individual medley for Para swimming is 150 m and does not include the butterfly stroke. In addition, there are male and female relays swum over 4x100 m and 4x200 m in Olympic swimming, with 4x50 m and 4x100 m in Paralympic swimming.

The Great Britain teams compete in international LC and SC competitions throughout the year with major LC 'meets' (competitions) typically taking place in the summer and major SC meets usually at the end of the calendar year.

1.3.1 Key skills in swimming and Para swimming

Strokes

Swimming competition comprises four swimming strokes. In relation to skills, the basic goal within each is to maximise propulsion and minmise drag. Broken down, this overarching aim involves a range of skills working in conjunction, including the arm pull, the leg kick, breathing, body position, and timing. The four primary strokes swum competitively are:

- **Freestyle** (Front Crawl): Swimmers use an alternating arm motion and a flutter kick. It is the fastest and most straightforward stroke and is often swum in freestyle events.
- **Backstroke**: Swimmers lie on their backs, using an alternating arm motion and a flutter kick. The backstroke is performed on the back throughout the race, and competitors must touch the wall at the finish while on their back.

- **Breaststroke**: Swimmers use a simultaneous arm movement (pull) followed by a simultaneous leg kick. It's characterised by the ‘frog-like’ leg motion and is known for its distinct stroke and kick synchronisation.
- **Butterfly**: Swimmers use an undulating, simultaneous arm movement and a simultaneous dolphin kick. The butterfly stroke is one of the most physically demanding due to the coordination required.

Starts

Start times (measured as the time to 15 metres) have been reported to account for anywhere between 0.8% and 26.1% of the total race time, depending on the event (Lyttle & Benjanuvatra, 2005) (i.e., the higher percentages reflecting proportions in sprint or short distance events). As such, effective swim start technique is a crucial component of competition performance.

Swimming start techniques

Block-Start: The block start in swimming typically takes the form of either the *track start* (i.e., one foot on the front and one foot on the back of the starting block) or the *grab start* (i.e., both feet on the front of the starting block), with front foot toes curled over the edge of the block and both hands tightly gripping the edge of the block. The block start is typically described in four phases (see Vantorre, Chollet, & Seifert, 2014 for a review):

- *Block phase*: This phase requires the optimisation of two distinct actions: (i) a fast reaction to the start signal, and (ii) a high impulse generated over the starting block. A compromise must be found between the two insofar as the reaction time needs to be brief, but enough time must be spent on the block to maximise impulse and achieve high horizontal velocity.
- *Flight and entry phase:* The flight and entry phase – strongly influenced by the block phase – involves attempting to achieve distance before hand entry in the pool, but also generating enough angular momentum to make a clean entry into the pool (i.e., entering the water through a small hole). There are several variations to the flight and entry phase, differing as a function of factors including angular trajectory and arm movement.

- *Glide phase:* The glide phase begins when the head enters the water and ends when the head breaks out of the water. The focus of this phase centres on maintaining a streamlined body position upon water entry to maintain velocity acquired in previous phases. It has been reported that glide time is more important to the start phase than either block or flight time, explaining 95% of the variance in start times for r = 0.97 (Guimares & Hay, 1985; Hay, 1988).
- *Underwater propulsion phase:* Following the initial glide, the swimmer must use only their legs to gain propulsion until the breakout whereupon they commence the swim stroke, and the start phase finishes at the 15-metre mark. This is except for the breaststroke, where the FINA rules state: "*after the start and after each turn, the swimmer may take one arm stroke completely back to the legs during which the swimmer may be submerged. A single butterfly kick is permitted during the first arm stroke, followed by a breaststroke kick*" (SW 7.1 FINA).

Backstroke Start: The backstroke start is considered technically more difficult than block starts (Mills, 2005) and is distinct in that the swimmer is required to start from inside the pool. At the 'take your marks' (or 'set') position, the swimmer places both feet on the wall and uses both hands to grip the bar attached to the starting block. Following push-off with the feet at start, a low resistance water entry is critical. Specifically, (and as with the block start) the swimmer will typically attempt a 'hole-entry' technique, where every body part should enter through the same small 'hole' in the water. This necessitates an arched back which allows the hip joint to extend fully and clear the hips of the water. Water entry precedes the glide and underwater propulsion phase on the back (see De Jesus et al., 2011 for a biomechanical analysis of the backstroke start).

Para swimming start techniques

Block start and backstroke start: Para swimmers with a classification that allows them to use the starting block (or the bar attached to the starting block) can employ similar techniques as non-disabled swimmers, depending on their specific classification and capabilities.

In-water start: Some Para swimmers may not have the ability to use the starting block and, therefore, use in-water starts. They can start from a stationary or floating position in the water, depending on their classification.

Assisted start: Some Para swimmers may require assistance on the start depending on their event and/or their level of disability. For example, a swimmer may need to hold onto a pole during an in-water start, or they may choose to do a block start, but require a member of support staff to assist them remaining stable on the block. (A description of the various classifications can be seen in section 1.4 below).

Turns

Whereas the relative contribution to swim races of starts decreases as the length of the event increases, the inverse is true of turns. Specifically, turns have been reported to represent 19.69 ± 0.24% (Morais et al., 2019) and 36.87 ± 0.61% (Morais et al., 2023) of total race time in 100 m and 1500 m long-course freestyle races, respectively. (In short-course events, which involve more turns, these figures would be much greater). Consequently, effective turn techniques are essential to competition performance.

Swimming turn techniques

Tumble turn (freestyle and backstroke): Swimmers execute a somersault or 'tumble' in the water as they approach the pool wall. The swimmer initiates the tumble upon hand entry on the last stroke, i.e., as the hand enters the water it pushes through, and the head follows round in rotation until the swimmer's feet touch the wall. In this way, the swimmer aims to minimise any *gliding* through the water to reach the optimum distance from the wall for the turn (approximately 1 m). Specifically, gliding should be avoided because it is associated with the athlete decelerating or not maintaining their speed. After completing the tumble, the swimmer extends their legs to push-off the wall. The push-off is a powerful movement generated by the legs to propel the swimmer back into the pool. The push-off initiates the glide and underwater propulsion phase of the turn and the swimmer should aim to emerge from the water just prior to the legal 'breakout' distance of 15 m (or as far as they are capable), thereby maximising the faster underwater phase. For some Para swimmers, physical disability may dictate they are unable to perform a tumble turn, and/or that their surface water swimming is faster than their underwater swimming. Para swimmers can instead opt to execute a ‘touch turn’, whereby they are required to touch the wall with both hands.

Open turn (butterfly and breaststroke): The open turn is used in butterfly and breaststroke events where the swimmer touches both hands on the wall simultaneously and then kicks off with their feet. As with the tumble turn, the swimmer aims to minimise any gliding through the water on approach to the wall so the final arm entry (on butterfly) or arm stretch (on breaststroke) should occur on or just before the wall. The swimmer should then rotate the body into the kick and streamline push-off the wall as quickly as possible.

Finishes

As with turn skills, the finish skill requires the minimisation of gliding on the approach to the wall – thus the final full stretched swim stroke should be timed with wall contact. Achieving this requires the skill of ‘spotting the wall’ on the approach. That is, upon the approach to the wall, the swimmer should see the wall and learn to know intuitively where their stroke will end and adjust it accordingly if necessary to minimise glide and maximise propulsion.

1.4 Classification in Para swimming

1.4.1 What is Classification?

Classification is a fundamental aspect of Para sports designed to uphold the fairness and integrity of competition. Its purpose is to ensure that victory in these sports is determined by the same essential sporting factors that apply to non-disabled athletes, including skills, fitness, strength, endurance, tactical acumen, and mental focus. The classification system is the cornerstone of this process. It serves two key functions: (i) determining which athletes are eligible to participate in a particular sport, and (ii) how these athletes are grouped together for competition. The goal is to minimise the impact of an athlete's impairment on their performance in the sport.

It's important to recognise that classification is sport-specific because the effect of an impairment on an athlete's performance can vary across different sports. Consequently, an athlete may meet the eligibility criteria for one sport but not for another. Simply having an impairment is not enough for an athlete to compete in Para sports.

Athletes are grouped into categories based on the extent to which their impairments limit their athletic abilities. These categories are referred to as 'Sport Classes', and they serve a similar purpose to grouping athletes by age, gender, or weight in other sports.

To participate in Para swimming, an individual must have an eligible impairment and meet the specified minimum impairment standards as outlined in the World Para Swimming (WPS) Classification Rules and Regulations (WPS Classification Rules and Regulations, 2022). WPS encompasses three categories of impairments: physical, intellectual, and visual impairments.

1.4.2 Sport Classes in Para Swimming

The sport class names in swimming consist of a prefix 'S' or 'SB' and a number. The prefixes represent the strokes, and the number indicates the sport classes. The prefixes stand for:

- **S**: freestyle, butterfly, and backstroke events
- **SB**: breaststroke
- **SM**: individual medley

Sport Classes S1-S10 / SB1-SB9 / SM1-SM10 - physical impairment

Ten sport classes ranging from 1 to 10 denote athletes with physical impairments. Each sport class group competes against one another as the classes are based on how the impairment influences swimming performance, rather than the impairment itself.

To assess how impairments impact an athlete's swimming ability, classifiers use a point system to evaluate all functional body structures and conduct a water-based assessment. The cumulative points obtained during this assessment determine the athlete's S and SB sport categories. Because S and SB events have varying requirements, swimmers are often assigned different S and SB sport classes. The SM sport category is derived from the athlete's S and SB sport classes.

Sport Classes S/SB11-13 - vision impairment

Three sport classes from S/SB11 to S/SB13 denote athletes with a vision impairment.

- **S/SB11**: Athletes with a very low visual acuity and/ or no light perception.

- **S/SB12**: Athletes with a higher visual acuity (than athletes competing in the S/SB11 sport class) and/or a visual field of less than 5 degrees radius.
- **S/SB13**: Athletes with the least severe vision impairment eligible for Paralympic sport. These athletes have the highest visual acuity and/or a visual field of less than 20 degrees radius.

Athletes in the S/SB11 sport class are required to wear blackened goggles to ensure fair competition. For safety reasons, all S/SB11 swimmers are required to use a tapper (a person standing at either end of the swimming lane with a long rubber-tipped pole to let the swimmer know when the wall is approaching). Swimmers in the S/SB12 and S/SB13 sport classes can choose whether or not to use one.

Sport Classes S/SB14 - intellectual impairment

S14 swimmers have an intellectual impairment, which is typically characterised by deficits in pattern recognition, sequencing, memory (particularly short-term or working memory), slower rates of learning, and/or slower reaction times – all of which impact on sport performance in general (see also Burns & Johnstone, 2020; Van Biesen et al., 2021). In addition, S14 swimmers often use a higher number of strokes relative to their speed as compared to non-disabled elite level swimmers.

1.5 Project rationale and introduction to chapters

1.5.1 Why my role was created

This research project and my development role as Skill Acquisition (SA) practitioner at British Para Swimming (BPS) was created in recognition from both coaches and the Sports Science and Sports Medicine (SSSM) team that something was missing between the biomechanical analysis of a swimmer's technique, and the application of coaching skills to implement any recommended changes. A persistent challenge faced by coaches was in getting new skills to 'stick'. More specifically, coaches had recognised that although skill changes or improvements could often be observed or measured during or immediately after practice (i.e., short-term *performance*), such changes were rarely observed after a more prolonged period or in an alternative environment (i.e., long-term retention or *learning*) (a phenomenon described in skill acquisition literature as the *performance-learning distinction*; Kantak & Winstein, 2012). In other words, over time and in transfer to competition settings, the swimmers would typically revert to performing skills in the way they had become accustomed to through years of practice. This challenge in sport, and in swimming in particular, is not uncommon. As has been noted in biomechanics literature, a plethora of research exists and continues to be produced on optimising swimming technique due to, among other things, technological advancements in biomechanical analysis, rule changes, and the continual evolution of the sport (Vantorre, Chollet, & Seifert, 2014). However, identifying potential improvements to technique is not effective if biomechanists are unable to change the behaviour of the swimmer (Barbosa et al., 2023). Consequently, the Head Coach and the SSSM team turned to the emerging field of skill acquisition for help. This thesis documents a significant part of my journey as both an academic researcher, and ultimately as an applied skill acquisition practitioner with the British Para Swimming team, as I attempt to discover ways of utilising scientific theory and findings to assist coaches in improving the learning and performance of motor skills, and hopefully to set the team on course for being a world leader in skill acquisition. For my work with the coaches to be effective, I first needed to understand more about the sport and about their current approaches to learning, and how the techniques they were adopting mapped onto current scientific recommendations.

1.5.2 Immersion in the sport

Some of the most common barriers to the uptake of skill acquisition expertise, and indeed sport science provisions in general, include coach perceptions that research aims lack practical relevance, that practitioners lack the necessary sport-specific knowledge to understand coach and athlete needs, and that practitioners are not able to communicate information effectively (Fullagar et al., 2019; Martindale & Nash, 2013; Schwarz et al., 2021; Steel et al., 2014; Stevens et al., 2021; Waters, Phillips, Panchuk & Dawson, 2019). As such, my first step was to immerse myself in the daily training environment at the National Performance Centre (NPC) in Manchester, familiarising myself with training methods, the language and culture of the sport, and most importantly building relationships with the coaches, athletes, and support staff. At every opportunity I would ask the NPC Head Coach questions and open discussions around techniques and approaches to learning. As a new member of a multidisciplinary sport science team, I was keen to contribute as quickly as possible, and I frequently found myself questioning the traditions of the sport, or coaching practices and philosophies acquired through experiential learning. Specifically, in line with the observations from other sports, the coaches appeared to be adopting techniques guided by tradition, intuition, and the emulation of other coaches, rather than techniques supported by the latest empirical evidence (e.g., Ford, Yates & Williams, 2010). However, understanding this experiential knowledge was key, as the most effective approach to practice design should involve a merging of the two perspectives (see also Button & Farrow, 2012; Greenwood et al., 2014). Furthermore, coach experiential knowledge at British Para Swimming carries even greater value due to the range of physical and mental disabilities among the athletes, each with entirely unique implications for learning and movement capability.

1.5.3 Skill acquisition principles of interest

Through my immersion in the training environment at the NPC and the first 6-12 months spent observing practice sessions, staff, and athletes, what struck me most was the complexity and intensity of the sport and of the team. Para athletes with a whole range of individual needs were being coached by one, two, sometimes three different coaches, each with unique approaches to learning. They would have scheduled meetings and sessions each week (often daily) with the physiotherapist, physiologist, psychologist, biomechanists, and strength and conditioning coaches. Every cog a piece in the machine. This was somewhat of a contrast to the academic literature in skill acquisition, with its neat and tidy experimental designs and controlled variables. At the same time, I was merely a student; a very small and insignificant cog placed somewhere close to the machine, with minimal experience even in my own field of designated expertise. I wanted to find a way into the complexity at the same time as acknowledging how little I understood. I realised the only way I was ever going to have any impact was to first spend significant time understanding what coaches were currently doing to facilitate learning and development relative to established principles in skill acquisition.

In observing the coaches some things were very apparent. First, the coaching of athletes involved extensive dialogue between athlete and coach. More restrained in their ability to talk to athletes *during* skill practice (i.e., when the swimmer is actually swimming), coaches would sometimes spend three, four, five minutes talking to swimmers both before and after skills were attempted. Within complex, interactional dialogue, I had noticed that coaches were often (but not always) quite prescriptive, and instructions would typically emphasise specific body parts in technique. I was aware that this contrasted with much of the literature on attentional coaching cues (e.g., Wulf, 2013), but either way, coaching cues and language were clearly an important part of coaching in swimming.

Second, training sessions for swimmers were all based on detailed pre-planned coaching sessions. Specifically, coaches at the NPC would write session plans specific to each swimmer, sometimes weeks in advance, denoting every feature of every metre swam or skill practiced. And almost every set within each week was different. This meant that the *scheduling* or structure of each swim session (i.e., the amount of variability or repetition involved) was both fairly rigid, or prescribed[2], and a significant feature of training design. In studying skill acquisition, I was aware of the potential relevance of this to the concept of contextual interference (e.g., Magill, 2011), but also with an academic background in cognitive psychology and memory, I was both aware and interested by the potential benefits to memory recall of variability or spacing effects (e.g., Cepeda et al., 2006).

Third, another feature of coaching I had observed were the occasional use of more non-prescriptive, or non-explicit approaches to learning and development. Specifically, the use of various equipment featured quite heavily in training, such as snorkels, fins, hand paddles, and paddle boards. Less frequent were examples such as 'bungee ropes' (i.e., long elasticated rubber ropes which would stretch the length of the pool), used either to pull the swimmer forward (increase propulsion) or pull the swimmer back (increase drag). Such examples could be considered forms of *constraints* (Newell & Jordan, 2007), i.e., manipulations of the task or environment to encourage one movement or discourage another. Coaches also appeared sometimes to use language as a more non-explicit approach. For example, there was the occasional use of analogies or metaphors to convey instructions (e.g., 'your arms are like a windscreen wiper action' for the arm movement following push-off from the wall on a turn). Coaches would also use language or instructions which appeared to be unique to the

[2] It must be noted that swimmers were also occasionally given choice or autonomy within swim sets. That is, while the volume would still be prescribed, part of a set may include a choice of stroke (e.g., '300 m of choice drill', or '200 m of freestyle or backstroke').

sport, but also carry relatively vague or non-descript information (e.g., ‘you’re slapping’ to convey that the arm entry into the water was not smooth).

Taken together, and over that initial period of immersion within the team, I decided that these were the areas of coaching and skill acquisition I wanted to explore further. In particular, in relation to coaching cues and language, the direction of the swimmers’ *focus of attention* encouraged by coaches (i.e., internal vs external focus; Wulf, 2013). Concerning the scheduling of practice and the level of repetition or variability prescribed by coaches, the concept of *contextual interference* (Magill, 2011). Finally, with regards to more non-prescriptive or non-explicit techniques such as the use of constraints or analogy cues, previous research has grouped these approaches under the umbrella term *implicit learning* (e.g., Poolton & Zackry, 2007; Winkelman, 2017). The similarities and differences among these forms of implicit learning, along with a justification for their grouping in the current thesis are discussed further in chapter 2.

Because these skill acquisition learning principles and their associated methods appeared to be prominent features of coaching in the sport, they offered the potential for practical *relevance*, and thus an opportunity for an entry point to ultimately begin to impact learning design with approaches not too far removed from techniques coaches were already adopting. Furthermore, some of the potential benefits of techniques associated with these skill acquisition principles had already been demonstrated in swimming (see chapter 2 and the literature review).

1.5.4 Introduction to chapters

Research in skill acquisition has the potential to inform coaching practice and enhance athlete learning and development. For example, findings have demonstrated the learning and performance benefits of facilitating an external focus of attention for the learner (Lohse et al., 2014; Wulf, 2013), of incorporating different forms of contextual interference (variability) in practice design (Magill, 2011; Wright & Kim, 2019), and of utilising more contemporary non-linear or implicit approaches to pedagogy (Masters, van Duijn, & Uiga, 2019; Pinder et al., 2011). Despite this, exploratory investigations across a range of sports indicate coaching practices often contrast with the scientific recommendations of best practice (Brackley et al., 2020; Diekfuss & Raisbeck, 2016; Porter, Wu, & Partridge, 2010; van der Graaff et al., 2018). Instead, coaches continue to rely upon experiential knowledge in their approach to practice design (Anderson, Stone, Dunn, & Heller, 2021; Brackley, Barris, Tor, & Farrow, 2020; Dehghansai et al., 2020; Powell et al., 2021 – chapter four). This trend is exaggerated in Para sports, where the constraints imposed on the coaches' role by a whole range of athlete disabilities are not supplemented by appropriate guidance resources (i.e., manuals, clinics, & seminars; Cregan, Bloom, & Reid, 2007). In relation to swimming specifically, skill acquisition research has identified techniques which can be used to enhance athlete learning and performance, involving both the use of coaching cues (Freudenheim et al., 2010; Komar, Chow, Chollet, & Seifert, 2014; Stoate & Wulf, 2011), and the manipulation of constraints (Guignard et al., 2019; 2014; Light, 2014). However, investigations in elite level swimming report that coaches have no knowledge of established skill acquisition principles, and typically adopt more traditional, explicit or prescriptive approaches to language and practice design (Brackley et al., 2020; Junggren, Elbæk, & Stambulova, 2018; Powell et al., 2021 – chapter four). This is perhaps unsurprising given the lack of skill acquisition information or guidance in formal swimming coach education or certification resources (e.g., Scottish Swimming, 2016).

The lack of uptake of skill acquisition findings and expertise in the sports setting has been attributed to a number of factors, including funding, the practical relevance of research techniques, and the accessibility of academic ideas and knowledge (Steel et al., 2014). Furthermore, formal education resources which *are* available do not align with coaches' learning preferences and have been shown to be ineffective in changing practice (Brink et al., 2018; Douglas, Falcão, & Bloom, 2018; Duarte et al., 2018; Fairhurst, Bloom, & Harvey, 2017; Kilic & Ince, 2015; McMaster, Culver, & Werthner, 2012; Pinder & Renshaw, 2019). The current research project sets out to address these issues, and more, and in turn to bridge the gap between skill acquisition research and applied coaching practice. In particular, in addressing the practical relevance of research techniques, a challenge for skill acquisition practitioners lies in identifying the more precise gaps between existing research and current applied practice, to provide context to begin to impact learning design (Pinder et al., 2020; Pinder et al., 2022 – chapter five; Powell et al., 2021 – chapter four). Previous attempts to achieve this have been limited to surveys exploring performers' perceptions of coach instructions and attentional focus (Dieffuss & Raisbeck, 2016; Guss-West & Wulf, 2016; Porter, Wu, & Partridge, 2010), quantitative measures of contextual interference in practice sessions for youth tennis players (Buszard et al., 2017), or qualitative analyses of coaches' perspectives towards the coaching of isolated swimming skills, including the freestyle stroke (Brackley et al., 2020), and the underwater fly kick (Margaret Thompson et al., 2022). Part of the current thesis represents the first attempt to provide an extensive examination of coaching practices across the British Para Swimming World Class Programme in relation to the recommendations from three key lines of enquiry in skill acquisition research: (i) *focus of attention*, (ii) *contextual interference*, and (iii) *implicit learning*. Specifically, study one (chapter three) explores athlete perceptions of coaching approaches during *start and turn* practice in relation to focus of attention cues and contextual interference, and further assesses whether practices differ as a function of athlete disabilities. In a mixed methods design, study two (chapter four) provides a quantitative analysis of nine senior British Para Swimming coaches' approach to practice design in relation to all three key principles of skill acquisition outlined above, and a qualitative analysis of coach interviews which serve to shed light on the rationale underpinning their approach. In utilising the findings and knowledge acquired from these studies to provide relevance to skill acquisition techniques in swimming and begin to impact learning design, study three (chapter six) explores the efficacy of an online skill acquisition coach education process with two senior coaches from British Para Swimming. More specifically, in attempting to address the barriers to the uptake of skill acquisition expertise described above, two coaches with no knowledge of skill acquisition principles are observed and interviewed both before and after a coach education process which emphasises simple and accessible terminology, visuals, and examples of practice (see Appendix D for baseline slides). The intervention is conducted via coaches' favoured approach, i.e., informally, and one-to-one (Fullagar et al., 2019), and encourages learning through coaches' preferred means, i.e., 'experiential learning', or learning by 'doing it' (Bates, 2007; Gilbert & Trudel, 2001; Greenwood et al., 2014; Maclean & Lorimer, 2016; Nash & Sproule, 2009; Rynne, Mallett, & Tinning, 2010; Sawiuk et al., 2018). With sessions that focus on enhancing the coaches' *understanding* of skill acquisition theory, and with an emphasis on no right or wrong approach, the study attempts to harness the coaches' own experiential knowledge (Greenwood et al., 2012, 2014), and explores what resonates and what works for them. In an investigation which is the first of its kind, the findings could have important implications for the field of motor learning and skill acquisition.

Finally, in between study two and three, and in slightly more chronological order in the thesis, chapter five provides an insight into some of my experiences as an applied skill acquisition practitioner with the British Para Swimming team over the course of the PhD project. This chapter represents a significant part of attempting to bridge the gap between research in skill acquisition and applied coaching practice in swimming. In particular, given the barriers to the uptake of skill acquisition in sport previously described, relatively few studies have explored the impact of skill acquisition in the applied environment, and a large proportion of research has been conducted in more controlled experimental settings (Buszard et al., 2017; Wulf, 2013). Among those studies which have been carried out in the field, particularly those concerning the effects of contextual interference, findings have been mixed (Barreiros et al., 2007; Farrow & Buszard, 2017). As such, there is a danger of this becoming a vicious cycle, as coaches, and particularly those in highly pressurised sports, may be less inclined to modify practice for the purposes of research if the benefits are not clearly demonstrable. Consequently, it is imperative that practitioners who are given the opportunity to be embedded in a sport share their experiences beyond well designed, publishable interventions. In doing so, they contribute to a framework of understanding which serves to break down the barriers to skill acquisition in sport, and facilitate future collaborations between coaches, athletes, and prospective skill acquisition practitioners. What’s more, knowledge sharing in this way carries further significance for those involved in Para sports, where guidance on coaching athletes with a range of unique learning and performance constraints is severely lacking (Cregan et al., 2007; Pinder & Renshaw, 2019). Chapter five describes some of my experiences in attempting to incorporate skill acquisition principles into the daily training environment at the National Performance Centre in Manchester, along with some examples of the application of skill acquisition theory with selected athletes.

1.6 Original project aims and objectives as laid out in RD2

The current research sets out to be the first to investigate multiple lines of skill acquisition research in the elite athlete setting. Specifically, the aim is to improve the learning of swim start and turn techniques in the British Para Swimming team by accelerating the learning process, generating skills with superior long-term retention and transfer capability, and skills which are more robust in the face of psychological or physiological fatigue.

The objectives of the thesis are as follows:

- *To identify skill acquisition current practices and needs from athletes and coaches.*
- *To examine the potential learning and performance benefits of facilitating an external focus of attention on a range of performance parameters in swim starts and turns.*
- *To assess if and how the CI effect will generalise to the applied setting.*

1.7 Adapted project aims and objectives

As can be seen in section 1.6 above, the original aims and objectives of the PhD project were firstly built around the analysis of the coaching of *start and turn skills* specifically. Furthermore, the aims concerned gaining an initial broad understanding of current coaching practices, before investigating the efficacy of various research-based skill acquisition interventions within the applied setting. That is, the initial plans for the project were largely experimental in nature.

As a result of several factors, as well as a natural evolution of the project through increased understanding of the demands of the sport, the project aims and objectives were adapted. First, the project was created initially with the intention of focusing skill acquisition provision on the development of start and turn skills. Within the BPS team, biomechanics support is split between a team of two – one biomechanist responsible for the development of start and turn technique, and one responsible for the development of swim stroke technique. My project supervisor was the former, and they left the research team, and subsequently the BPS team, approximately one year after the project began. Consequently, my Director of Studies, and the biomechanist for swim strokes, Dr Carl Payton, became also my lead supervisor, and it was felt that the emphasis of the project should shift from starts and turns to swimming skills more broadly. This coincided with the decision that a more extensive understanding of coaching practices was needed following the athlete survey for study one (chapter three). In line with this, I had approached Dr Phillip Kearney to ask for help in designing a more extensive coach analysis study. Amongst his suggestions, Phil recommended the inclusion of implicit learning as part of the analysis alongside focus of attention and contextual interference. Plans were made and data collection began for observing and interviewing coaches across the BPS programme (study two – chapter four).

Soon after data had been collected from the ninth coach, the COVID pandemic began, and swimmers and coaches at BPS did not return to the pools for approximately 15 months. From the perspective solely of data analysis, this break from the pool proved to be somewhat fortuitous. Specifically, it could be argued in hindsight that the scope of this study was ambitious in scale. COVID provided time to analyse what was a very large dataset, as well as the time to process and understand the information in relation to the potential needs of the coaching and athlete team.

Rather than simply exploring subsequent experimental interventions, the research team and I began to discuss the potential for utilising the findings from study two to create a more lasting impact for skill acquisition in the team. At the same time, COVID had actually *increased* communication between the wider BPS team members. Specifically, the introduction of regular Zoom meetings meant I was more often in communication with coaches outside the National Performance Centre (prior to COVID I worked daily at the NPC in Manchester, but the majority of BPS coaches are based at different clubs around the country). Towards the end of COVID two coaches in particular had begun to contact me expressing an interest in understanding more about skill acquisition. This ultimately led to further changes in the final stage of the project, where study three (chapter six) would become one with a focus on coach education in skill acquisition.

The revised objectives of the PhD research project were as follows:

(i) To identify the gaps between skill acquisition research recommendations and applied coaching practice on the British Para Swimming World Class Programme, to provide context to begin to impact learning design.

(ii) To utilise findings to help bridge the gap between skill acquisition theory and applied practice in swimming through applied interventions and coach education.

CHAPTER TWO

2. Literature Review

2.1 Focus of attention

In the motor learning literature, *focus of attention* (FOA) refers to the location of an individual's attention in relation to the performance task/environment (Wulf, 2007). In particular, attention can be directed either *internally* towards components of the body movement, thereby facilitating conscious awareness of *how* the skill is being performed, or *externally* towards the intended movement *effect* on the environment or end goal (e.g., motion of an implement, hitting a target, exerting force against an object) (Lewthwaite & Wulf, 2017). Evidence has accumulated to suggest that adopting an *external* (vs. *internal*) FOA enhances the learning and performance of motor skills (for reviews, see Lohse et al., 2014; Wulf, 2013). As a practical example, if an athletics coach wanted to increase the leg speed of a sprinter, research indicates they would benefit from using instructions such as, "try to minimise ground contact", as opposed to, "extend the knees as rapidly as possible". Although both instructions have the same goal (to increase leg speed), the former attempts indirectly to increase leg speed through a focus on the movement *effect* of minimising ground contact (external focus), whereas the focus of the latter is the *knee* and therefore the movement itself (internal focus). Indeed, research demonstrates that merely changing one or two words in the coaching instructions (e.g., "the club" versus "your hand") is sufficient to generate external or internal focus (e.g., An, Wulf, & Kim, 2013; Wulf, 2016).

2.1.1 Mechanisms for the external focus effect

In an attempt to explain the potential cognitive and neural mechanisms underpinning the external focus effect, Wulf and colleagues proposed the *constrained action hypothesis* (Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001; McNevin, Shea, & Wulf, 2003). According to this framework, an internal FOA induces conscious control processes which constrain the neuromuscular system by interfering inadvertently with automatic modes of control which would normally regulate skilled movement. In contrast, an external focus facilitates the automatic system by generating fast, unconscious, and reflexive control processes, allowing it to self-organise more naturally, unconstrained by the interference of conscious control attempts.

To test the assumptions of the constrained action hypothesis, research set out to investigate the extent to which automatisation of movement differs as a function of attentional focus. One method of assessing movement automaticity involves measuring the effects of secondary task loading on primary motor task performance (the dual-task paradigm) (Abernethy, 1988). In particular, as automatically controlled skills are thought to place fewer demands on working memory than consciously controlled skills, superior performance in a simultaneous secondary task requiring additional cognitive resources would be considered indicative of automaticity in the primary task. Adopting this approach, Wulf, McNevin, and Shea (2001) reported that external focus was not only associated with superior balancing performance, but also with faster reactions to auditory stimuli during the balance task compared to internal focus. Similarly, Poolton, Masters, Maxwell, and Raab (2006) reported that golf putting performance was maintained during secondary task loading (i.e., a tone counting task) when participants were instructed to focus externally, but not when focus was directed internally.

Movement automaticity as a function of FOA has also been explored via alternative means. For example, as automatic movements are thought to represent a more efficient mode of motor control (Wulf et al., 2010), consciously controlled movements are expected to produce higher levels of electromyographic (EMG) activity. In line with this, studies have shown that internal focus leads to significantly higher levels of EMG activity than external focus (Lohse, Sherwood, & Healy, 2010; Wulf et al., 2010; Zachry et al., 2005). Two additional parameters purported to be indicative of movement automaticity are *movement fluency* (e.g., Shemmell et al., 2005), and *movement regularity* (e.g., Roerdink, Hlavackova, & Vuillerme, 2011). Movement fluency is thought to increase through the process of skill acquisition (Hreljac, 2000; Shemmel et al., 2005; Thomas, Yan, & Stelmach, 2000), and is exemplified by the fluid and smooth swing of elite golfers compared with the rigid movements of novice players. Fluency of movement is defined as the rate of change of acceleration of the moving limb and is typically operationalised through the *dimensionless jerk* (Hogan & Sternad, 2009). Greater movement fluency is characterised by lower dimensionless jerk values. Movement regularity is a measure derived from the theory of stochastic dynamics and is operationalised using sample entropy (SEn; Richman & Moorman, 2000). For static tasks such as balancing, movement automaticity is associated with a *higher* SEn (i.e., lower regularity) (Lamoth, van Lummel, & Beek, 2009; Roerdink et al., 2006, 2011). Conversely, for cyclical, dynamic tasks such as running, a *lower* SEn (i.e., a higher regularity) is thought to be indicative of movement automaticity (Newell, Broderick, Deutsch, & Slifkin, 2003; Vaillancourt & Newell, 2002; Vaillancourt, Sosnoff, & Newell, 2004). Incorporating all the aforementioned measures, Kal, Van der Kamp, and Houdijk (2013) conducted a comprehensive test of the predictions of the constrained action hypothesis. The authors reported not only that external FOA resulted in superior motor performance in a cyclic one-leg extension-flexion task than internal focus, but that dual-performance in a cognitive letter fluency task was also enhanced. Moreover, increased automaticity as a function of external focus was demonstrated via reduced levels of EMG activity, enhanced movement fluency, and greater movement regularity. These findings have since been extended to show enhanced movement automaticity through external focus via increased *joint coordination* during skill execution. In particular, Vidal, Nakajima, and Becker (2018) replicated previous research in reporting that external (vs. internal) focus enhanced performance in a standing long jump task, but in a dynamical systems approach using a modified method of vector coding (Chang, Van Emmerik, & Hamill, 2008), the authors also demonstrated that performance was characterised by increased coordination patterns between the knee and ankle in the downward phase of the jump compared with a knee-dominated flexion under internal focus instructions. This provided an illustration of how internal focus constrains the motor system by reducing the degrees of freedom.

In a more recent expansion of the constrained action framework, Wulf and Lewthwaite (2010) supposed that an internal FOA causes a ‘self-invoking trigger’, leading to overt movement control which would otherwise be automatic, and resulting in a continual series of ‘micro-choking’ episodes. As such, the authors argued that an external focus plays a dual role in (i) reducing a focus on the self, and (ii) directing attention towards the task goal (Wulf & Lewthwaite, 2010, 2016). In this way, it is suggested that by suppressing off-task and self-focused attention, supported by the so-called default mode network in the brain (Buckner, 2012; Buckner, Andrews-Hanna, & Schacter, 2008), an external focus contributes to *goal-action coupling* by promoting functional connectivity between spatially distinct neural regions associated with higher levels of motor skill (e.g., Ito, Matsuda, & Shimojo, 2015).

2.1.2 Demonstrations of the external focus effect

In the first demonstration of FOA effects, Wulf, Höß, and Prinz (1998) (experiment 1) reported that participants practicing slalom-type movements on a ski simulator task instructed to focus on the pressure they exerted on the *wheels* underneath the apparatus (external focus) exhibited superior performance compared to participants instructed to focus on their *feet* exerting the pressure (internal focus), and compared to a third group who received no explicit instructions (control). Significantly, the external group was more effective than both the internal and control groups during a delayed retention test where no instructions were given, providing evidence that an external FOA enhances the long-term learning of motor skills relative to an internal or non-directed FOA. Subsequent research has replicated the external focus effect in a range of sports, particularly those involving external implements such as in basketball free throwing (Zachry, Wulf, Mercer, & Bezodis, 2005), dart throwing (Lohse, Sherwood, & Healy, 2010), golf pitching (Bell & Hardy, 2009; Wulf & Su, 2007), golf putting (Poolton et al., 2006), tennis ball tossing (Saemi et al., 2013), discus throwing (Zarghami, Saemi, & Fathi, 2012), volleyball serving (Wulf, McConnel, Gärtner, & Schwarz, 2002), baseball batting (Castaneda & Gray, 2007; Gray, 2004) and weight lifting (Marchant, Greig, Bullough, & Hitchen, 2011). In such studies, attention in the external focus conditions is typically directed towards the intended movement of the implement used, or towards a target that implement might strike (e.g., a dart board), compared to the internal focus conditions where attention is directed towards the respective limbs involved in the movement. The external focus advantage has also been demonstrated in non-implement sport skills, such as standing long jumps (Becker, Fairbrother, & Couvillion, 2020; Porter, Ostrowski, Nolan, & Wu, 2010), vertical jumps (Psotta, Abdollahipour, & Janura, 2020; Wulf & Dufek, 2009; Wulf, Dufek, Lozano, & Pettigrew, 2010), gymnastics (Abdollahipour et al., 2015), and sprinting (Ille, Selin, Do, & Thon, 2013; Porter et al., 2015). Evidence for the effect has now been obtained from tasks ranging from music performance (Mornell & Wulf, 2019) to wild water kayak racing (Banks, Sproule, Higgings, & Wulf, 2015), in both children (e.g., Wulf, Chiviacowsky, Schiller, & Ávila, 2010) and adults (e.g., Chiviacowsky, Wulf, & Wally, 2010), either learning new skills (e.g., Totsika & Wulf, 2003) or performing rehearsed skills (e.g., Schücker, Hagemann, Strauss, & Völker, 2009). Furthermore, a number of studies report that when no FOA instructions are provided (control groups), participants typically perform similarly to when attention is directed internally (e.g., Landers et al, 2005; McNevin & Wulf, 2002; Mornell & Wulf, 2019; Wulf & Su, 2007; Wulf, Zachry, Granados, & Dufek, 2007), perhaps suggesting a natural inclination towards adopting an internal focus in the absence of instructions (e.g., Land, Tenenbaum, Ward, & Marquardt, 2013; Pascua, Wulf, & Lewthwaite, 2015).

With particular relevance to the current research project with the British Para swimming team, findings suggest that the external focus effect also extends to the performance of swimming skills. More specifically, in studies with both intermediate (Freudenheim et al., 2010) and expert (Stoate & Wulf, 2011) level swimmers, front crawl speed was increased significantly when participants were instructed to "push the *water* down/back" (external focus), compared with instructions to "pull your *hands* back" (internal focus). A range of additional benefits observed in external focus research could also apply to various performance parameters in swimming, including enhanced movement efficiency (e.g., conserving energy through the water) (Lohse, Sherwood, & Healy, 2011), maximal force production (e.g., pushing off the block) (Halperin et al., 2016; Wu, Porter, & Brown, 2012), muscular endurance (e.g., maintaining race pace and distance per stroke) (Marchant et al., 2011), and reduced reaction times (e.g., reacting to the gun) (Ille et al., 2013). Findings also indicate that the complexity of technical skills in swimming (e.g., starts and turns), requiring control of multiple degrees of freedom - albeit in a relatively closed environment - (see Guadagnoli & Lee, 2004; Farrow & Buszard, 2017), may accentuate the external focus effect (Wulf, Töllner, & Shea, 2007). Furthermore, Mornell and Wulf (2019) report that external focus instructions enhance the performance capability of experienced performers *under pressure*, which, given the pressurised nature of elite level swimming, could have a significant impact on competition results[3]. With additional relevance to the Para swimming team, the external focus advantage has now been demonstrated in participants with both physical (Fasoli, Trombly, Tickle-Degnen, & Verfaellie, 2002) and intellectual impairments (Chiviacowsky, Wulf, & Avila, 2013).

[3] It is suggested that when an athlete feels pressure, they will often direct attention internally towards the *self*, which has frequently been shown to impair motor performance (Baumeister, 1986). By directing attention away from body movements and towards the task goal, external focus is thought to reduce the focus on the self (e.g., McKay, Wulf, Lewthwaite, & Nordin, 2015; Wulf & Lewthwaite, 2016).

2.1.3 Novices vs. experts

The majority of research investigating the external focus effect has been conducted using novice performers (Wulf, 2013). Tests involving participants with a higher level of expertise have yielded more mixed results (Porter and Sims, 2013; Halperin et al., 2017). In particular, studies examining performance in a range of motor skills have reported that attentional focus cues (internal *or* external) either had no effect or negatively impacted performance for experts compared to baseline (e.g., Couvillion & Fairbrother, 2018; Porter and Sims, 2013; Wulf, 2008). In assessing ten metre sprint times in highly experienced sprinters, Winkelman, Clark, and Ryan (2017) reported that while external focus conditions resulted in significantly faster sprint times than internal focus conditions, there was no significant difference between times in the external and control (no instructions) conditions. The authors suggest that as experience increases, so too does the benefit of the athlete's *normal* focus. This suggestion would appear logical, as experience presumably promotes development of the implicit (unconscious or automatic) motor plan (Porter and Sims, 2013; Winkelman et al., 2017). In the implicit motor plan, movement processes have become consolidated and exist within automatic control structures, therefore requiring little explicit control as a function of instructional cues (Lohse, Wadden, Boyd, & Hodges, 2014). Consequently, it's possible that in some instances instructional reminders of any kind interfere with efficient and established processes and become detrimental to performance.

However, there are alternative explanations for the inconsistencies observed in the external focus effect among expert performers. For example, in demonstrating performance deficits in speed jump roping following *both* internal and external focus cues, Couvillion and Fairbrother (2018) also reported that only two out of fifteen of the expert participants were *familiar* with the external cues. The importance of familiarity with task instructions was demonstrated by Maurer and Munzert (2013). In their study with skilled basketball players, free throw success rate was higher for individually preferred (i.e., inter-individually different) familiar cues relative to unfamiliar cues, irrespective of attentional direction (internal or external). In acknowledging such methodological limitations in previous research, Wulf (2016) suggests it would be unwise to leave expert athletes to their own devices and assume they will find the focus that is optimal for them. This assertion is supported by research indicating that expert performers' chosen foci (control condition) are not always optimal for performance when compared with being encouraged to focus externally (Abdollahipour et al., 2015). Furthermore, in a study with experienced swimmers, post-trial interviews designed to elucidate the type of focus athletes voluntarily adopted in control conditions revealed that swimmers who reported using an external focus exhibited superior performance to those who focused internally (Stoate & Wulf, 2011). In addition to this, despite some inconsistencies several studies have shown that highly experienced individuals still benefit from an external FOA (e.g., Bell & Hardy, 2009; Ille et al., 2013; Mornell & Wulf, 2019; Wulf & Su, 2007).

In a more recent study among skilled swimmers, Maloney and Gorman (2021) reported no differences in outcome measures of the swim start technique (i.e., relative peak power, horizontal velocity, and time to 5 m) between internal and external focus conditions. However, kinetic and kinematic measures revealed all movement events occurred earlier in the movement sequence, indicating enhanced neural self-organisation in the external focus condition. The authors therefore concluded that external focus may be beneficial for the preparation and organisation of movement control in skilled swimmers but may not have an immediate effect on performance outcome.

2.1.4 Just external focus?

Following the initial findings from FOA research, related lines of investigation have begun to make the case that the dichotomous nature of the internal-external distinction may be insufficient when translated to the applied setting (e.g., Becker, Georges, & Aiken, 2019; Mullen, Faull, Jones, & Kingston, 2015; Toner & Moran, 2015). For example, in experimental studies, researchers are able to take the time to design external focus cues which fit the task. However, identifying appropriate external focus cues in daily practice can be a challenge for coaches and athletes, particularly in sports not involving an implement or clearly discernible external target (i.e., in contrast to sports such as darts or archery). In the search for alternative cues which might confer similar learning benefits, research has highlighted *holistic process cues* (Mullen et al., 2015). Holistic cues conceptualise the *feeling* of the movement as a whole, in contrast to internal cues which direct attention to *component parts* of the movement. As a practical example, an internal focus cue in golf might encourage a focus on the motion of the *arms*, whereas a holistic cue might simply emphasise a *smooth* swing. According to this line of research, it is *internal* cues specifically which generate the conscious control processes thought to be detrimental to performance (e.g., Mullen & Hardy, 2010; Mullen et al., 2015). This conscious control is based on explicit knowledge of skill components, which is then accessed in a step-by-step manner resulting in movements that are typically slow and effortful (Masters, 1992). Holistic cues serve to camouflage explicit movement information by coding instructions kinesthetically (Mullen & Hardy, 2010), inhibiting the accrual of explicit knowledge, and thereby reducing reliance on conscious processes which in turn accelerates the acquisition of skills as a function of a more automatic mode of control (Mullen et al., 2015; Mullen et al., 2016). In demonstrating the efficacy of holistic cues as a viable alternative to external focus cues, Becker et al. (2019) reported that both external and holistic focus cues enhanced performance in a standing long-jump relative to baseline compared with internal focus cues, with no significant differences between external and holistic focus.

In contrast to the dual process nature of much of the FOA literature, i.e., internal (conscious) focus is characterised as suboptimal and external (automatic) focus optimal, an alternative line of research proposes a hybrid perspective. Specifically, it is suggested that while external focus is beneficial in certain conditions, elite-level athletes can also benefit from an internal focus or *increased* conscious processing during practice. For example, skill modification or refinement studies report that an internal focus of attention should be used initially to destabilise ingrained movement patterns before the skills become (re)automated through practice (Carson & Collins, 2011; Carson, Collins, & Kearney, 2017). In this way, it is suggested that expert performers are required continually to switch between reflective (or conscious) modes of bodily awareness (i.e., when correcting skills during practice) and largely automated states (i.e., when competing). The ability to do this successfully, and thus engage in *continuous improvement* even once a level of expertise has been reached, has been explained as a function of 'somaesthetic awareness' (i.e., a heightened sense of body consciousness) (Toner & Moran, 2014, 2015a, 2015b). Indeed, it is thought a functional somaesthetic awareness in athletes accounts for more short-term adjustments and error correction *during* performance. For example, Bernier et al. (2016) reported flexibility and variability in attentional focus among expert figure skaters in response to changing circumstantial factors in competition. Nyberg (2015) found that elite freeskiers consciously attended to on-line skill execution to help identify movement features which might require alteration/adjustment to maintain performance proficiency. In line with this interactional view of controlled (conscious) and automated processes in motor performance (see Toner & Moran, 2021), it is suggested that research should differentiate the circumstances under which varying proportions of FOA cues might be optimal (Collins, Carson, & Toner, 2016).

Further to the notion that the effectiveness of adopting an internal or external FOA might be contingent on the stage of learning or the circumstances of competition, initial findings also highlight the potential significance of the type of task or skill to-be-learned. In particular, Gottwald et al. (2020) reported that an internal (vs. external) focus may be preferable when congruent with task demands. More specifically, the effectiveness of internal focus cues may increase as the pertinence of proprioceptive task information increases. In their study, proprioceptive feedback pertinence was enhanced by removing visual information during a computerised aiming task (Exp. two), and through an ankle weight on a leg-extension task (Exp. three). It was found that internal (vs. external) focus cues in these instances resulted in reduced amplitude errors and increased muscle movement efficiency, indicative of enhanced planning. The implication proposed by the authors are that an internal FOA may be more effective in sports high in pertinent proprioceptive feedback, such as gymnastics, weightlifting, diving, or swimming. In other words, an internal focus should enhance congruence between the instructions and feedback, which is largely proprioceptive in nature in these sports. However, laboratory derived findings require more ecologically valid testing.

2.1.5 Focus of attention in practice

Although FOA effects are now well established in the motor learning literature, little is known in relation to how findings have translated to the applied setting. In one frequently referenced study, 84.6% of athletes participating in the USA Track and Field Outdoor National Championships reported that their coaches most often provide instructions during practice that promote an *internal* FOA (Porter et al., 2010). The remaining 15.4% reported receiving a mixture of IF and EF instructions, and none reported receiving exclusively EF instructions. Similar findings have emerged in volleyball (Diekfuss & Raisbeck, 2016), baseball (van der Graff et al., 2018), amateur boxing (Halperin et al., 2016), and ballet (Guss-West & Wulf, 2016). As such, it may be that elite coaching practices in relation to attentional foci in sport are sub-optimal for skill learning and performance. In a study from the clinical setting examining FOA during treatment of the hemiplegic arm, video recordings revealed that 95% of feedback statements provided to patients by physiotherapists emphasised an internal focus of attention (Durham et al., 2009).

2.2 Contextual interference

The Contextual Interference (CI) effect refers to the relatively robust finding that the learning of multiple skills, or variations of a single skill, is enhanced as a function of *interference* during practice (Magill, 2011). Interference can be created through a manipulation of the scheduling of practice trials within a session. In particular, high levels of CI emerge when the learner switches between multiple skills throughout practice (e.g., ACBABCACA), whereas low levels of CI are involved when one skill is repeatedly practiced before moving on to the next skill (e.g., AAA BBB CCC). The latter schedule is typically referred to as *blocked* practice (e.g., Farrow & Buszard, 2017). Findings reveal that although low levels of CI typically produce better performance during practice, high CI typically leads to better performance during retention and transfer tests (Wright & Kim, 2019).

2.2.1 Demonstrations of the contextual interference effect

In the first demonstration of the CI effect, Battig (1972) reported that the verbal learning of paired-associate words was enhanced under conditions of high (vs. low) CI. More specifically, although participants who learned the twelve paired-associate word lists in a blocked (low CI) practice schedule (one list at a time) exhibited superior memory performance during practice than those practicing in a high CI schedule (switching randomly between paired-associates on any list), a later test of free recall revealed that the pattern of results was reversed, with the high CI practice group showing superior retention and retrieval capability. Following these findings, Shea and Morgan (1979) set out to investigate the CI effect in relation to the learning of motor skills. In their experiment, participants were required to learn three variations of a complex arm movement which involved picking up a tennis ball in response to a light stimulus, knocking down three freely moveable barriers, and then placing the ball in its final location. Participants practiced the three arm movements for a total of 54 trials in either a blocked (18 trials of one movement pattern before moving on to the next) or high CI (randomly switching between the three movements for the total 54 trials) practice schedule. In line with Battig's predictions for the CI effect, the blocked group performed better in practice than the random group, but in a 10-minute retention test the pattern of results was reversed. Furthermore, in a 10-day retention test, although participants who had practiced in a blocked schedule performed better in a blocked test than those in a random-to-random test group, the random-to-blocked group significantly outperformed the blocked-to-random group. As such, the results indicated not only that CI led to better skill retention, but also that CI provided a means of eliminating dependency on reinstating the practice context for optimal performance. In other words, the learned skills were now more adaptable to different environments. Early findings now extend to recent research in the clinical setting, where the efficacy of the CI effect has been demonstrated in motor skill learning among post-stroke patients (Jo, Noh, & Kam, 2020; Moliterno et al., 2020).

2.2.2 Mechanisms for the contextual interference effect

Theoretical explanations for the CI effect are based around cognitive processes during performance. For example, the *forgetting-reconstruction hypothesis* (Lee and Magill, 1983) proposes that high levels of CI cause the performer to forget repeatedly task-specific information between practice trials, thereby requiring them to (re)construct the action plan on each attempt. This process is thought to develop the learner's ability to retrieve and construct action plans, thus enhancing the acquisition of skills. In contrast, the *elaboration hypothesis* (Shea and Morgan, 1979) suggests that high CI causes the performer to engage in a process of *comparing and contrasting* the skills being practiced. As a result, a more elaborate and distinctive representation of the motor skill is created in memory. Although these theoretical frameworks provide different explanations for the precise mechanisms underpinning CI effect, they share the assumption that the CI effect operates as a function of a limited capacity system such as working memory. This limited capacity system causes the performer either to forget previous skill-specific information in conditions of high CI (the forgetting-reconstruction hypothesis), or to compare-contrast new information with the previous attempt (the elaboration hypothesis). Support for this idea was provided by findings indicating that participants practicing under conditions of high CI, compared to those in conditions of low CI, show slower reaction times to a probe both prior to movement (when action reconstruction is thought to occur), and in the inter-trial period (when elaboration processing is thought to occur) (Li & Wright, 2000). Slower reaction times are indicative of greater working memory involvement (i.e., cognitive processing). Further support that the CI learning benefit is dependent upon cognitive processes that occur during the inter-trial period has been provided by neurophysiological measures. In particular, inhibiting activation of the primary motor cortex during the inter-trial period via transcranial magnetic stimulation was reported to negatively impact high CI practice, but not low CI practice (Lin et al., 2008, 2009). A potential limitation of this research, however, pertains to the simplicity of the motor tasks involved (e.g., finger tapping tasks). The generalisability of such findings to applied sport settings may require the analysis of more complex skills, and/or the development in situ measures of brain behavior (Farrow & Buszard, 2017).

Whereas the traditional explanatory frameworks emphasise the CI effect in relation to more explicit or conscious processes such as forgetting-remembering or comparing-contrasting, an alternative explanation proposed by Rendell et al. (2010) is derived from the theory of implicit motor learning. Implicit motor learning (discussed in detail in section 3 below) is thought to occur in the absence of explicit or conscious awareness of skill-related information, thereby reducing reliance on working memory processes (Masters, 1992; Masters & Poolton, 2012). In reporting the retention benefits of high CI practice for two motor skills in Australian Rules Football (handball and kicking), Rendell et al. (2010) made two further observations. Firstly, relative to low CI practice, high CI practice generated greater levels of cognitive activity. Secondly, learning of the more complex of the two motor skills (kicking) during high CI practice was characterised by processes which typically underpin implicit learning (i.e., participants displayed superior secondary task transfer performance and were less able to access verbally based task-specific knowledge). As such, the authors suggest that the demands placed on working memory resources as a result of task switching in high CI practice may overwhelm this limited capacity system to the extent that the learner is unable to test hypotheses relating to the movement solutions generated, or to rehearse and store explicit task-specific information (the implicit learning hypothesis – Masters, 1992). Taken together, therefore, there appears to be consensus that the CI effect operates as a function of increased cognitive effort/processing, but it is as yet unclear whether the mechanisms which underpin learning result from an *increase* in task-related processing (forgetting-reconstruction & elaboration hypotheses), or a *reduction* in task-related processing (CI as a form of implicit learning).

2.2.3 The influence of skill complexity

Evidence for the CI effect derives predominantly from controlled laboratory experiments investigating the learning of simple motor skills among novice performers. Less consistent are findings which emanate from applied sport settings involving the practice of more complex skills (Farrow & Buszard, 2017). For example, in meta-analyses of CI studies conducted by Brady (1998, 2004), it was reported that effect sizes for simple motor skills (e.g., finger tapping tasks) were considerably larger than for more complex applied skills (e.g., tennis groundstrokes). In a further meta-analysis, Barreiros et al. (2007) revealed positive CI effects in relation to skill retention were recorded in only 11 of 27 studies in applied settings. This discrepancy has led to suggestions that the CI effect may not translate to the learning of complex skills in sport (Brady, 2008; Wulf & Shea, 2002), and to an alternative theoretical explanation that CI practice benefits may relate simply to one of *specificity* with the performance context (Farrow & Buszard, 2017; Lee, 1988). That is, if competition features high CI, high CI practice might produce skills which are more transferable to competition, and vice versa if competition features low CI (see also Russell & Newell, 2007).

A potential explanation for the reduced effect of CI in applied settings concerns the relative difficulty of the skills being practiced. More specifically, in line with various accounts of learning (e.g., *challenge point framework*, Guadagnoli & Lee, 2004; *desirable difficulty proposition*, Christina & Bjork, 1991), learning is more robust when the task involves an optimal level of challenge for the performer (i.e., difficult but not too difficult). As complex motor skills potentially already require high levels of cognitive effort to perform (at least initially), the additional cognitive effort required for high CI practice scheduling (see also Broadbent et al., 2017; Patterson & Lee, 2007) presumably exceeds the optimal level of challenge for learning (see also Farrow & Buszard, 2017). Consequently, some researchers have argued that a certain level of skill is required to reap the benefits of high CI practice (e.g., Magill & Hall, 1990; Herbert, Landin, & Solmon, 1996; Farrow & Maschette, 1997; Guadagnoli & Lee, 2004). This idea has been supported by findings which indicate that as skill develops during practice, a *gradual increase* in levels of CI can enhance the learning of complex skills including golf putting, disc throwing, and basketball shooting (Hodges et al., 2011; Porter & Magill, 2010; Saemi et al., 2012). In these experimental studies, a gradual increase in CI levels has typically been facilitated by the inclusion of a moderate or serial level CI practice schedule in between the blocked and random phases, which comprises a more predictable sequence of task switching (e.g., ABC ABC ABC). A potential problem with this predetermined form of practice scheduling pertains to an uncoupling with the performer's success rate. In particular, according to Guadagnoli and Lee's (2004) challenge point framework, optimal learning occurs as a function of adapting task difficulty to an individual's skill proficiency or rate of learning. A practical solution to this has emerged in the form of the *Win-Shift/Lose-Stay* (WSLS) paradigm (Simon, Lee, & Cullen, 2008), whereby the level of CI a performer experiences is contingent on performance itself. Here, as the name suggests, after a successful skill attempt (win), the performer switches to practicing an alternative skill. If the attempt is unsuccessful (lose), the performer repeats the same skill. In this way, application of the WSLS means a generally proficient performer will switch between tasks more frequently, thus experiencing higher levels of CI, while a generally less proficient performer will switch less frequently, experiencing lower levels of CI. Initial research assessing the efficacy of the WSLS as a means of facilitating the learning of complex skills in the applied setting has reported significant improvements relative to baseline in the performance of basketball shooting, with no significant differences between blocked, random, or WSLS groups (Porter, Greenwood, Panchuk, & Pepping, 2020). Overall, however, few studies have investigated the CI effect in any form in the applied setting with highly skilled performers (for exceptions, see Hall et al.,1994; Ollis et al., 2005). As such, it is difficult to conclude that the high CI learning advantage will be more pronounced among athletes with a greater level of skill.

The lack of CI research involving highly skilled performers is perhaps not surprising given the lack of conclusive evidence from the applied setting. Elite level athletes and coaches (in often highly pressurised environments) may be less inclined to modify practice for experimental purposes if the advantages are not clear (Buszard et al., 2017). This perhaps places greater emphasis on the need firstly to examine and evaluate *existing* coaching practices at the highest level of performance, where athletes presumably operate on a level of skill sufficient for CI to be effective. Further, the ability to measure CI objectively in the applied setting could allow for tests of comparisons between various forms of practice scheduling without the need to interfere with daily practice (Buszard et al., 2017). In a previous observation of this kind, it was reported that experienced players and coaches in football typically design practice schedules which are low in CI (Williams & Hodges, 2005). In a more recent study, Buszard et al. (2017) examined practices among skilled youth tennis players. More specifically, the authors designed a metric to assess quantitatively the levels of CI involved in practice as a product of two further variables: (i) *between-skill variability*, and (ii) *within-skill variability*. Between-skill variability describes the switching between different skills during practice (e.g., practicing a tennis serve followed by a backhand), whereas within-skill variability refers to discernible variations in the execution of the same skill (e.g., practicing a T serve followed by a wide serve). It was reported that tennis practice comprised very little between-skill variability, but higher levels of within-skill variability. However, a notable limitation of both aforementioned studies has been the failure to capture the coaches' intended training outcomes, and thus the rationale for their approach. For example, it may be that coaching techniques observed are being utilised with the relative difficulty of the task, or stage of learning for the athlete in mind.

2.3 Implicit learning

Implicit learning describes the process of acquiring a skill in the absence of conscious or explicit knowledge about how that skill is performed. In contrast, explicit learning refers to the acquisition of a skill alongside a conscious understanding of the facts and rules pertaining to that skill (Kleynen et al., 2014; Masters & Poolton, 2012). Experimental research indicates that implicit (vs. explicit) learning produces skills which are more robust in the face of performance-induced pressure (Lam, Maxwell, & Masters, 2009; Masters, 1992) and under physiological fatigue (Masters, Poolton, & Maxwell, 2008; Poolton, Masters, & Maxwell, 2007), without slowing the rate at which those skills are acquired (Masters, van Duijn, & Uiga, 2019). As a practical example of these distinct pathways to learning, a child learning to ride a bike might first explore the required movements with the aid of stabilisers. A parent/instructor might then remove the stabilisers and provide basic instructions which do not pertain directly to the movement pattern required (e.g., "pedal faster"), rather than giving explicit information around how to steer, balance, or maintain posture. In this way, the movement pattern emerges from a desire not to fall, rather than through a conscious understanding of the skill. This would represent an example of the implicit learning pathway. Alternatively, a child attending golf lessons may be taught more formally and is therefore more likely to acquire that skill explicitly (at least in the initial stages of learning). In particular, an instructor might first be expected to describe the fundamental movement patterns which underpin successful execution (e.g., feet shoulder width apart, little finger clasping index finger, head still), and would therefore provide a conscious understanding of these processes to the learner. In doing so, the instructor would assume that a conscious focus on the key elements of the skill would accelerate learning relative to the learner being left to their own devices. It would then also be assumed that through practice, skill performance would eventually become more automatic. This constitutes an example of the explicit learning pathway.

2.3.1 Mechanisms for the implicit learning effect

The implicit learning advantage has been explained via *reinvestment theory* (Masters, 1992; Masters & Maxwell, 2008), which has also been described as Master's *conscious processing hypothesis* (e.g., Mullen & Hardy, 2010; Wilson, Smith, & Holmes, 2007). According to this theory, performers in situations involving psychological stress (e.g., competition), will, to varying degrees of propensity, attempt to control consciously previously automated movements, causing those skills to break down (a phenomenon termed *reinvestment*). Conscious motor control operates as a function of accessing explicit, rule-based knowledge of a skill in working memory, which is then accessed in a step-by-step manner resulting in movements that are typically slow and effortful (Masters, 1992). Reinvestment theory suggests that implicit learning minimises the accrual of such knowledge, thereby reducing the opportunities for reinvestment and performance breakdown.

2.3.2 Implicit learning in the applied setting

In experimental research, implicit learning has typically been facilitated through the dual-task paradigm. In particular, participants learning a task implicitly, such as golf putting, are required concurrently to perform a secondary task (e.g., a letter generation task) during the acquisition phase. The secondary task is designed to occupy enough processing capacity in working memory to inhibit conscious awareness of the primary task (putting). Findings reveal these implicit learners report little explicit task-related knowledge compared to participants who learn via explicit instruction or guided discovery (controls) yet exhibit superior performance in high anxiety transfer tests (e.g., Hardy, Mullen, & Jones, 1996; Masters, 1992; Mullen, Hardy, & Oldham, 2007). The limitation of the dual-task approach is its impracticality for the applied coaching environment (Masters, 2000). Moreover, it can slow the rate of learning relative to explicit or even guided discovery learning (Masters & Poolton, 2012). As such, researchers have sought to identify implicit learning techniques which are more conducive to the applied setting. Prominent amongst those highlighted in the literature are (i) *errorless learning*, (ii) *analogy learning*, and (iii) *constraints-based learning* (see, for example, Lam, Maxwell, & Masters, 2009; Poolton & Zackry, 2007; Winkelman, 2017).

Before discussing each of these applied techniques in turn below, it is pertinent to first describe fundamental differences and similarities underpinning the approaches, and thus, provide further explanation and clarity as to their inclusion under the umbrella term of implicit learning in the current thesis. Distinctions between these forms of implicit learning relate primarily to whether they operate as a function of *passive* or *active* learning strategies. Specifically, as in the aforementioned dual-task learning, errorless learning involves the acquisition of skills in a passive manner (Prather, 1971). That is, whereas dual-task learning promotes passive learning by exhausting working memory resources, errorless learning is passive insofar as successful (errorless) practice negates the active search for optimal movement solutions. In contrast, analogy and constraints-based learning represent more active implicit learning strategies. Specifically, analogy or metaphor learning cues code or chunk explicit movement information such that the learner is guided to uncover the related procedural information for themselves. As Duit (1991, p. 650) states, 'metaphors are comparisons where the basis of comparison must be revealed or even created by the addressee of the metaphor'. Similarly, constraints-based learning encourages active exploration of movement solutions through the adaptation to constraints. Indeed, as research has recently suggested, analogies can themselves act as a form of constraints (Winkelman, 2020).

Although differences exist in these learning strategies in relation to passive and active learning, they share the property of being non-prescriptive or 'non-explicit' in nature. For example, each of errorless learning, analogy learning, and constraints-based learning have been shown to limit the accrual of explicit skill knowledge in practice (Brocken, van der Kamp, Lenoir, & Savelsbergh, 2020; Maxwell, Masters, Kerr, & Weedon, 2001; Masters & Maxwell, 2008) – a fundamental characteristic of implicit learning (Masters & Maxwell, 2008). As such, and in line with previous research (see Poolton & Zackry, 2007; Winkelman, 2017), errorless learning, analogy learning, and constraints-based learning are categorised under the umbrella term of implicit learning for sections of this thesis. However, in study two (chapter four) implicit learning refers only to analogy and constraints-based learning, and in study three (chapter six) implicit learning refers only to analogy learning.

2.3.3 Errorless learning

Errorless learning refers to a technique which involves keeping errors to a minimum during practice (not removing them completely as the name suggests). Its efficacy is predicated on evidence which suggests that making errors in practice causes the learner to consciously construct and test movement hypotheses in an attempt to correct their mistakes, creating a buildup of explicit knowledge (Lam, Masters, & Maxwell, 2010). Consequently, reducing the number of errors reduces this propensity. One way to facilitate errorless learning in practice is to move progressively *from easier to more difficult* goals (which contrasts with maximising errors by beginning with the difficult task). For example, Maxwell et al. (2001) compared an errorless learning group in golf putting, who moved incrementally from 25cm to 200cm from the hole, with an *errorful* group, who moved incrementally from 200cm to 25cm from the hole, and a third group who putted from different distances in a random order (controls). It was reported that errorless learning improved performance, and further that only the errorless learners were able to maintain performance when a secondary tone-counting task was introduced, indicating that both the errorful and control groups were over reliant on working memory (explicit) processes. Similar findings have since been obtained in relation to the acquisition of fine hand motor skills in dentistry (El-Kishawi et al., 2021; Winning, Malhotra, & Masters, 2018). Despite these and other promising results (Capio et al., 2013; Poolton, Masters, & Maxwell, 2007), no study has yet (to the knowledge of the research team) attempted to assess whether coaches in the applied sport setting adopt errorless learning techniques.

2.3.4 Analogy learning

Analogy learning is another practical method coaches can use to facilitate the acquisition of skills via the implicit learning pathway. In particular, whereas the previously described *holistic* instructional cues can help reduce conscious processing by coding movements kinesthetically, analogies serve to code movement instructions *symbolically*, thereby camouflaging task-specific rules and helping to avoid the accrual of explicit skill knowledge (Masters et al., 2019). For instance, instructional movement analogies have been shown to reduce working memory involvement relative to explicit instructions in the learning of table tennis strokes (Koedijker et al., 2011; Liao & Masters, 2001), basketball shooting (Lam et al., 2009), and dynamic balance skills (Kim, Qu, & Lam, 2021). In addition to reduced processing demands, Komar, Chow, Chollet, and Seifert (2014) reported that novice swimmers learning through movement analogies improved inter-limb swimming coordination during the underwater phase of the breaststroke relative to participants receiving explicit instructions. More specifically, although neither group developed stable coordination patterns, the analogy group exhibited movements which were biomechanically more efficient. The authors suggested that the use of non-prescriptive (implicit) instructions in the form of analogies may have allowed the swimmers to develop desirable movement solutions while preserving functional variability (flexibility), whereas prescriptive pedagogy would typically lead to the development of a single ideal movement pattern (see also Chow et al., 2006, 2011).

Examples of analogical instructions in experimental research have included, 'move the bat as though it is travelling up the side of a mountain', or 'pretend to draw a right-angled triangle with the bat' for a table tennis forehand topspin shot (Koedijker, Oudejans, & Beek, 2008, 2011; Liao & Masters, 2001; Poolton et al., 2007), 'move the stick as if you are sloshing a bucket of water over the floor' for a hockey push-pass (van Duijn, Hoskens, & Masters, 2019), 'put your hand into a cookie jar' for a basketball shot (Lam et al., 2009; van Duijn, Crocket, & Masters, 2020), 'perform the movement like a pendulum' for golf putting (Schucker, Hagemann, & Strauss, 2013), 'pretend to be soldiers standing on guard outside Buckingham Palace' for a balance task (Orrell et al., 2006), and 'pretend that you are following footprints in the sand as you walk' to improve gait in Parkinson's disease (Jie et al., 2016). More recently, Winkelman (2020) proposed three categories of analogies to facilitate skill learning: (i) scenario-based analogies (i.e., reference to an analogous scenario, such as the 'reaching for the cookie jar' analogy for a basketball throw); (ii) constraint-based analogies (i.e., the channelling of pertinent movement information, such as 'imagine you've got a pole going through your body from fingers to legs' to guide a swimmer's glide position); and (iii) object-based analogies (i.e., featuring an inanimate object, such as 'you're scraping the froth off a cappuccino cup' for a swimmer's breaststroke; 'you're squeezing a tennis ball between your ankles' for a swimmer's set position on a jump start). To date, only one (known) study has explored how coaches and athletes make use of analogy learning techniques within the applied setting. Specifically, Guss-West and Wulf (2016) surveyed professional ballet dancers to determine what constitutes their typical focus of attention during the execution of movements (this measure was also used to infer likely coach instructions). It was reported that the dancers utilise analogy cues (e.g., 'feeling like a swan') to facilitate performance 28% of the time.

2.3.5 Constraints-based learning

Constraints-based learning (CBL) has been described as a conceptual framework which can be used by coaches to design learning rich environments (Winkelman, 2017). According to this framework, coordinated movements emerge as a function of learners adapting to the constraints imposed on them during practice. These constraints involve the individual characteristics of the learner (*organismic constraints*), the requirements of the task (*task constraints*), and the environmental conditions (*environmental constraints*) (Newell & Jordan, 2007). Constraints can be manipulated such that the desired movement emerges through a process of self-organisation, rather than via prescriptive (explicit) instruction. In this way, CBL is also considered to promote implicit learning processes by way of a reduction in the accrual of explicit skill knowledge (e.g., Brocken et al., 2020; Winkelman, 2017).

A key concept in the CBL approach pertains to *representative learning design* (Pinder et al., 2011), i.e., the extent to which practice replicates the performance context. Representative learning is described as a function primarily of two factors: (i) *functionality*, and (ii) *action fidelity*. Functionality relates to the extent to which the practice task maintains the coupling between perception and action that is present in the real-world performance context; whereas action fidelity refers to the degree to which the training environment is representative of the performance environment. The

CBL approach encourages the design of a practice setting which affords the learner a high level of both functionality and action fidelity.

Experimental research has provided various examples of how a CBL approach can be implemented in practice to enhance the learning experience. For instance, decreasing the surface area of the court in tennis resulted in prolonged rallies for low-skilled participants and subsequently improved hitting success rates relative to participants using standard constraints (Farrow & Reid, 2010). More recently, Buszard et al. (2014) extended these findings to show not only that the scaling of equipment (racquet, ball, court) in children's tennis improved hitting performance and technique, but also reduced working memory involvement, in line with the premise of implicit motor learning. In a further example of CBL in practice, Stretch, Nurick, and McKellar (1998) modified a cricket bat to one third of its regulation size to improve their batsmen's ability to strike the ball with the middle of the bat. In conducting a review of the literature to establish the efficacy of a CBL approach to learning in interceptive sports specifically, Clark, McKewan, and Christie (2019) reported that 77.7% of the studies found a positive effect on the acquisition of skills following manipulation in training protocol. Finally, in an example from swimming, Guignard et al. (2019) manipulated the swimming speed (task constraint) and the fluid flow (environmental constraint) in a flume and reported that elite swimmers adapted their open pool technique to maintain performance by changing their arm-to-leg coordination pattern, without any explicit instruction to do so.

To date, little research has explored the extent to which coaches adopt a CBL approach in the applied setting. In swimming, applied insights from previous observation research indicate that elite coaches rely heavily on more traditional skill acquisition techniques such as verbal feedback and part-task training, which involves the decomposition of skills into component parts through the explicit prescription of drills (e.g., the full swimming stroke is reduced to the kick component); yet coaches are also shifting towards the use of more contemporary implicit and 'non-linear' methods like CBL (Brackley et al., 2020; Junggren et al., 2018). However, the use of such techniques in the applied setting appears to have evolved intuitively, and coaches may be unaware of the theoretical context underpinning their efficacy (Renshaw et al., 2019). Furthermore, it is suggested that effective implementation of CBL requires an understanding of *ecological dynamics* (see Chow et al., 2019), and that the dense academic language associated with this field has provided a barrier to its take-up in the applied setting (Renshaw & Chow, 2019).

2.4 Overlapping learning principles

Although the three learning principles outlined above (focus of attention, contextual interference, and implicit learning) have been presented and described separately, research highlights considerable overlap between the three. For example, in reporting the learning benefit of contextual interference in practice for overhand throwing (Exp. one & three) and golf putting (Exp. two), Chua et al. (2019) also found that enhanced learning through variability was associated with greater external focus of attention among participants. A range of other overlaps exist in the literature, such as the use of analogies to facilitate an external focus of attention (e.g., Poolton and Zachry, 2007; Wulf et al., 2002), or as a form of constraints (Otte et al., 2020; Winkelman, 2020). In another such example, when reporting the learning benefit of contextual interference for complex motor tasks in Australian Rules Football, Rendell et al. (2010) found that learning was characterised by processes typically associated with implicit learning (i.e., superior secondary task transfer performance and reduced explicit skill knowledge). Such findings present not only overlaps between learning principles but theoretical contradictions. Specifically, both external focus and implicit learning effects are thought to operate as a function of reduced working (or conscious) memory involvement (Masters & Maxwell, 2008; Wulf, 2013). In contrast, explanations for the contextual interference effect infer cognitively demanding processes in working memory via (re)construction (Lee and Magill, 1983) or elaboration (Shea and Morgan, 1979). Potential paradoxes exist also in learning recommendations which, for example, discourage the search for optimal movement solutions (e.g., errorless learning) versus those which encourage an active search (e.g., constraints-based learning); or those which generate automatic control processes (external focus), versus those which heighten conscious awareness (internal focus).

Clearly, the overlaps described present challenges for discussing these learning principles independently. Furthermore, potential contradictions present challenges for coaches attempting to reconcile theories of best practice. Nevertheless, the complexity and nuance among learning principles is reflected in the complexity and nuance of elite level sport. As such, the first step for research is to acquire a greater understanding of the constituent parts of each to highlight precise gaps between research and practice to begin to provide context to impact learning design (see also Pinder et al., 2022). Furthermore, while the learning principles described may in some instances complement or counteract one another, research still successfully highlights differential learning effects among them within the same sports (e.g., Gray, 2020), thus illustrating the potential benefit of discussing them independently as a starting point.

CHAPTER THREE

3. Study One: Focus of attention and variability at British Para Swimming: athlete perspectives of coaching approaches during start and turn skill practice

3.1 Introduction

The development of effective start and turn techniques in swimming is critical to overall performance at the highest level of competition (e.g., Vantorre, Chollet, & Seifert, 2014). Exploratory reports within skill acquisition literature suggest coaching practices in a range of sports may be sub-optimal for skill learning relative to the scientific recommendations of best practice (Buszard et al., 2017; Porter, Wu, & Partridge, 2010; Williams & Hodges, 2005). The current study surveys athletes from the British Para swimming (BPS) World Class Programme to investigate athlete perceptions of the practices adopted by elite level coaches during the coaching of start and turn skills in relation to two prominent lines of skill acquisition research: (i) focus of attention, and (ii) contextual interference.

3.1.1 Focus of attention

Focus of attention (FOA) refers to the location of an individual's attention in relation to the performance task/environment (Wulf, 2007). More specifically, attention can be directed either *internally* towards component parts of the body movement, or *externally* towards the intended movement effect (e.g., motion of an implement; hitting a target; exerting force against an object; Lewthwaite & Wulf, 2017). Research has demonstrated that adopting an external (vs. internal) FOA can enhance the learning and performance of motor skills across a range of sports (see Wulf, 2013 for a review). The external focus advantage is typically explained via the constrained-action hypothesis, which states that attention focused internally generates conscious control processes which constrain the neuromuscular system by inadvertently disrupting the automatic control processes thought to govern skilled movements (Kal et al., 2013). Conversely, an external focus of attention is thought to promote movement automaticity. Concerning swimming, front crawl performance improvements have been reported as a function of instructions to 'push the *water* down/back' (external focus), compared with instructions to 'pull your *hands* back' (internal focus), among both intermediate (Freudenheim et al., 2010) and expert (Stoate & Wulf, 2011) level swimmers. Evidence of enhancements in related skills from other sports also indicates that the external focus benefit will extend to the performance of swim starts and turns, such as increased maximal force production (e.g., pushing off the block; Wu, Porter, & Brown, 2012), and faster reaction times (e.g., reacting to the gun; Ille et al., 2013). However, alternative research has presented evidence to indicate expert athletes can also benefit from adopting an *internal* focus of attention in practice, particularly when attempting to change or refine ingrained skills. Specifically, it is thought conscious processes may be required initially to destabilise well established movement patterns (Carson, Collins, & Kearney, 2017; Collins, Carson, & Toner, 2016). Moreover, there are initial suggestions that internal focus cues may be advantageous for learning more generally in sports high in proprioceptive feedback, such as swimming, through enhanced congruence between instructions and feedback. In particular, Gottwald at al. (2020) reported that as the pertinence of proprioceptive task information increased during both an aiming and leg-extension task, so too did the learning benefits of internal (vs. external) focus cues.

Although FOA effects are now well established in the motor learning literature, little is known about how findings have translated to the applied setting. In one frequently referenced study, 84.6% of athletes participating in the USA Track and Field Outdoor National Championships reported that their coaches most often provide instructions during practice which promote an *internal* FOA (Porter, Wu, & Partridge, 2010). The remaining 15.4% reported receiving a mixture of internal and external instructions, and none reported receiving exclusively external instructions. Similar findings were reported in another study surveying volleyball players (Diekfuss & Raisbeck, 2016), suggesting coaching practices in relation to attentional foci in sport may be sub-optimal for skill learning and performance. However, both previous studies included potential methodological limitations. Specifically, the authors presented athletes with example statements for internal, external, and mixed FOA cues and instructed the athletes to indicate which of the statements they felt best represented the type of instructions they receive *most often*. In other words, if an athlete had felt they receive only slightly more internal than external cues, it would not have been captured in the results. Furthermore, while only one internal focus and one mixed focus example statement was provided, *two* examples were provided for external focus (one describing environment-focus cues and one describing implement-focus cues). In this way, for athletes involved in implement sports (e.g., javelin or volleyball), the external focus ‘vote was split’. Additional measures have involved inferring coach attentional foci in practice by asking athletes what they focus on during performance or competition (e.g., Fairbrother, Post, & Whalen, 2016; Guss-West & Wulf, 2016). However, it is possible athletes have learned to adopt effective focus strategies during competition *despite* their coaches’ use of focus cues (Wulf, 2016). As such, further research is needed on athlete perceptions of coaching cues which addresses previous methodological issues described.

3.1.2 Contextual interference

A second key skill acquisition principle relates to the way in which coaches structure or schedule practice sessions for their athletes, and in particular the extent to which learning involves the repetition or variation of skills. The Contextual Interference (CI) effect refers to the relatively robust finding that the learning of multiple skills, or variations of a single skill, is enhanced as a function of *interference* during practice (Magill, 2011). High levels of CI emerge when the learner switches between multiple skills throughout practice (e.g., ACBABCACA), whereas low levels of CI are involved when one skill is practiced repeatedly before moving on to the next skill (e.g., AAA BBB CCC). The latter schedule is typically referred to as *blocked* practice (e.g., Farrow & Buszard, 2017). Findings reveal that although low levels of CI typically produce better performance during practice, high CI typically leads to better performance during retention and transfer tests (Wright & Kim, 2019).

The CI effect is typically explained via cognitive processes during performance. In particular, it is suggested that task switching (high CI) strengthens skill retrieval mechanisms through a process of either repeatedly forgetting and (re)constructing action plans (the *forgetting-reconstruction hypothesis*; Lee and Magill, 1983), or comparing and contrasting the skills being practiced, thereby creating a more elaborate and distinctive representation of the motor skill in memory (the *elaboration hypothesis*; Shea and Morgan, 1979). Such theoretical frameworks derive from robust laboratory-based experimental evidence for the CI effect examining the learning of simple motor skills (e.g., finger tapping tasks). Less consistent have been the findings involving more complex skills in the applied setting (see Barreiros et al., 2007 for a review), leading to the suggestion that any CI practice benefit relates simply to one of *specificity* with the performance context (Farrow & Buszard, 2017; Lee, 1988). That is, if competition features high CI, high CI practice might produce skills which are more transferable to competition, and vice versa if competition features low CI. An alternative explanation for mixed results in applied settings pertains to the relative difficulty of the skill being practiced. More specifically, several researchers have suggested a certain level of skill is required to reap the benefits of high CI practice (Magill & Hall, 1990; Herbert, Landin, & Solmon, 1996; Farrow & Maschette, 1997; Guadagnoli & Lee, 2004); an idea supported by findings which indicate that as skill develops during practice, a *gradual increase* in levels of CI can enhance the learning of complex skills in various sports (Hodges et al., 2011; Porter & Magill, 2010; Saemi et al., 2012). However, a paucity of research among highly skilled performers in the applied setting has restricted any conclusions that a high level of skill facilitates the CI effect (for exceptions, see Hall et al., 1994; Ollis et al., 2005).

A problem for researchers is that a lack of consensus with regards to precisely how CI exerts its effect prohibits further investigation in the highest level of sport. Assessing the effects of practice scheduling requires the control of multiple variables within a naturalistic setting, and coaches and athletes are less inclined to modify practice for experimental purposes if the benefits are not clear (Buszard et al., 2017). In light of this, it is perhaps surprising that so few studies have attempted to capture, without interference, the practice scheduling approaches already adopted by elite level coaches. A greater understanding of the gaps between existing research recommendations and current applied practice could provide context and windows of opportunity through which skill acquisition practitioners can attempt to impact learning design and carry out research 'in situ'. In one exception to this, Buszard et al. (2017) examined practice sessions among skilled youth tennis players relative to the CI levels involved as a function of two further variables: (i) *between-skill variability*, and (ii) *within-skill variability*. Between-skill variability describes the switching between multiple skills during practice (e.g., practicing a tennis serve followed by a backhand), whereas within-skill variability refers to discernible variations in the execution of the same skill (e.g., practicing a T serve followed by a wide serve). It was reported that tennis practice comprised very little between-skill variability, but relatively high within-skill variability. As yet, no known study has attempted to capture the coaching practices in relation to CI in swimming, nor in any sport at the highest level of performance.

3.1.3 The current study

The current study surveyed athletes at British Para Swimming to capture their perspectives on coaching practices in relation to focus of attention and contextual interference during start and turn skill practice. For FOA, the study aimed to address methodological issues highlighted in previous research by allowing swimmers to estimate quantitatively how often they feel they receive internal or external cues from their coaches, thus accounting for the fact that both types of cues can be provided simultaneously during any given set of coach instructions or feedback (see also Becker & Fairbrother, 2019). For CI, swimmers rated the extent to which they perceived training throughout the season to involve practice scheduling which constitutes either blocked practice, within-skill variability, or between-skill variability. Although observations of practice (e.g., Buszard et al., 2017) carry clear merits in objectivity, they provide potentially only a snapshot of practice design in a particular part of the season. Furthermore, coaching practices may be influenced due to being observed for the purposes of research (e.g., Powell et al., 2021 – chapter four).

In surveying swimmers and asking them to consider their coaches' approach to attentional foci and practice scheduling over the course of the previous twelve months, the study aimed to account for potential changes in a coach's approach across the season as a function of, for example, an athlete's stage of learning or competition proximity. That is, it is possible a coach may use more internal focus cues when attempting to change or refine skills, or more blocked practice close to competition based on performance specificity in swimming.

The study involved an additional aim of examining whether coaching practices differ as a function of athlete disability. Specifically, while most athletes on the BPS World Class Programme have physical disabilities, a large proportion (34%) are athletes with intellectual impairments. Findings from FOA literature indicate that external focus instructions provide similar benefits for both non-disabled and intellectually impaired learners (Chiviacowsky, Wulf, & Avila, 2013). However, in relation to contextual interference, research focusing on the potential learning implications of intellectual impairments has suggested athletes may benefit from greater levels of repetition in practice (Burns & Johnstone, 2020; Van Biesen et al., 2023). Specifically, a common characteristic of intellectual impairment is a deficit in working memory capacity (Vicari, 2004), which in turn leads to slower rates of learning. Practice under conditions of high CI is characterised by increased working memory demands (Li & Wright, 2000; Patterson & Lee, 2008). As such, the level of challenge in high CI practice could more easily exceed the 'optimal' level of challenge for learning in athletes with intellectual disabilities (see the *challenge-point framework*; Guadagnoli & Lee, 2004). Previous research reports that coaches - often from non-disabled coaching backgrounds - lack access to appropriate guidance on coaching Para athletes, and consequently do not typically adapt their approach (Cregan et al., 2007).

Based on previous findings, it was hypothesised that coaches would make use predominantly of internal FOA cues (Diekfuss & Raisbeck, 2016; Porter et al., 2010); that coaching sessions would typically comprise low levels of contextual interference (Buszard et al., 2017); and that approaches to coaching would not differ significantly as a function of athlete disability classification (Cregan et al., 2007).

3.2 Method

3.2.1 Participants

Participants were 32 swimmers from the British Para swimming (BPS) World Class Programme, together coached by a total of 21 coaches. Participants were both male (N=13) and female (N=19), with ages ranging from 16-24 years. All the swimmers were internationally classified and had competed at international level representing BPS and were therefore considered elite-level swimmers. The impairment level of the swimmers included 10 S14 athletes (intellectual impairment) (31.3%), two S13 athletes (visual impairment) (6.2%), and 20 S4-S10 athletes (various levels of physical impairments) (62.5%). All participants and their parents/guardians where necessary provided written informed consent.

3.2.2 Data Collection

The survey (see Appendix A) was distributed online via SurveyMonkey to all athletes registered on the British Para Swimming World Class Programme (N = 46). An email with a link to the survey was sent via British Para Swimming written by the lead researcher explaining that there was no obligation to participate, and that Para swimming coaches and staff would not be aware of their choice to participate. It was explained that the survey would contribute to the scientific understanding of coaching and learning practices in Para swimming. The survey comprised a participant information sheet which described the full details of the study and confidentiality of the data. Specifically, personal data was collected in the form of names and classification types. Names were collected to allow the lead researcher to follow-up on responses to check the survey was accessible and could be understood (i.e., for athletes with visual or intellectual impairments), and to allow participants to withdraw their data at any time. Athletes were informed that the data would remain fully confidential and could be accessed only by the lead researcher and research team at Manchester Metropolitan University. Data was pseudo-anonymised before being stored on a password protected laptop.

Thirty-six athletes initially responded to the survey. Of these 36 respondents, four sets were removed from the data due to incomplete or inadequate responses. More specifically, two had answered every VAS question with '100', and two had answered every VAS question with '0'. Given the nature of the questions, this was taken to suggest they had not been sufficiently understood or attempted. A parent/guardian of one of the S14 (intellectual impairment) respondents also contacted the research team to say that they were not sure the questions had been fully understood when the survey was being completed. Consequently, this form was removed from the data and the athlete completed the survey for a second time with the help of the research team. Following this, all other S14 respondents were contacted to check that the survey questions had been clearly understood. Of the remaining 32 survey forms, 1 respondent had completed all but the questions relating to contextual interference. As such, the data comprised 32 respondents for the focus of attention analysis, and 31 respondents for the contextual interference analysis.

3.2.3 Measures

All questions and response options were designed through collaboration between the research team, the national head coach, and the head of sports science and sports medicine at BPS. The survey was then subject to a development process involving extensive discussions between the primary researcher and Dr Philip Kearney from the University of Limerick, who acted as a 'critical friend' in examining the questions through an alternative lens. The survey was piloted to two BPS athletes at the National Performance Centre – one S9 athlete (physical disability) and one S14 athlete (intellectual impairment). The head coach at the performance centre then also checked over the survey in relation to both the relevance of cue and variability examples, and the perceived suitability of questions for S14 athletes. No standardised tests of reliability or validity were performed given the challenges in accessing a large enough sample of athletes. However, through pilot tests and discussions with athletes, coaches, and support staff it was concluded that both face validity and construct validity was high.

The survey contained seven questions which all pertained to training over the previous full season (one year). Questions 1-4 were designed to ascertain how often during a season an athlete typically works on improving specific aspects of swim start and turn skills, either with their coach or on their own. These questions were included to provide information for the coaching and sports science staff at BPS, and to ensure that subsequent questions focusing on start and turn practice specifically were applicable. Questions 5 and 6 were designed to assess the extent to which coaches encourage their swimmers to focus their attention either internally or externally during start and turn focused practice. In line with previous research of this kind (Diekfuss & Raisbeck, 2016; Porter, Wu, & Partridge, 2010), coaches' use of attentional foci was explored via both instructions and feedback separately to account for the increased likelihood that (augmented) feedback will contain more information pertaining to movement *effects* (e.g., time to 15 m) (i.e., knowledge of results; Magill, 2001). The wording in the questions, in relation to the examples of internal and external cues provided, was also adapted from previous FOA research in sport (Diekfuss & Raisbeck, 2016; Porter, Wu, & Partridge, 2010). Respondents were provided with both internal and external cue example statements and required to indicate how often their coaches use such cues in practice via a visual analogue scale (VAS) ranging from 0 to 100 and labelled as 'never' (0) to 'all the time' (100). As an example, for a measure for attentional focus *instructions*, Q5 asked the swimmers:

Just *before* practicing my starts or turns, my coach will tell me to focus on:

a) What I am doing with my body. For example, how I position my body; how I swing my arms; how I move my head; or how I use my legs, feet, or hands:

(drag the slider to the preferred position or enter a numerical rating in the text box)

Never ____ All the time ☐

b) Areas outside of my body in the environment around me. For example, how I should use the wall or the starting block; areas I should look or aim towards; the effect I'm having on the water:

Never ____ All the time ☐

This method provided a separate measure for both internal and external cue usage, at the same time as allowing for the potential overlap likely to exist between the two. Specifically, any given set of instructions or feedback may encourage *both* an internal and external FOA simultaneously to varying degrees (e.g., 'reach your *arm* (internal) further to push more water (external) away'). In this way, swimmers were able to indicate they feel they receive, for example, internal focus instructions 70% of the time, and external focus instructions 70% of the time.

Question 7 was designed to measure the extent to which coaches incorporate contextual interference into start/turn focus practice sessions. Respondents were presented with three example statements, each representing a different form of practice scheduling. Based on previous contextual interference research in sport (Buszard et al., 2017), statement (a) was designed to represent practice involving high levels of *within-skill variability* (i.e., discernible variations in the execution of the same skill); statement (b) was designed to represent *blocked practice* (i.e., low variability); and statement (c) was designed to represent practice involving high levels of *between-skill variability* (i.e., changes between different skills). Again, respondents were required to indicate on a VAS below each statement the extent to which they felt their coaches adopt each form of practice scheduling. Q7 can be seen below:

When working on improving my starts or turns with my coach in training, my coach will:

a) Get me to experiment with different approaches to practising that skill. For example, changing starting positions; switching left/right hands/feet; speeding something up or slowing it down; or using different apparatus:

Never ____ All the time ☐

b) Get me to try to execute the skill in the same way a number of times before moving on to something else:

Never ______________________________ All the time ☐

c) Get me to practice that skill alongside other skills and switch randomly between them. For example, if I'm working on my start, my coach might get me to do one or two starts, and then switch to a turn or a stroke, and then continue to switch between 2 or 3 skills so that no skill is repeated in a block of sets:

Never ______________________________ All the time ☐

3.2.4 Data analysis

All analyses for focus of attention were based on total scores comparing differences for classification type and examined separately for overall coach dialogue, instructions, and feedback. The analyses themselves consisted of 2 (focus of attention: internal vs. external) within-subjects x 2 (classification type: physical vs. intellectual) between-subjects mixed ANOVA. Analysis for contextual interference was also based on total scores comparing differences for classification type. The analysis consisted of a 3 (practice type: blocked vs. within-skill vs. between-skill) within-subjects x 2 (classification type: physical vs. intellectual) between-subjects mixed ANOVA. Effect sizes for ANOVA's are reported as partial eta squared ηp^2. Only two athletes were classified as visually impaired in the focus of attention analyses and one for contextual interference, so they were not included in the statistical analysis. The descriptive statistics can be found in Table 3.1, 3.2, 3.3, and 3.4. Shapiro-Wilk and skewness z scores were calculated to assess normality of data (see Table A1 & A2 in appendix B). In the one case where parametric assumptions were not met (external focus cues for intellectually impaired athletes), Wilcoxon test was used to compare overall internal vs. external focus. Mann-Whitney test was used to compare internal focus and external focus as a function of impairment classification.

3.3 Results

3.3.1 Focus of Attention

Internal versus external

Table 3.1

Descriptive statistics for overall internal and external focus of attention cues as a function of athlete impairment type.

	Classification	Mean	SD
Internal focus	Physical impairment	64.4	26.5
	Visual impairment	50.3	24.4
	Intellectual impairment	71.7	21.4
External focus	Physical impairment	63.5	20.3
	Visual impairment	35.5	31.1
	Intellectual impairment	58.2	14.2

In relation to overall coach internal and external cues reported by the athletes, a 2 (focus of attention: internal vs. external) within-subjects x 2 (classification type: physical vs. intellectual) between-subjects mixed ANOVA revealed the following: a non-significant main effect of focus of attention, $F(1, 28) = 3.11$, $p = .089$, $\eta p^2 = .1$, observed power = .40. The main effect of classification type was not significant, $F(1, 28) = .02$, $p = .893$, $\eta p^2 = .001$, observed power = .05. Additionally, the interaction was not significant, $F(1, 28) = 2.36$, $p = .136$, $\eta p^2 = .08$, observed power = .32.

Wilcoxon tests were also used to assess the difference between overall internal and external focus cues reported. The results indicated a non-significant difference, $z(28) = - 1.57$, $p = .116$. Mann-Whitney tests were used to compare internal focus and external focus as a function of impairment classification. For internal focus there was no significant difference between physical and intellectual impairment, $z(28) = - .48$, $p = .628$. For external focus there was also no significant difference between physical and intellectual impairment, $z(28) = - 1.10$, $p = .271$.

Coach instructions

Table 3.2

Descriptive statistics for internal and external focus of attention cues during coach instructions as a function of athlete impairment type.

	Classification	**Mean**	**SD**
Internal instructions	Physical impairment	63.5	33.7
	Visual impairment	56.5	19.1
	Intellectual impairment	68.0	30.5
External instructions	Physical impairment	63.0	29.5
	Visual impairment	15.0	14.1
	Intellectual impairment	52.3	23.6

For internal and external cues reported by the athletes during coach instructions, a 2 (focus of attention: internal vs. external) within-subjects x 2 (classification type: physical vs. intellectual) between-subjects mixed ANOVA revealed the following: a non-significant main effect of focus of attention, $F(1, 28) = 1.55$, $p = .223$, $\eta p^2 = .05$, observed power = .26. The main effect of classification type was not significant, $F(1, 28) = .10$, $p = .754$, $\eta p^2 = .004$, observed power = .06. Additionally, the interaction was not significant, $F(1, 28) = 1.40$, $p = .247$, $\eta p^2 = .048$, observed power = .21.

Coach feedback

Table 3.3

Descriptive statistics for internal and external focus of attention cues during coach feedback as a function of athlete impairment type.

	Classification	**Mean**	**SD**
Internal feedback	Physical impairment	65.3	27.1
	Visual impairment	44.0	29.7
	Intellectual impairment	75.4	26.2
External feedback	Physical impairment	63.9	23.7
	Visual impairment	56.0	48.1
	Intellectual impairment	64.1	21.0

In relation to internal and external cues reported by the athletes for coach feedback, a 2 (focus of attention: internal vs. external) within-subjects x 2 (classification type: physical vs. intellectual) between-subjects mixed ANOVA revealed the following: a non-significant main effect of focus of attention, $F(1, 28) = 2.33$, $p = .138$, $\eta p^2 = .08$, observed power = .31. The main effect of classification type was not significant, $F(1, 28) = .35$, $p = .560$, $\eta p^2 = .012$, observed power = .09. Additionally, the interaction was not significant, $F(1, 28) = 1.39$, $p = .249$, $\eta p^2 = .047$, observed power = .21.

3.3.2 Contextual interference

Table 3.4

Descriptive statistics for contextual interference as a function of athlete impairment type.

	Classification	Mean	SD
Blocked practice	Physical impairment	58.15	27.3
	Visual impairment	52.00	N/A*
	Intellectual impairment	75.40	23.0
Within-skill variability	Physical impairment	48.05	26.9
	Visual impairment	23.00	N/A*
	Intellectual impairment	48.40	24.1
Between-skill variability	Physical impairment	30.55	22.7
	Visual impairment	6.00	N/A*
	Intellectual impairment	37.90	31.1

*Only one visually impaired athlete provided data for contextual interference, and as such no standard deviation was recorded.

Concerning the scheduling of practice reported by the athletes, a 3 (practice type: blocked vs. within-skill vs. between-skill) within-subjects x 2 (classification type: physical vs. intellectual) between-subjects mixed ANOVA revealed the following: a significant main effect of practice type, $F(2, 56) = 13.16$, $p < .001$, $\eta p^2 = .320$, observed power = 1.00. The main effect of classification type was not significant, $F(1, 28) = 1.48$, $p = .234$, $\eta p^2 = .05$, observed power = .22. Additionally, the interaction was not significant, $F(2, 56) = .89$, $p = .416$, $\eta p^2 = .031$, observed power = .20.

To examine the main effect of practice type, paired comparison t-tests were used to assess the difference between the groups. Comparing blocked practice to within-skill variability, the results indicated a significant difference, $t(29) = 2.56$, $p = .008$ (one-tailed), whereby blocked practice was higher than within-skill variability (63.90 vs. 48.17). The comparison between blocked practice and between-skill variability also indicated a significant difference, $t(29) = 5.17$, $p <.001$ (one-tailed), whereby blocked practice was higher than between-skill variability (63.90 vs. 33.00). Finally, comparing within-skill variability to between-skill variability, the results indicated once more a significant difference, $t(29) = 2.59$, $p = .015$ (two-tailed).

3.4 Discussion

The current study surveyed swimmers from the British Para swimming team to explore their coaches' use of attentional foci and approach to practice scheduling (contextual interference) during start/turn focused practice sessions. Based on previous research, it was hypothesised that coaches would make use predominantly of internal FOA cues (Diekfuss & Raisbeck, 2016; Porter et al., 2010); that coaching sessions would comprise low levels of contextual interference (Buszard et al., 2017); and that approaches to coaching would not differ significantly as a function of athlete disability classification (Cregan et al., 2007).

3.4.1 Focus of attention

For FOA, results were partially in line with study predictions. Specifically, while athletes reported their coaches more often make use of internal (M = 66.8) than external (M = 61.7) focus cues, the difference was not significant ($p = .089$). There were also no significant differences between internal and external foci during either coach instructions or feedback, and no significant differences between athletes with physical or intellectual disabilities. Although no differences were reported, the findings indicate a contrast with formal recommendations of best practice in much of the FOA literature, which state that coaches should make use predominantly of external focus cues (e.g., Lohse et al., 2012; Wulf, 2013). Consequently, it may be that coaching practices at BPS are suboptimal for the acquisition of skills as a function of attentional foci during practice. However, the discrepancy reported between coaches' use of internal and external cues was much smaller than those previously reported in athletics (84.6% internal focus; Porter et al., 2010), and volleyball (88.9% internal focus; Diekfuss & Raisbeck, 2016). This may in part be due to methodological limitations highlighted in previous research and addressed in the current study. That is, rather than only allowing athletes to indicate which type of FOA cues they feel they receive most often, the current study enabled respondents to provide quantitative estimates of both, thus accounting for the fact that both types of cues can be provided simultaneously during any given set of coach instructions or feedback (Becker & Fairbrother, 2019).

There are potential explanations for the parity between internal and external focus cues reported. Specifically, it may be that coaches at BPS have learned the differential benefits of both. For example, initial findings suggest internal focus cues may be particularly beneficial in sports such as swimming, where body-focus instructions enhance the ability to process proprioceptive task information through increased congruence between instructions and feedback (Gottwald et al., 2020). Additionally, research highlights the potential benefits of internal focus in the early stages of attempting to change or modify well established motor skills, as conscious processes may be required initially to destabilise ingrained movement patterns (Carson, Collins, & Kearney, 2017; Collins, Carson, & Toner, 2016). As such, it is possible that a proportion of the internal cues reported to be used by coaches in the current study are part of deliberate learning strategies with specific training outcomes in mind. Alternatively, it may be that the use of external cues is a function of the skills being practiced. That is, starts and turns in swimming require the interaction with aspects of the external environment (i.e., the wall and the starting block). In line with this, a consideration for future research concerns capturing the coaches' intended training outcomes and rationale for their approach.

3.4.2 Contextual interference

The findings in relation to contextual interference were in line with study predictions. Specifically, swimmers reported their coaches incorporate significantly more blocked practice scheduling (M = 63.9) than scheduling that involves either within-skill (M = 48.2) or between-skill (M = 33.0) variability. The low levels of between-skill variability reported are in line with previous research of this kind in sport (Buszard et al., 2017; Williams & Hodges, 2005), and suggests coaches at BPS typically coach specific skills in large practice blocks without incorporating additional skills – a form of scheduling which may be suboptimal for motor skill learning (Brady, 1998; Magill, 2011; Wright & Kim, 2019). Swimmers reported receiving significantly more practice involving within-skill variability than between-skill variability, similar to scheduling previously observed in tennis (Buszard et al., 2017). This is perhaps surprising given tennis performance in competition *requires* variability to react to, and outwit opponents in an open environment, whereas swimming performance requires repeatedly performing the same skill within a closed environment. As such, if the contextual interference benefit for complex skills operates only as a function of specificity between the learning and performance context (e.g., Farrow & Buszard, 2017), it may not emerge as a function of the variability reported in the current study.

No significant differences for practice scheduling were reported between athletes with physical or intellectual disabilities, which could have important implications for learning in Para sport. Specifically, although there is little consensus among researchers in relation to precisely how CI exerts its effects on skill acquisition, there is agreement that high CI practice is characterised by increased cognitive effort and working memory involvement (Li & Wright, 2000; Patterson & Lee, 2008). A common characteristic of intellectual impairment is reduced working memory capacity (Vicari, 2004), and it is suggested intellectually impaired athletes would benefit from greater levels of repetition in practice (at least in the initial stages of learning) to allow them time to process and store new information (Burns & Johnstone, 2020; Van Biesen et al., 2023). Findings from the current study therefore provide indications that coaches in elite level Para sport may not be adapting their approach to practice scheduling sufficiently to account for the learning implications in athletes with intellectual impairments. This is in line with previous research, where coaches with little-to-no access to appropriate guidance on coaching athletes with disabilities, reported that their approaches to coaching and learning did not differ between their Para and able-bodied athletes (Cregan et al., 2007).

3.4.3 Limitations

A potential limitation in relation to the FOA analysis pertains to the dichotomous nature of the cues investigated (i.e., internal vs external). In particular, research has begun to identify alternative cues which might confer similar learning benefits to external cues, including *holistic process cues* (e.g., Becker et al., 2019), and *analogy* or *metaphor* cues (e.g., Guss-West & Wulf, 2016; Winkelman, 2020). According to these lines of research, it is internal cues *specifically* which generate the conscious control processes thought to be detrimental to performance (e.g., Mullen & Hardy, 2010; Mullen et al., 2015). This conscious control is based on explicit knowledge of skill components, which is then accessed in a step-by-step manner resulting in movements that are typically slow and effortful (Masters, 1992). Holistic cues serve to conceptualise the global *feeling* of a movement (e.g., ‘a *smooth* rotation on the turn’), and thereby camouflage explicit information by coding it kinesthetically. This is thought to prevent the accrual and subsequent access to explicit skill knowledge, thus facilitating a more automatic mode of control (Mullen et al., 2015). Similarly, analogies (e.g., 'imagine swimming between two planes of glass') serve to code explicit movement information symbolically (Mullen & Hardy, 2010). Future research of this kind should attempt to incorporate the analysis of these alternative cues, particularly as identifying appropriate external cues in sports not involving an implement or clearly discernible external target (e.g., swimming) can be a challenge for coaches (Collins, Carson, & Toner, 2016). In line with this, because external, holistic, and analogy cues operate as a function of more implicit (unconscious) processes (see also Poolton & Zachry, 2007), they may not be as readily available for memory retrieval, when, for example, an athlete is filling out a questionnaire (i.e., these cues may fall victim to the *availability heuristic* – see Tversky & Kahneman, 1973). Taken together, the next stage of analysis of coaches' use of attentional foci, which incorporates all the aforementioned FOA cues, may require direct coach observation.

One advantage of assessing coaching practices through athlete surveys is the longitudinal nature of the data captured. The questions used in the current survey pertained to training over the previous full season (one year), which would cover the full periodisation involved in any skill learning cycles (see Otte, Millar, & Klatt, 2019). For example, if a coach is deliberately incorporating more or less variability into practice at any given time of the season, based, for instance, on the relative difficulty of the skill being practiced (e.g., Guadagnoli & Lee, 2004), it is likely to be accounted for using the athlete survey method adopted here. However, difficulties lie in attempting to draw conclusions from data taken from survey responses alone. For example, the nature of high (vs. low) CI practice, involving the construction of more robust (Lee and Magill, 1983) or more elaborate (Shea and Morgan, 1979) representations of motor skills in memory, might also reasonably be expected to make the associated practice sessions themselves more memorable. If so, it's possible that swimmers might overestimate the occurrence of high CI practice. As with the FOA analysis, the next step for research is to attempt to corroborate these findings with direct coach observation coupled with an exploration of coaches' rationale for their approach.

3.5 Conclusion / Summary

Overall, the study provides valuable insights into coaching practices at BPS. Although coaches were reported to be using more internal than external focus cues, contrary to previous research in other sports the difference was not significant. Coaches were reported to adopt significantly more blocked practice scheduling than practice involving either within-skill or between-skill variability, and practice design did not differ between athletes with physical or intellectual disabilities. The findings provide initial indications that coaching practices may be suboptimal for the acquisition of skills. However, limitations highlighted in relation to athlete self-report measures mean the next stage for research in swimming should involve coach observation and the identification of a rationale for their approach. Potential contradictions in FOA research, particularly in relation to sports high in proprioceptive feedback such as swimming (see Gottwald, 2020), coupled with a lack of consensus on how CI exerts its effects, makes a greater understanding of expert coaching practices an imperative next step in elucidating the optimal strategies for athlete learning and development.

CHAPTER FOUR

4. Study Two: Skill acquisition practices of coaches on the British Para Swimming World Class Programme

4.1 Introduction

Experimental research in skill acquisition has identified a range of techniques that can enhance athlete learning and performance. Examples of such techniques include the use of various coaching cues including those with an external focus (Winkelman, 2020; Wulf, 2013), the structure and scheduling of training and the introduction of variability into practice (Magill, 2011; Wright & Kim, 2019), or the design of the athlete practice environment such that desired movements emerge naturally through the response and adaptation to the manipulation of constraints (Pinder et al., 2011; Woods et al., 2020). Despite this, exploratory investigations suggest coaching practices often contrast with the scientific recommendations of best practice (Diekfuss & Raisbeck, 2016; Porter, Wu, & Partridge, 2010; van der Graaff et al., 2018). In highlighting the gap between research and applied practice, studies indicate coaches rarely refer to academic journals when seeking to expand their knowledge (Stoszkowski & Collins, 2016), and tend to adopt techniques guided by tradition, intuition, and the emulation of other coaches (Ford, Yates & Williams, 2010). As stated in chapter 3, however, a notable limitation of much previous research has been the failure to capture the coaches' intended training outcomes and justifications for their approach (Kearney, Carson, & Collins, 2018). The current study set out to examine both the practices *and* rationale of elite level coaches in the British Para swimming World Class Programme (BPS) in relation to three prominent lines of skill acquisition research: (i) focus of attention, (ii) contextual interference, and (iii) implicit learning. It is hoped that this link between coaching practices and research recommendations will serve to highlight and explain potential gaps in understanding on both sides, and thereby facilitate future collaborations between coaches and skill acquisition practitioners.

Focus of attention (FOA) refers to the location of an individual's attention in relation to the performance task/environment (Wulf, 2007). Attention can be directed either *internally* towards parts of the body movement, or *externally* towards the intended movement effect (e.g., motion of an implement, hitting a target, exerting force against an object; Lewthwaite & Wulf, 2017). Research has consistently demonstrated that adopting an external (vs. internal) FOA can enhance the learning and performance of motor skills in a wide range of sports tasks (see Wulf, 2013 for a review). The benefits of an external focus (EF) of attention are most commonly explained via the constrained-action hypothesis. This hypothesis suggests an internal focus (IF) of attention constrains the neuromuscular system by activating conscious control processes which inadvertently disrupt automatic modes of control that typically govern skilled movements (Kal et al., 2013). An external focus of attention, in contrast, is thought to promote greater automaticity in movement. In relation to swimming performance, external focus instructions (e.g., "push the water back") have been shown to improve swimming performance compared to internally focused (e.g., "pull your hands back") instructions (Freudenheim et al., 2010; Stoate & Wulf, 2011). However, alternative research suggests athletes can benefit from a *heightened* sense of body consciousness during practice. Specifically, it is argued that skill learning and *continuous improvement* among elite or expert performers operates as a function of 'somaesthetic' training (i.e., paying heightened attention to and mastery of somatic functioning) (Toner & Moran, 2014, 2015a, 2015b). Moreover, initial findings suggest internal focus cues may be advantageous in sports such as swimming, where the ability to process proprioceptive task information can be enhanced as a function of bodily focus through increased congruence between instructions and feedback (Gottwald et al., 2020).

Although FOA effects are now well established in the motor learning literature, relatively little is known in relation to how findings have translated to the applied setting. In one frequently referenced study, 84.6% of athletes participating in the USA Track and Field Outdoor National Championships reported that their coaches most often provide instructions during practice that promote an *internal* FOA (Porter et al., 2010). The remaining 15.4% reported receiving a mixture of IF and EF instructions, and none reported receiving exclusively EF instructions. Similar findings have emerged in volleyball (Dieffuss & Raisbeck, 2016), baseball (van der Graff et al., 2017) and ballet (Guss-West and Wulf, 2016). As such, it may be that elite coaching practices in relation to attentional foci in sport are suboptimal for skill learning and performance. However, in a recent study surveying athletes at British Para Swimming, swimmers reported no significant differences between their coaches' use of either internal and external focus cues during start and turn practice (chapter three). It may be that these results were a function of the skills being practiced, i.e., starts and turns require interaction with aspects of the external environment such as the wall and the starting block, and as such more research is needed into attentional foci in swimming in general.

Additionally, recent research has identified alternative focus cues thought to confer a similar learning benefit to external focus. *Holistic* focus cues conceptualise the overall *feeling* of a movement (e.g., 'a *smooth* rotation', '*explode* off the block'), in contrast to internal cues which emphasise focus towards *component parts* of a movement (e.g., '*head tucked* on rotation', '*arms tight* on the block'). In this way, holistic cues are thought to code explicit (conscious) movement information kinaesthetically, thereby generating a more automatic mode of motor control (Becker et al., 2019; Mullen et al., 2015). The use of holistic focus cues by coaches in the applied setting has yet to be explored and could be particularly pertinent in sports such as swimming, where identifying appropriate external focus cues may be a challenge for coaches given the lack of implements or clearly discernible external targets (unlike interceptive sports such as cricket, tennis, or darts).

A second key skill acquisition principle relates to the amount of practice variability incorporated during the learning process. The Contextual Interference (CI) effect refers to the relatively robust finding that the learning of multiple skills, or variations of a single skill, is enhanced as a function of *interference* during practice (Magill, 2011). High levels of CI emerge when the learner switches between multiple skills throughout practice (e.g., ACBABCACA), whereas low levels of CI are involved when one skill is repeatedly practiced before moving on to the next skill (e.g., AAA BBB CCC). The latter schedule is typically referred to as *blocked* practice (e.g., Farrow & Buszard, 2017). Findings reveal that although low levels of CI typically produce better performance during practice, high CI typically leads to better performance during retention and transfer tests (Wright & Kim, 2019).

Theoretical explanations for the CI effect are based around cognitive processes during performance. For example, the *forgetting-reconstruction hypothesis* (Lee and Magill, 1983) proposes that high levels of CI cause the performer to forget repeatedly task-specific information between practice trials, thereby requiring them to (re)construct the action plan on each attempt. This process is thought to develop the learner's ability to retrieve and construct action plans, thus enhancing the acquisition of skills. Alternatively, the *elaboration hypothesis* (Shea and Morgan, 1979) suggests that high CI causes the performer to engage in a process of comparing and contrasting the skills being practiced. As a result, a more elaborate and distinctive representation of the motor skill is created in memory. Such theories derive from robust experimental findings for the CI effect. However, results from applied settings involving more complex motor skills have been less consistent (see Barreiros et al., 2007 for a review), leading to an alternative suggestion that CI practice benefits relate simply to one of *specificity* with the performance context (Farrow & Buszard, 2017; Lee, 1988). That is, if competition features high CI, high CI practice might produce skills which are more transferable to competition, and vice versa if competition features low CI.

In addition to uncertainty surrounding potential CI effects, little is known about the extent to which coaches incorporate CI into training. In one recent study, Buszard et al. (2017) examined practice among skilled youth tennis players. More specifically, the authors assessed the levels of CI involved in practice as a product of two further variables: (i) *between-skill variability*, and (ii) *within-skill variability*. Between-skill variability describes the switching between different skills during practice (e.g., practicing a tennis serve followed by a backhand), whereas within-skill variability refers to discernible variations in the execution of the same skill (e.g., practicing a T serve followed by a wide serve). It was reported that tennis practice comprised very little between-skill variability, but relatively high within-skill variability.

Implicit learning describes the process of acquiring a skill in the absence of conscious or explicit knowledge about how that skill is performed. In contrast, explicit learning refers to the acquisition of a skill alongside a conscious understanding of the facts and rules pertaining to that skill (Masters, 2000). Experimental research indicates that implicit (vs. explicit) learning produces skills which are more robust in the face of performance-induced pressure and fatigue, without slowing the rate at which those skills are acquired (Masters & Poolton, 2012).

The implicit learning benefit has been explained via *reinvestment theory* (Masters & Maxwell, 2008). According to this theory, performers in situations involving psychological stress (e.g., competition), will, to varying degrees of propensity, attempt to control consciously previously automated movements, causing those skills to break down (a phenomenon termed *reinvestment*). Conscious motor control operates as a function of accessing explicit, rule-based knowledge of a skill in working memory. Reinvestment theory suggests that implicit learning minimises the accrual of such knowledge, thereby reducing the opportunities for reinvestment and performance breakdown.

Recent research has identified a range of implicit learning techniques conducive to the applied sport setting. Teaching skills using analogies serves to code movement instructions *symbolically*, thereby camouflaging the rules pertaining to the skill and minimising the accrual of explicit knowledge (Masters & Poolton, 2012). The subsequent facilitation of a more automatic mode of processing has been demonstrated in swimming, where Komar, Chow, Chollet, and Seifert (2014) reported that instructional analogies improved inter-limb coordination during the underwater phase of the breaststroke. Constraints-based learning (CBL) is also thought to promote implicit learning processes by way of a reduction in the accrual of explicit skill knowledge (e.g., Brocken et al., 2020). According to this framework, coordinated movements emerge as a function of learners adapting to the constraints imposed on them during practice. These constraints involve the individual characteristics of the learner (*organismic constraints*), the requirements of the task (*task constraints*), and the environmental conditions (*environmental constraints*) (Newell & Jordan, 2007). Constraints can be manipulated such that the desired movement emerges through a process of self-organisation, rather than via prescriptive (explicit) instruction. For example, Guignard et al. (2019) manipulated the swimming speed (task constraint) and the fluid flow (environmental constraint) in a flume and reported that elite swimmers adapted their open pool technique to maintain performance by changing their arm-to-leg coordination pattern, without any explicit instruction to do so.

While implicit learning benefits have been demonstrated consistently in experimental settings, there is a paucity of research examining the extent to which coaches actually adopt these learning techniques. Only one study has examined the use of analogy learning in the applied setting to date; Guss-West and Wulf (2016) surveyed professional ballet dancers and reported that dancers make use of analogy cues (e.g., "feeling like a swan") to facilitate performance 28% of the time. In swimming, applied insights from previous observation research indicate that elite coaches rely heavily on more traditional skill acquisition techniques such as verbal feedback and part-task training, which involves the decomposition of skills into component parts through the explicit prescription of drills (e.g., the full swimming stroke is reduced to the kick component); yet coaches are also shifting towards the use of more contemporary implicit and ‘non-linear’ methods like CBL (Brackley et al., 2020; Junggren et al., 2018). However, the use of such techniques in the applied setting appears to have evolved intuitively, and coaches may be unaware of the theoretical context underpinning their efficacy (Renshaw et al., 2019).

To date, very little applied skill acquisition research has been conducted among Para athletes, with concerns regarding population validity or the extent to which research settings are representative of performance contexts (Churton & Keogh, 2013; Pinder, Headrick, & Oudejans, 2015). Individualised case studies from skill acquisition specialists have begun to demonstrate the efficacy of implementing a CBL approach to coaching in Para sport (Pinder & Renshaw, 2019). However, as with coaches of able-bodied athletes, little is known regarding the adoption of such research-based techniques in the applied Para coach setting. In one study investigating knowledge in elite level coaches of Para swimmers, coaches, who had come from able-bodied coaching backgrounds, reported having to obtain disability-specific knowledge independently, but that by and large coaching approaches to learning did not differ between their Para and able-bodied athletes (Cregan et al., 2007). Furthermore, these coaches, and other elite Para and able-bodied athlete coaches still report informal learning opportunities (e.g., trial and error; observing or communicating with other coaches) to be the most beneficial for coach development (Blackett, Evans, & Piggott, 2017; Dehghansai et al., 2020; Fairhurst, Bloom, & Harvey, 2017).

4.1.1 The current study

The current study set out to gain insight into the practices adopted by elite level Paralympic swimming coaches and to shed light on the knowledge and rationale underpinning their approaches. Specifically, coaches at British Para Swimming were observed to assess their use of attentional foci including internal, external, and holistic focus cues during both swimming stroke (i.e., freestyle, backstroke, breaststroke, and butterfly) and start and turn practice; their incorporation of variability in training sessions; and their approach to practice design in relation to traditional explicit or more contemporary non-linear or implicit techniques. Coaches were then interviewed to explore the reasons for their approaches to learning design and their knowledge/views on skill acquisition more broadly. It was hypothesised that quantitative data obtained from the observation of coaches during practice would reveal that (i) coaches would make use predominantly of internal (vs. external) FOA cues during swimming stroke practice (Porter et al., 2010), but that no difference would be observed during the coaching of starts and turns (chapter three), (ii) coaching sessions would comprise relatively low levels of both within-skill and between-skill variability, as this would reflect the conditions typically experienced during competition performance (chapter three; Farrow & Buszard, 2017; Lee, 1988), and (iii) coaches would heavily apply more traditional *explicit* learning techniques, such as verbal feedback and part-task training (Brackley et al., 2020; Junggren et al., 2018). Qualitative data obtained from coach interviews was used both to corroborate quantitative findings and to explore the coaches' knowledge of the key principles and recommendations from skill acquisition research.

4.2 Method

4.2.1 Design

A mixed-methodology design was used to explore coaching practices within the British Para swimming World Class Programme. Specifically, coach observation through video analysis of coaching sessions provided quantitative data for FOA cues, CI levels, and implicit learning techniques. These observations were supplemented by semi-structured coach interviews designed to elucidate coach knowledge and understanding of the formal recommendations from the three lines of research under investigation, along with their rationale for adopting any given approach. In this way, the qualitative results served to provide context and meaning for the quantitative data (Cresswell & Clark, 2017). The design adopted was classified as a concurrent mixed methods design and allowed comparison of the methods (Maggs-Rapport, 2001; Miller & Fredericks, 2006).

4.2.2 Participants

Nine coaches from the British Para swimming (BPS) World Class Programme were recruited to take part in the study. Coaches had between 10 and 35 years of coaching experience ($M_{experience}$ Years = 18.6, SD = 8.5), and were aged between 35 and 59 (M_{age} Years = 45.6, SD = 8.8) at the time of the analysis. The swimmers coached in the swim sessions were both male (N=8) and female (N=2) (one coach coached two male swimmers separately), ranging from ages 16-24 years, with impairments both physical (S7 N=2, S9 N=4, S10 N=3) and visual (S12 N=1). All the swimmers were internationally classified and had competed at international level representing BPS and were therefore considered elite-level athletes. Ethical approval to conduct the study was provided by the Manchester Metropolitan University Faculty Ethics Committee. Coaches, swimmers coached, and swimmers' parents (where necessary) were informed that the coach was the focus of the study and would be the one being filmed during dialogue with the athlete. They were informed that only the coaches' voice would be captured/recorded by the microphone, and that the swimmers would be filmed once a lap of the pool had begun only to corroborate the skills being prescribed by the coach. Coaches, swimmers, and parents were informed that participation was entirely voluntary; that no person within the BPS organisation would be made aware of their decision to participate or otherwise; and that none of the footage would be available to anyone outside of the research team. All participants and parents gave written informed consent before data collection.

4.2.3 Coach Observation

Coaches were asked to design a one-to-one coaching session with a BPS swimmer of their choice, lasting anywhere between 60-90 minutes, including 'some focus on both swim strokes and starts and/or turns'. The latter criteria were included to assess potential differences in the coaching of skills typically considered to represent distinct segments of a swim race, involving different sets of biomechanical expertise (i.e., starts/turns are performed either from the block or underwater) (e.g., Veiga & Roig, 2016). The timeline for the sessions was set to reflect a naturalistic setting and to allow coaches flexibility in their approach. Specifically, swimming sessions in the wider BPS programme typically vary in length from anywhere between 90-120 minutes, which includes both the warm-up swim and 'swim-down' at the end. The length of the session may vary as a function of what else the swimmers have done that week, or how close they are to competition. Instructions of 60-90 minutes would allow coaches to design a session which would not be too disruptive to any training plans. In relation to the objective of the sessions, coaches were simply instructed that the session should be centred on learning/improving technique. This is in contrast to a focus on performance parameters such as times, rates, and/or an emphasis on physiological factors such as endurance. Sessions were video recorded using a Sony Handycam camera and coaches were fitted with a WM8S UHF Wireless Lavalier microphone. Coach observation videos were transcribed using Youtube's video transcription service. These transcripts were then checked for accuracy and to delineate where each set of instructions and/or feedback had started and finished. As has been suggested in skill acquisition literature (e.g., Winkelman, 2017), coach feedback provided following the completion of a practice trial is often interwoven with instruction meant to influence the ensuing practice. In these instances, feedback was recorded as having finished and instructions began at the point where coach feedback switched from past to future tense. Coach instructions and feedback were also recorded as either *start/turn* or *swimming stroke* focused (i.e., all swimming outside of starts and turns).

4.2.4 Measures

Focus of Attention. To analyse the direction of attentional focus within the coaches' instructions and feedback, a table of definitions for FOA cues was designed based on previous FOA research (e.g., Becker et al., 2019; Porter et al., 2010; Winkelman, 2020; Wulf, 2013) (see Table 4.1). The FOA cues were categorised as *internal focus* (IF), *external focus* (EF), *mixed focus* (M), *holistic focus* (H), *unclassified focus* (U), and *outcome focus*[4] (O). Identification of internal and external cues in particular during coach observation was further facilitated with reference to Winkelman's (2020) cue anatomy framework. Specifically, internal focus cues typically involve a biomechanical emphasis with focus on *component parts* of body movements (e.g., 'extend the knees on the push-off'; 'rotate the hip'). External cues typically emphasise some element of distance (e.g., proximal or distal), direction (e.g., towards/away or up/down), or descriptions (e.g., action verbs or analogies/metaphors). Holistic focus cues conceptualise the overall *feeling* of the movement (e.g., 'a *smooth* rotation'). Each set of instructions and feedback, marked as either swimming stroke or start/turn practice,

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[4] Outcome cues are external focus cues in the sense that they convey information relating to movement *effects*. However, the information relates purely to overall performance outcome measures (e.g., speed to 15m, reaction time off the block). They describe *knowledge of results* (vs. knowledge of performance) (Magill, 2001). Consequently, one is likely to observe more of these cues during feedback (vs. instructions). Recording them as outcome cues helps to distinguish them from external cues in the pure form (e.g., 'drive hard away from the wall').

were then coded for attentional focus cues in each session. As instructions can also take two forms in that they can either be technically oriented (relate directly to refining technique) or task-oriented (relate indirectly to refining technique through the learning activity to be participated in), FOA cues were *not* recorded for task-oriented instructions in instances where the cues did not actively interfere with the task focus. For example, if the task focus was the arm pull, “swim without legs” would not be recorded as a FOA cue, whereas “swim with your hands in a fist” would be recorded as a FOA cue. Frequencies for each type of cue were converted into proportions for each set of instructions and feedback. In this way, proportions reflected the likely FOA generated by the coach immediately prior to or after any given skill practiced by the swimmer. As such, the total number of any given cue used was not taken into account in the overall analysis. For example, a coach might be recorded during one set of instructions using 24 IF cues and no other focus cues over a period of two minutes, and in another set of instructions using only 1 IF cue with no other cues over a period of ten seconds. However, on both occasions it would be interpreted that the coach is encouraging 100% internal focus in their swimmer prior to attempting a skill. Importantly, this method of analysis would also help to account for the inherent difficulties in using exclusively external FOA cues for complex motor skills, as highlighted in previous research (e.g., Poolton & Zachry, 2007). In particular, the use of EF cues might still require a full debriefing of the fundamentals of the movement (using IF cues) for initial practice trials, before emphasising a key external component on subsequent attempts once the basics are understood. This method also helped to account for differences between coaches in the amount of dialogue used. The transcript for the first recorded video was initially coded independently by three members of the research team to reach consistency in assigning the codes, and a check of inter-rater reliability was performed, producing an agreement level of 80%. Where discrepancies occurred, discussions were held until a consensus was reached. (Pope et al., 2000). The remaining transcripts were then coded by the primary researcher.

Table 4.1

Cue definitions & examples for internal (IF), external (EF), holistic (H), unclassified (U), outcome (O), and mixed (M) focus cues.

Cue	Definition	Example
IF	Directs attention towards component parts of the movement	'Keep your head down'
EF	Directs attention towards movement effects and/or aspects of the external environment	'Drive off the wall'
H	Conceptualises the feeling of the movement as a whole	'Smooth rotation on the turn'
U	Cues which are ambiguous and/or carry no clearly definable explicit meaning	'You're slipping around'
O	Cues relating to overall performance outcome measures	'That one was 6.2 seconds'
M	Encourages attention to be distributed equally between any two or more of internal, external, and holistic focus	'Arms straight as you push off the wall'

Contextual Interference*.* For *contextual interference*, the video recorded practice sessions were mapped out chronologically onto an excel spreadsheet recording the pool length and lengths swam, skills practiced (stroke type, start, turn, finish), any equipment used, brief descriptions of any coach instructions given prior to skill practice, and any distinct practice or recovery blocks. The spreadsheets were corroborated through a triangulation of coach session plans, coach observations, and coach interviews. CI was calculated as the percentage of opportunities taken to change the skill, or skill variation practiced (relative to the previous attempted skill) versus the percentage of opportunities not taken. Opportunities taken to change skill were coded as '1', and opportunities not taken were coded as '0'. As such, the first skill practice in each session was not coded as there was no preceding skill practice. Opportunities to change *not* taken (i.e., repetition) were categorised as *blocked* practice. Opportunities taken to change were categorised as either *within-skill variability* (discernible variations in the execution of the same skill), or *between-skill variability* (changes between different skills). For example, changes in a swimming drill that related to the same overarching skill of freestyle stroke (e.g., freestyle with or without a snorkel) were identified as within-skill changes, whereas changes between the strokes (e.g., freestyle to backstroke) were identified as between-skill changes. In this way, each coaching session provided a proportion of CI in the form of within-skill and between-skill variability, and a proportion of blocked practice. Coach instructions were used to guide the process of analysis. In particular, coach instructions would help to identify changes within-skills which might otherwise be difficult to discern (e.g., 'this time dive deeper off the wall'). Coach instructions also served to highlight the focus of the skill practice. In this way, skill changes which were simply a by-product of the constraints of the pool within the learning activity (e.g., the turns at each end of a 100m backstroke swim) but were not intended as part of the learning focus, were not recorded as skill changes in the analysis. Coach instructions, along with a 'variability line' of 100 metres, were also used to delineate variability in practice. More specifically, if coach instructions comprised a practice block of 8x25 metres, variability would be coded every 25 metres. If instructions comprised 3x100m swims variability would be recorded every 100m. However, if swims or instructions involved skill practice *over* the variability line of 100m (e.g., 4x200m), variability would still be recorded every 100 metres.

Implicit Learning*.* For *implicit learning*, two prominent examples of implicit learning techniques identified in skill acquisition literature were investigated: (i) *analogy learning*, and (ii), *constraints-based learning*. Any examples of these techniques used by the coaches were recorded and described. Examples of constraints-based learning (CBL) were defined as any instance where the coach manipulated constraints specifically to facilitate implicit learning through self-organisation and/or exploration of the perceptual landscape as a function of the applied constraint. CBL was not recorded in instances where constraints were used in order to facilitate *explicit* learning methods such as part-task decomposition through the prescription of drills. For example, if a snorkel were used to remove the breathing element of a stroke to allow focus to be directed towards arm movement in a freestyle arm drill, this was not recorded as an example of CBL. In this way, coach instructions were also used to aid the coding process. The purpose of this coding process was to attempt to identify and isolate 'pure' examples of non-linear pedagogy (implicit learning techniques). Observation also related to whether implicit learning techniques were subject to *explicit contamination* through the concurrent use of explicit (rule-based or declarative) instructions or feedback.

Overlap between analyses exists in that analogies were also recorded as external focus cues based on previous research (Poolton & Zachry, 2007; Winkelman, 2020; Wulf et al., 2002). This was regardless of how analogies were phrased, on the basis that all analogies share the property of being understood implicitly via imagery. That is, if an analogy emphasised the feel of a movement (holistic), it was still recorded as an analogy, and as EF. If the phrasing of an analogy was unclassified (ambiguous), it was not recorded as an analogy as by the nature of the phrasing it could not be understood implicitly. Identification of analogies was facilitated by Winkelman's (2020) cue anatomy framework, which describes three categories of analogy cues in sport: (i) scenario-based analogies (i.e., reference to an analogous scenario, such as the 'reaching for the cookie jar' analogy for a basketball throw); (ii) constraint-based analogies (i.e., the channelling of pertinent movement information, such as 'imagine you've got a pole going through your body from fingers to legs' to guide a swimmer's glide position); and (iii) object-based analogies (i.e., featuring imagery of an inanimate object, such as 'you're scraping the froth off the top of a cappuccino cup' for the arm movement on a swimmer's breaststroke; 'you're squeezing a tennis ball between your ankles' for a swimmer's set position on a jump start).

4.2.5 Coach Interviews

A semi-structured interview comprising ten questions was designed to allow flexibility in questioning for the interviewer. Clarification, elaboration, and detail orientated probes were also used throughout the interview process to elicit richer data (Smith & Sparkes, 2016). Questions included asking the coach what type of things they were encouraging their athlete to focus on or think about when attempting to execute a skill and why; how they structured the session and individual practice blocks and why; what the thinking/rationale was behind any implicit learning techniques they may have used; how they tend to adapt sessions for athletes with different disabilities or sessions that include able-bodied athletes; and if they were able to provide both positive and negative examples of coaching practice in relation to the facilitation of learning (see Appendix C). Coaches were not asked explicitly about their knowledge of skill acquisition research principles as the intention was not to give the impression of right or wrong, but to allow the coach to feel comfortable and open when articulating responses. Openness was also facilitated by the primary researcher's relationship with the coaches, built up over the previous eighteen months working as part of the same team. Interviews were video recorded using a Sony Handycam camera and coaches were fitted with a WM8S UHF Wireless Lavalier microphone. Interviews were transcribed using Youtube's video transcription service.

4.2.6 Qualitative analysis

Given relatively little is known concerning elite coaching perspectives and approaches to skill acquisition, a thematic interpretational content analysis was identified as the appropriate analytical method (Aronson, 1994; Côté, Salmela, & Baria, 1993; Gibbs, 2007). This approach has the potential to generate knowledge through the development and interpretation of themes from the interview transcripts. It also allows the researcher to deal with blurred boundaries between categories of text, with the goal of minimising the overlap between categories (Côté et al., 1993). Following this procedure, the first step involved immersion and familiarisation with the transcribed data. Specifically, this comprised reading the transcripts repeatedly and identifying meaningful segments of the raw data pertaining to skill acquisition practices/principles/perspectives/knowledge/intentions/rationale, whilst also noting down initial thoughts in relation to these. These segments or 'meaning units' were tagged initially with short paraphrases reflective of their content. Tags were then coalesced into clusters of topical commonalities which generated lower order and higher order categories. For example, raw data tags such as, 'physical recovery' and 'mental recovery', were grouped to create the lower order theme of 'level of challenge'. Although the analysis involved predominantly inductive procedures, the latter stages of the process also involved an element of deductive reasoning. In particular, the objectives of the study necessitated an element of honing in on coach rationales that pertained, at least loosely, to the three principles of skill acquisition investigated. Furthermore, the appellation of higher order themes identified was influenced by skill acquisition literature (e.g., 'part-task training'). This approach to qualitative data analysis is not uncommon, as Gibbs (2007) noted: "It is very hard for analysts to eliminate completely all prior frameworks ... inevitably qualitative analysis is guided and framed by pre-existing ideas and concepts" (p. 45).

Coding and categorisation in the thematic analysis was conducted by the lead researcher. However, the second, third, and fourth authors acted as 'critical friends', using the primary researcher as a 'theoretical sounding board' to reflect upon and evaluate lower and higher order themes, along with their explanations and interpretations in relation to the overarching theoretical framework and concepts of interest (Burke, 2016). Specifically, throughout transcription and coding, the three critical friends and primary researcher engaged in discussions, reviewing content and deliberating theme developments. These critical friends were mindful of personal biases and challenged one another's beliefs and assumptions throughout the process, which served to ensure transparency of process and diligence in verification of the organisation of the data (Sparkes & Smith, 2009; Sparkes & Smith, 2013). Additionally, any disagreements or uncertainties were resolved through further engagements and discussions among the research team.

4.3 Results

4.3.1 Focus of Attention

Three of the coaches chose only to coach starts and/or turns in their sessions, so FOA analysis for swimming stroke data specifically comprised only the remaining six coaches. Initial tests were performed to assess the normality of the data and results indicated that the data was not normal, therefore non-parametric tests were implemented.

Wilcoxon tests were used to assess the difference between the groups. Comparing internal focus to external focus for swimming stroke instructions, the results indicated a significant difference, $z(5) = -2.20$, $p = .014$ (one-tailed), whereby internal focus was higher than external focus (62.0 vs. 2.3). Comparing internal focus to external focus for start and turn instructions, the results indicated a non-significant difference, $z(8) = -.18$, $p = .859$ (two-tailed). Comparing internal focus to external focus for swimming stroke feedback, the results indicated a significant difference, $z(5) = -2.20$, $p = .014$ (one-tailed), whereby internal focus was higher than external focus (57.6 vs. 5.0). Comparing internal focus to external focus for start and turn feedback, the results indicated a non-significant difference, $z(8) = -.06$, $p = .953$ (two-tailed). The comparison between internal focus and external focus for overall instructions indicated a significant difference, $z(8) = -1.96$, $p = .025$ (one-tailed), whereby internal focus was higher than external focus (45.5 vs. 18.3). Finally, for the comparison between internal focus and external focus for overall feedback, the results also indicated a significant difference, $z(8) = -2.55$, $p = .005$ (one-tailed), whereby internal focus was higher than external focus (33.8 vs. 18.9).

Table 4.2

Descriptive statistics for coach instruction and feedback FOA cue proportions for swimming stroke and start/turn skill practice.

FOA Cue	Instructions		Feedback		**Totals**	
	Swim Strokes	Starts & Turns	Swim Strokes	Starts & Turns	**Instructions**	**Feedback**
Internal	62.0	33.9	57.6	23.5	**45.5**	**33.8**
External	2.3	31.5	5.0	24.5	**18.3**	**18.9**
Holistic	15.1	14.4	19.2	15.0	**15.8**	**15.8**
Unclassified	11.6	5.4	5.5	15.5	**8.2**	**13.1**
Outcome	8.2	10.3	11.0	18.2	**10.3**	**16.5**
Mixed	0.8	4.4	1.7	3.3	**2.9**	**2.0**

Coach interviews indicated that the coaches had limited knowledge of the principles of FOA research. Coaches were asked what they wanted their swimmers to think about or focus on during skill execution in both swimming stroke and start and turn practice trials; examples of cues they like to use to promote the desired focus; and what their rationale was behind this. Responses typically described internal (bodily focus) or holistic (e.g., swim-specific general movement focus such as *rotation*, *glide*, or *streamline*) FOA cues for all skills, and centred on cue simplicity rather than type of cue:

> *‘Generally when I’m giving feedback it will be ‘glide’ or ‘head position’, so instead of a long conversation with them usually it would be short and snappy so they can remember’. (C2)*

> *‘Yeah I try not to over talk too many times when I give him his skill so sometimes it’ll just be a sentence of, ‘keep your hands or fingers in a fist’ and swim one length’. (C9)*

Responses implied that the frequent use of internal focus cues may stem from coach education programmes:

> *‘I watched him swim some backstroke first and then I broke the stroke down using the BLABT principle which is body position, legs, arms, breathing, timing… I always like to break the strokes down and start with body position and kick first’. (C6)*

'I don't know what you call it but in swimming the five key elements are body position, kick or leg action, arms, breathing, and timing, so whenever I do stroke technique development I basically follow that process so develop body position and kick first and then work on adding the arms in'. (C7)

The coaches were probed on these responses and asked if they could provide any examples of other types of cues they might use for any other reason or skill type. Five of the coaches could not provide examples of cues outside of those associated with an internal or holistic focus. The rationale for the example cues provided typically involved emphasising the importance of body position in swimming and the desire to increase the swimmers' somatic awareness:

'It's about your body awareness because (when) you are at the wall, it's then knowing where your arms and your legs are so you can rotate as quickly as possible'. (C5)

'But a lot of swimming is just body position so everything will relate back to that generally'. (C2)

Four of the coaches did provide some variation in responses to probing questions that accounted for the some of the variety of cues observed across the sessions. For example, C8 made use of a relatively high number of *unclassified* focus cues (34.9% compared to 7.3% used by coaches overall). This appeared to be a deliberate approach designed to encourage the athlete to problem solve:

'It might be as simple as 'you're slapping – try and clean that up a little bit', and then where possible probably wouldn't say more than that as I'd be hoping he'll try and figure it out for himself'. (C8)

Two of the coaches described their use of analogies as cues (recorded as external focus) as a means of helping the athlete to understand instructions more easily:

'So imagine you've got like a little finger or a pea in your belly button and you've gotta suck it in so it stays there… to a young person it's dead simple. Also when I say stand to attention like a soldier everyone knows what I mean'. (C7)

'When placing his feet on the wall I might reference that the wall is red hot to then try and push off the wall really quickly and give him something to visualise'. *(C9)*

4.3.2 Contextual Interference

Across the nine coaching sessions, training on average comprised 41.3% within-skill variability, 21.6% between-skill variability, and 31.7% blocked practice. Three of the nine coaches (C3, C4, C5) chose to focus only on starts and/or turns in their sessions. Within these sessions, C3 coached one turn (backstroke turn) throughout the session, while C4 coached the freestyle turn, butterfly turn, and dive starts. C5 coached a medley swimmer and chose to coach all three medley turns in the session. This contributed to a between-skill variability score (62.5%) which was higher than the average (21.6%). The remaining six coaches all incorporated aspects of both free swimming and starts and/or turns practice, as per the session guidelines. Although C6 coached both the butterfly start and the backstroke, this was done with two different swimmers meaning no between-skill variability was recorded.

Initial tests were performed to assess the normality of the data and results indicated that the data was not normal, therefore non-parametric tests were implemented.

A Friedman's analysis was performed on the contextual interference data with three levels (blocked practice, within-skill variability, between-skill variability). The results indicated a non-significant difference, $df = 2$, $\chi^2 = 4.67$, $p = .097$.

Table 4.3

Descriptive statistics for proportions of each coaching session comprising within-skill variability, between-skill variability, or blocked practice.

	Coach									
CI %	C1	C2	C3*	C4*	C5**	C6	C7	C8	C9	Ave.
Within-skill	4.5	33.3	31.3	46.2	18.8	59.1	62.5	61.8	54.1	41.3
Between-skill	45.5	21.2	0	23.1	62.5	0	12.5	21.8	8.1	21.6
Blocked	50.0	45.5	68.7	30.7	18.7	40.9	25.0	16.4	37.8	37.1

*Coached starts/turns only

**Coached all medley turns only

Coach interviews indicated that the coaches had no knowledge of the formal recommendations made by CI research. A common theme reported by the coaches to explain the level of variability in their sessions was the *level of challenge* involved for the swimmers. Manipulating the level of challenge typically involved breaking skills down into smaller component parts after initially observing the skill as a whole, before building back into the full skill/swim – a process described by many of the coaches as, 'whole-part-whole' (also referred to in the skill acquisition literature as *part-task decomposition*; Seifert, 2018):

> *'The structure was pretty simple, it was whole-part-whole… I work on a very simple philosophy of you look at the whole, you break it down into parts, and then you put it back together again as a whole and you can assess what effect you're having on the execution'*. *(C3)*

> *'If you notice in the drill generally I'll go whole-part-whole. So the whole stroke, break it apart, back to whole, you know what I mean'*. *(C2)*

Progression through skill components was typically contingent on performance:

> *'When I felt he did that really well then we progressed, if he wasn't doing it very well then we just stayed there'*. *(C7)*

Equipment was often used by the coaches to facilitate skill breakdown, which provided additional levels of skill progression:

> *'On the first few lengths I put a snorkel on him so he didn't have to figure out when to breathe and could just focus purely on his head position and his body'*. *(C7)*

> *'If you give them too many things to focus on you don't get anything done and I wanted to really focus on body position so fins just make that easier for them'*. *(C6)*

Two of the coaches indicated that progression through different stages of a skill is typically a slow process that they may have accelerated for the purpose of the observation research:

> *'I'm a very structured person in terms of building things up… I could have continued a lot longer than we did, I normally like to make sure again… I'd rather spend the majority of the session just doing one thing over and over*

again… To me there's no point practicing something and then going and doing something else'. (C6)

'After 16 years old if you're teaching a new skill the amount of retention of that skill they can maintain is very little so actually repeating the process time and time again will help reinforce that skill so I will often repeat the skill many times and transfer it into their swim slowly'. *(C9)*

Interviews also revealed that an element of both *within* and *between*-skill variability emerged as a function of coaches actively incorporating physical and psychological recovery time into the sessions and practice blocks in an attempt to maximise learning opportunities:

'I believe if you're gonna do a good job on starts you're only gonna get about 12 in a session because you're gonna end up with neural fatigue…so what we did is small blocks, little recovery swim activating the core, small blocks, little recovery swim (again)'. *(C1)*

In responses more closely aligned to scientific theory underpinning the efficacy of high CI during practice, two of the nine coaches described practice blocks that were designed to encourage the athletes to *compare and contrast* the different elements of a skill:

'The key element focusing on the turns themselves was the idea that if you have two fast, two steady turns each 125… the idea behind that is it's more raising awareness of the differences on those steady to fast'. *(C8)*

'I put him at a disadvantage where one of the hand drills he wasn't allowed to use his fingers, he had to use fists (every 10 metres then every 25), which reduces the amount of catch in the water, so then when I introduced the fingers back he could feel the difference… he understood what poor felt like and what great felt like'. *(C9)*

Coaches were also asked whether they might adapt sessions for athletes with different disabilities or sessions that include able-bodied athletes. Coaches suggested that where possible the structure of sessions would remain the same ('*it will always be whole-part-whole'; C2*. *'I don't think it changes the structure and I don't know whether you'd change many of the reps because there's a psychosomatic effect of somebody* *doing less'; C1*). Coach responses often centred on the endurance capabilities of the athletes ('*I would adopt a similar type of approach across the board but base it on the condition of the athlete'; C4)*. However, the coaches acknowledged exceptions such as for athletes who have severe physical impairments meaning the session would need to be less physically demanding, or for athletes with intellectual impairments (S14s), for whom skill progression might need to be slower *('an S14 might not be able to do four turns in a row without feedback'; C8*).

4.3.3 Implicit Learning

Five of the coaches made use of analogy learning techniques at some point during their session. One coach used analogies four times during their session, and four coaches used one analogy each in their sessions. Analogies were used to convey appropriate body positions, speed of movements, and other movement effects to the swimmers.

> *'Imagine it's red hot (the wall) and you don't want to burn your feet'. (C9)*
>
> *'It's almost like a windscreen wiper action'. (C6)*
>
> *'So I want you flat like a soldier standing to attention'*. *(C7)*

None of the eight analogies used could be said to have been the main focus or emphasis within a given set of instructions as each one was used alongside multiple other focus of attention cues. For example, C7 used two analogies during one set of instructions concerning the execution of a freestyle swimming drill but these were used alongside 22 other focus cues during two minutes of dialogue.

Four examples of CBL were recorded from four of the nine coaches. Three examples involved the coaches manipulating the *environmental constraints*, and one example involved the manipulation of *task constraints* (Newell & Jordan, 2007) such that the swimmers would be implicitly directed towards the to-be-learned movement solution. First, C4 identified that their swimmer wasn't getting into their kick quickly enough off the wall and instructed the swimmer to perform a number of tumble turns without the aid of a wall to push-off and gain propulsion. As such, the natural (intended) solution to regaining the now constrained propulsion in order to change direction quickly would be to start kicking straight away. Second, C6 instructed their swimmer to balance a rubber duck on their forehead during a backstroke drill to facilitate learning to keep the head still. Third, C1 attempted to encourage the learning of core and trunk engagement during the freestyle stroke by creating imbalance through the use of one paddle and one fin on opposite sides of the swimmer's body. Fourth, C9 manipulated the task constraints for their swimmer during a freestyle drill such that every 10 or 25 metres they switched between a flat hand and a fist shape on the pull through the water. The contrast in feel was designed to encourage the exploration of the perceptual-motor landscape in order to find more effective movement solutions when the hand was flat. Each of these examples of CBL were implemented in conjunction with *explicit* coaching methods. More specifically, rather than the swimmer finding the movement solution within the designed constraints through the exploration of the movement alone, the movement solution was also described explicitly to the swimmer and reiterated prior to each practice trial. For example, *'the principle of this drill is I'm trying to get you to kick your legs straight away when you've turned' (C4). 'So this is forcing you to keep that head really still because when we're swimming we don't want to be bouncing around so again duck on your head, head nice and still okay' (C6). 'I want you to concentrate on the engagement of the core… I'm not looking for perfect streamlining, just for you to be able to lift it' (C1)*. *'I want you to count your strokes fist to 25 and then stroke count hands to 25 and see if there's a difference' (C9)*. Practice trials were then also followed up with explicit forms of feedback provision relating to the movement solutions, including *prescriptive feedback* (e.g., *'okay so now I want you to lift your tummy and hips but still keeping that head still'; C6*), or questioning techniques (e.g., *'so did you feel anything in your hip flexors?'; C1*).

During the interviews, all coaches showed limited knowledge of the fundamental principles of implicit learning. Two of the nine coaches neither implemented any implicit techniques in their sessions, nor provided or discussed any examples of implicit techniques used or observed in previous sessions. Among the remaining seven coaches, the interviews indicated that each coach had developed their own experientially and informally derived understanding of implicit learning techniques, which produced both consistencies and inconsistencies in the data. For example, there appeared to be little consensus among these coaches regarding *when* to implement implicit techniques during practice, with decisions based on subjective judgement and experience:

> *'There's a time and a place for probably being a bit more prescriptive. I couldn't tell you as and when, it would probably be more gut feel'.* (*C8)*

There were also discrepancies among coach perceptions concerning the mechanisms which might underpin the efficacy of implicit techniques such as CBL, with coaches describing both unconscious (e.g., *'so you have to use your trunk and your core without being conscious; it's a subconscious activation'; C1*), and conscious processes (e.g., *'it's making decisions themselves, so even though I was telling him what to do, he had to make a decision'; C4*).

Greater consistency emerged in relation to *why* these coaches might adopt implicit learning techniques, and in their descriptions of the perceived effects. In particular, the coaches described various constraints-based approaches to learning as helping to enhance the swimmer's *understanding* and *awareness* of their movements:

> *'So it's promoting that ability to understand actually that push-off didn't work… it's making sure they understand what impact a technical element has and getting them to feel it gives them that deep-seated understanding'. (C1)*

> *'One of the interesting things I've seen done is trying to drive off the blocks and being restricted with a towel round the waist so they're having to find a way, so in terms of actually making the athlete more aware that's probably one of the best I've seen'. (C8)*

For the coaches, it appeared that regardless of *how* skills had been learned (i.e., through the implicit or the explicit pathway), any form of 'understanding' should be amenable to verbal analysis and reflection. In other words, skill performance should be accompanied by explicit knowledge of how it was performed, and for the coaches, the two appeared to hold equal significance:

> *'So we'll try and make a difference but could he actually feel there had been any difference and then feedback for myself on why they were observed as well… in the race on the second turn he needs to know that was either great or that was a crap one… he needs awareness to adapt and evolve as the race is going on'. (C8)*

'I gave him a chance to explain it which gave me a chance to see what his self-awareness was, what does he know about it… so they know why they're doing it and they can think about it when you're not there'. (C7)

4.4 Discussion

The current study examined both the practices adopted by elite level coaches in swimming, and the rationale underpinning their approaches. Based on previous findings, it was hypothesised that (i) coaches would make use predominantly of internal (vs. external) FOA cues during swimming stroke practice (Porter et al., 2010), but that no difference would be observed during the coaching of starts and turns (chapter three), (ii) coaching sessions would comprise relatively low levels of both within-skill and between-skill variability (chapter three; Farrow & Buszard, 2017; Lee, 1988), and (iii) coaches would heavily apply more traditional *explicit* learning techniques (Brackley et al., 2020; Junggren et al., 2018).

As predicted, elite coaches at BPS emphasised significantly more internal focus cues than external focus cues during the coaching of swimming strokes (i.e., freestyle, backstroke, butterfly, and breaststroke), but in line with findings from the previous chapter (chapter three), no significant difference was observed during the coaching of start and turn techniques. The coaches' overall use of more internal (vs. external) focus cues during instructions (45.5% vs. 18.3%) to a lesser extent reflect those reportedly used by elite track and field athletics coaches (84.6% internal focus; Porter et al., 2010), volleyball coaches (88.9% internal focus; Diekfuss & Raisbeck, 2016), and baseball coaches (69% internal focus; van der Graaff et al., 2018). That no difference was observed between for start and turn practice may be because starts and turns offer more opportunities to interact with the environment (e.g., the wall or the block), and coaches are taking advantage of this. Equally, the complexity of start and turn skills (movements involving multiple degrees of freedom executed both through the air and underwater *at speed*) may be less amenable to skill breakdown, which forms the basis of internal cues (Mullen & Hardy, 2010).

The coaches' rationale for their use of internal focus cues was typically based around cue simplicity and the facilitation of body/body position awareness. Their approach in this regard poses interesting questions for skill acquisition research. Specifically, while much of the FOA literature postulates that external focus is optimal for performance and learning (Wulf, 2013), alternative research emphasises the importance of body consciousness or 'somaesthetic awareness' to facilitate *continuous improvement* among elite level athletes (Toner & Moran, 2014, 2015). That is, it is suggested that the ability to improve or refine motor skills requires heightened attention towards and mastery of somatic functioning. Furthermore, findings indicate internal focus cues could benefit learning in sports such as swimming, where a somatic focus prior to skill practice can improve processing of proprioceptive task information through increased congruence between instructions and feedback (Gottwald et al., 2020). It is possible that swimming coaches have become intuitively aware of the benefits of increased somatic awareness during practice and their use of simple internal cues are thus a deliberate learning strategy designed to aid this process. Indeed, much of the coaches' explanations/justifications refer to athlete 'feel', 'awareness', and 'understanding'.

In line with this, the coaches do not appear to view conscious (internal) and automatic (external) processes as mutually exclusive, but rather as interchangeable or overlapping. Research highlighting the potential for internal focus cues suggests that athletes are required continually to switch between conscious and automatic modes of control during performance (see Collins, Carson, & Toner, 2016). Additionally, the internal/external nature of a cue and resulting neural processes may be superseded by the athletes' *familiarity* with it. Specifically, Maurer and Munzert (2013) reported that free throw success rate among skilled basketball players was higher for individually preferred (i.e., inter-individually different) familiar cues relative to unfamiliar cues, irrespective of attentional direction (i.e., internal or external). In this way, internal cues may become so familiar they become part of an athlete's 'normal' (i.e., effective or automatic) focus (see also Porter and Sims, 2013; Winkelman et al., 2017) while allowing for enhanced somatic awareness. Taken together, it could be argued that the current findings among expert coaches further call into question the rigidity of the external focus effect and the assumptions of the constrained action hypothesis (see also Collins, Carson, & Toner, 2016; Gottwald et al., 2020). However, this suggestion is contradicted by the coaches' use predominantly of external cues during start and turn practice.

The predictions in relation to the level of practice variability observed in the coaching sessions were partially supported. In particular, between-skill variability was low in seven of the nine coaching sessions (two of these seven were recorded as zero), and moderately high-to-high in the remaining two. This suggests that coaches typically coach specific skills in large practice blocks without incorporating additional skills. One coach had also suggested that were it not for the purposes of being observed the session would have involved more repetition. However, these figures must be approached with caution as no significant differences in practice scheduling were recorded in this small sample. The pattern of results was reversed in relation to within-skill variability. More specifically, within-skill variability was moderate to high in seven of the nine coaching sessions, and low in the remaining two. These findings reflect the practices observed among skilled youth tennis players (Buszard et al., 2017). This is perhaps surprising given that tennis performance in competition *requires* variability to react to, and outwit opponents in an open environment, whereas swimming performance in competition requires repeatedly performing the same skill within a closed environment. In this way, if the contextual interference benefit for complex skills relates only to one of *specificity* between the learning and performance context (e.g., Farrow & Buszard, 2017; Lee, 1988), it may not emerge as a function of the practice scheduling observed in the current study.

During the interviews, coaches did not demonstrate knowledge of any of the formal recommendations from contextual interference research. Coach rationale for session structure typically concerned the level of challenge involved for the swimmers. This was manipulated using a skill development process of 'whole-part-whole' (i.e., part-task training), whereby skills were firstly observed, then broken down into component parts (less challenging), before being built back into the full skill or stroke (more challenging). As such, sessions and practice blocks often took the form of drills through which the athletes would progress contingent on performance. In this way, a large proportion of the variability observed did not involve the swimmers switching between skills or skill variations (i.e., back and forth), but rather progressing through the different elements or stages of that skill, whereby the focus of learning changed at each stage throughout. According to theoretical explanations, the mechanism through which contextual interference exerts its effect operates as a function of switching *back and forth* between skills or skill variations, strengthening the memory trace of the skill either by facilitating a process of forgetting and then reconstructing movement schemas (the *forgetting-reconstruction hypothesis*; Lee and Magill, 1983) or comparing and contrasting movement patterns (the *elaboration hypothesis*; Shea and

Morgan, 1979). Consequently, although the coaches were incorporating relatively high levels of (within-skill) variability into practice sessions, this type of variability may not confer the learning benefits suggested by scientific research.

Further in line with the study hypotheses, coaches were observed using predominantly more traditional explicit approaches to skill acquisition, but as in previous investigations of this kind, there were indications that coaches are shifting towards the use of more contemporary implicit techniques (Brackley et al., 2020; Junggren et al., 2018). However, the implicit learning strategies adopted were consistently supplemented by explicit coaching methods. For example, five of the coaches made use of analogy learning techniques at some point in their sessions, but on each occasion the analogies were used alongside multiple other FOA cues, including internal cues. Four coaches were also observed incorporating a form of constraints-based learning into practice drills within their session. However, rather than allowing the athlete to find the desired movement solution within the designed constraints, the coaches simultaneously used prescriptive instructions and feedback to describe the explicit rules that govern the movement. Furthermore, in the case of both analogy and CBL techniques, athletes were typically asked to provide explicit verbal reflections following each skill practice. Consequently, although evidence of the use of implicit learning techniques is encouraging, it may be that the potential learning benefits of these approaches (i.e., limiting the accrual of explicit skill knowledge) are compromised by the coaches' method of delivery. This suggests that a greater understanding of underlying mechanisms is needed for such techniques to be used effectively (Cushion, 2013; Renshaw et al., 2019).

Coaches did not demonstrate knowledge of skill acquisition research in relation to implicit motor learning. There was also no consensus among coaches with regards to *when* implicit techniques should be implemented, or *how* they exert their effects on learning. This perhaps provides evidence that the benefits of such approaches have been discovered by some coaches intuitively rather than through coach education programmes. Greater consensus emerged in relation to *why* coaches adopt implicit techniques. In particular, the coaches described such techniques as a method to further increase athlete *awareness* and *understanding* of skills. The notion that *implicit* techniques might enhance more *explicit* cognitive processes such as these is in direct contrast to the suggestions from implicit learning research (e.g., Masters & Poolton, 2012).

A potential limitation of the study relates to its ecological validity. During the interviews two coaches (who recorded high within-skill variability) indicated that they would typically progress through the stages of the drills more slowly and incorporate significantly higher levels of repetition (i.e., lower variability) when not being observed for the purposes of the research. As such, the practices observed (relatively high variability) may in part stem from the coaches' desire to demonstrate a range of skills in one session rather than for pedagogical purposes. Furthermore, the coaches were asked to conduct sessions on a one-to-one basis with their swimmers, which is not typical of interactions in most training sessions where a number of swimmers are coached simultaneously.

4.5 Conclusion / Summary

Overall, the current study highlights a disconnect that exists between applied coaching practice at the elite level and the scientific recommendations of best practice which emanate from three prominent lines of skill acquisition research. It must be noted, however, that these lines of research do not constitute the full spectrum of learning theory within skill acquisition literature. Furthermore, commonalities reside among these lines of research themselves. For example, it is suggested that both external FOA and implicit learning operate as a function of reduced conscious processes in movement control (e.g., Chow, 2013). Alternative lines of research argue that an *increase* in conscious processing, via, for example, an internal FOA, can also be beneficial in elite athlete learning, such as when attempting to change or modify well established motor skills (e.g., Carson & Collins, 2011; Carson, Collins, & Kearney, 2017). Other applied research suggests that optimal learning of swimming skills occurs via the *interaction* between implicit learning techniques such as CBL, and subsequent explicit learning facilitated by dialogue between athlete and coach (Light, 2014). The coaches in the current study appear to have developed their own practice-informed theories of how to coach, presumably through informal learning opportunities and personal experience of what works for them (see Blackett et al., 2017; Dehghansai et al., 2020; Fairhurst et al., 2017). That these approaches could be said to incorporate elements of techniques reflected in a range of research perspectives perhaps only strengthens the need to harness coaches' experiential knowledge in future research (see also Greenwood, Davids, & Renshaw, 2012). Equally, current research presents a potential problem for coaches insofar as attempting to reconcile best practice approaches where the associated underlying learning mechanisms are conflicting or unknown. In particular, traditional explanations for the CI effect infer a cognitively demanding explicit learning process in working memory (via reconstruction or elaboration), whereas FOA and implicit learning techniques are designed to reduce working memory involvement. A practical solution may lie in an alternative theory for the CI effect, which proposes that the excess demands placed on cognitive resources through task switching actually *prevents* explicit processing in working memory, and instead promotes learning via implicit pathways (Rendell et al., 2010). As such, more ecologically valid testing of scientific theory and results is needed to provide clarity on skill acquisition research recommendations. These aims can be achieved through greater collaboration between coaches and skill acquisition practitioners, and research that takes place 'in situ'. It is hoped that in highlighting potential gaps in understanding on the part of both sides, the current paper goes some way towards facilitating this process.

CHAPTER FIVE

5. Experiences of a Skill Acquisition Practitioner

5.1 Aim of the chapter

The aim of this chapter is to provide a slightly more anecdotal account of some of my attempts as an applied practitioner to begin to bridge the gap between research in motor learning and skill acquisition and coaching practice in swimming. In particular, while there is now a large body of experimental research in skill acquisition, relatively few studies have explored the impact of learning techniques in the field (Buszard et al., 2017; Wulf, 2013), and literature describing the experiences and approaches of skill acquisition practitioners embedded within the sporting context is even more scarce (for exceptions see - Button & Farrow, 2012; Pinder et al., 2022 – this chapter; Pinder & Renshaw, 2019). For the latter in particular, this can be explained through the most common barriers to the uptake of skill acquisition provision in sport, including funding, a perceived lack of research relevance for the applied setting, and poor practitioner understanding of coach and athlete needs (Steel et al., 2014). As such, it is essential that practitioners who *are* given the opportunity to be embedded in a sport share their experiences beyond well designed, publishable interventions. In doing so, they contribute to a framework of understanding which serves to *break down* the barriers to applied skill acquisition practice, and facilitate future collaborations between coaches, athletes, and prospective skill acquisition practitioners. What's more, the importance of knowledge sharing in this way is magnified in Para sport, where guidance on the constraints of athlete disabilities is severely lacking (Cregan et al., 2007; Pinder & Renshaw, 2019).

In this chapter, I share some of my experiences as an applied practitioner in skill acquisition with the British Para Swimming team. My role as a practitioner as part of the PhD studentship project was set up as a development role. That is, for much of my time spent with the team I would not have described myself as a practitioner, and my opportunities for meaningful work with coaches and/or athletes for the first few years was limited, as was my understanding of applied skill acquisition in swimming. As such, the reflections and examples I provide here represent predominantly work towards the later stages of the project, and in some instances, there was little opportunity to monitor long-terms performance improvements among athletes. That being said, attributing performance gains to *any* intervention or discipline specifically in high performance sport is extremely challenging, and often the best source of evidence of impact comes through feedback from the athletes and coaches.

What follows in this chapter involves predominantly two parts. The first section (*Identifying the gaps*) is taken from a book chapter contribution (see Pinder et al., 2022) and details some of my experiences working with coaches at the National Performance Centre in Manchester, where I was based, in the year or so leading into the Tokyo 2021 Paralympic Games. This period follows on from study one and two (chapters 3 and 4) and describes some of my work with coaches facilitated by the findings and knowledge acquired from these studies and by a greater understanding of the demands of the sport gained over time. The second section presents four example case studies of individualised skill acquisition approaches for athletes with a range of disabilities. Rather than an emphasis on working with a coach, these examples involve more specific athlete interventions where a coach or biomechanist has asked me to assist with an athlete in a particular session, sometimes with swimmers from another club on a short visit to the Performance Centre. In this way, these interventions are often time pressured and practice techniques are identified through a process of getting to know the athlete (and their disability) and trial and error, rather than any extensive pre-planning. However, while it is sometimes possible to work with one athlete over an extended period, these situations of working on a particular skill with a particular athlete when the opportunity presents itself are quite typical, and often produce some of the most surprising results. Lastly, I give a brief account of my approach and experience as Performance Communication Lead in the relay race training camp just prior to the Tokyo Paralympic Games before reflecting on some of the challenges faced.

5.2 Identifying the gaps

- This section is adapted from my contribution to the book chapter, entitled 'The role of skill acquisition in coach and athlete development in Paralympic Sport' (Pinder et al., 2022).

After around 12-18 months and once I had developed my own experiential understanding of the sport and current approaches to learning and development, the next step involved a more formal analysis of coaching practice. In particular, I set out to examine practices relative to the established principles and recommendations from skill acquisition research. Coaching sessions across the Programme (i.e., senior coaches from across the UK) were observed, and interviews served to shed light on the knowledge and rationale underpinning the approaches. This research (see Pinder et al., 2022 – this chapter; Powell et al., 2021 – chapter four) helped lay the foundations for work with the coaches in the lead up to the Tokyo 2021 Paralympic Games.

It was apparent from early discussions that the coaches had limited knowledge of key skill acquisition concepts. Furthermore, the coaches, who had all come from backgrounds in non-disabled sport, did not report that they followed any formal guidance with regards to the coaching of Para athletes. In line with previous findings (Cregan et al., 2007; Dehghansai et al., 2020; Fairhurst et al., 2017), coaches favoured informal learning opportunities for development (e.g., trial and error; observing or communicating with other coaches). As such, they had developed their own practice-informed theories of how to coach, based on what had worked for them.

In relation to language, coaches were observed using cues which predominantly focused athletes' attention internally towards component parts of the body movement (e.g., "pull your hands back"), as opposed to cues which focused attention externally towards movement effects (e.g., "push the water back"), indicating practices may be suboptimal for the acquisition of skills (Wulf, 2013). Interestingly, this was not the case during the coaching of start and turn skills, where no difference between internal and external cues was observed (see Figure 5.1), and coaches adopted a range of alternative cues that research suggests better facilitate athlete learning, including both holistic cues (Mullen et al., 2015) and analogies (Masters et al., 2019). However, the coaches reported little awareness of their use of such cues, and/or did not appear to view them as significant. On occasions when coaches were observed using cues such as analogies or external focus outside of starts and turns, they were typically used alongside multiple other (predominantly internal) cues, making it difficult to detect an athlete's subsequent focus. In one typical example, a coach was observed using two analogies during one set of freestyle drill instructions alongside 22 other focus cues within two minutes of dialogue. These observations and insights provided a framework for discussions and exploring new approaches with the coaches. For instance, I was able to use the coaches' own analogies (e.g., "imagine the wall is red hot and kick off as quickly as possible") to describe how subsequent learning benefits operate as a function of reducing the athletes' reliance on working memory processes during practice (i.e., by allowing athletes to label movement instructions symbolically). Subsequently, through a collaborative approach, new verbal cues were explored (e.g., in the butterfly: "imagine swimming between two panes of glass"). This approach (i.e., analogy learning) has been well received by athletes with visual impairments, who have described the benefits of being able to visualise movements in their mind's eye. In addition, the coaching team is now exploring the use of analogies as a means of enhancing communication between coaches and athletes with intellectual impairments, where working memory capacity often hinders their ability to process more explicit instructions.

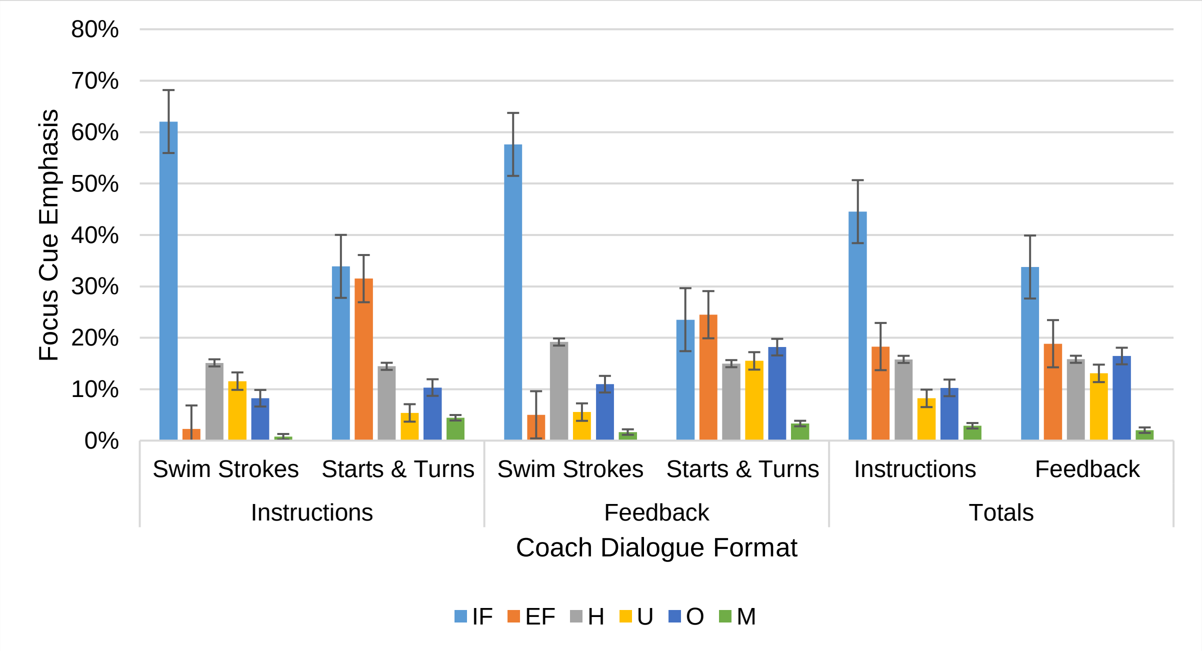

Figure 5.1: Coach focus of attention cue emphasis during instructions and feedback for swimming stroke and start/turn skill practice.

In assessing practice design, coaching sessions tended to comprise practice blocks which focused on a single skill for a large period of time. These blocks often took the form of part-task training, whereby skills are decomposed into component parts through the prescription of drills and then built progressively back into the full stroke or skill (e.g., the full swimming stroke is first reduced to the leg kicking component, before adding in the arm movements and breathing action). This technique is common in swimming training (see also Brackley et al., 2020), but the extent to which it facilitates the transfer of skills to other performance contexts remains an area of debate within SA literature and is perhaps indicative of the disconnect between theory and practice (Barris et al., 2013; Pinder et al., 2011; Seifert, Button, & Davids, 2013). This notwithstanding, it was apparent that progression through isolated part-task drills or blocks comprising high volumes of repetition (as opposed to any process of switching *back and forth*) provided little opportunity to explore learning or different levels of challenge for the athlete.

Through discussions with the coaches regarding the potential impact of increased variability, Programme coaches began experimenting with the scheduling of practice trials. Coaches would provide their plans for the session, and without changing the prescribed volume (typically the priority), I would highlight ways to break large practice blocks down into smaller ones and distribute them across the session. For example, rather than practicing ten dives at the end of a session, a swimmer might practice three at the start, four in the middle, and three at the end. Within-skill variations could also be incorporated where necessary to promote movement exploration. I reinforced to coaches that, although learning may not be immediately observable and may even be characterised by increased errors in practice, the benefits could be explored and assessed in ‘race sets’ at the end of the week designed to more closely replicate the performance context. Importantly, variability in practice was something the swimmers enjoyed!

Although coaches were using predominantly more prescriptive techniques such as part-task training, my observations suggested there may have been attempts to align some task designs more closely with contemporary nonlinear approaches. However, it was clear that these were not underpinned by an understanding of key concepts of the approach, such as self-organisation under constraints. As an example, one of the coaches ‘removed’ the wall during turn practice (i.e., the coach asked the swimmer to turn in the middle of the pool - which could be considered a *task constraint*, see Newell & Jordan, 2007) to encourage their swimmer to get into the kick phase faster without the aid of the wall to gain propulsion. Interviews with coaches revealed that such techniques aimed to further enhance explicit (declarative) cognitive processes such as athlete awareness and understanding of movements, in contrast with research recommendations that constraints should be designed and associated with more implicit (non-declarative) learning pathways (Brocken et al., 2020). This blurred line between explicit and implicit learning manifested in coaches adopting prescriptive instruction and feedback methods alongside the use of constraints during practice (e.g., “the principle of this drill is I’m trying to get you to kick your legs straight away when you’ve turned” – Powell et al., 2021, p1106). Furthermore, the coaches felt that regardless of how a skill is learned (with or without explicit skill knowledge) it should be demonstrated through verbal feedback and reflection from the swimmer (e.g., “so we’ll try and make a difference, but could he actually feel there had been any difference and then feedback for myself on why they were observed as well” – Powell et al., 2021, p. 1106). Based on these insights, part of the current focus of my work with BPS involves experimenting with the role of constraints as a means of replacing or reducing reliance on explicit instruction and allowing the athlete to explore the movement more freely before reflection and dialogue with the coach.

In summary, my analysis of coaching practices at BPS served to highlight the gaps between skill acquisition research and applied practice. In doing so, it provided not only an understanding of the coaches’ approaches and perspectives, but a framework through which to harness their experiential knowledge.

5.3 Individual athlete interventions

Part of my role is to work in conjunction with the biomechanists, coaches, and athletes to identify and help implement approaches which might facilitate the learning and performance of technique changes or refinements. Here, I provide four examples of technique-related goals identified by coaches and/or the biomechanics team with four different athletes and the specific learning strategies I explored with each.

As described above, these case studies provide some of my reflections on instances where I’ve had the opportunity to work directly with one athlete for a full session. As is often the case in my experience in high performance sport, many of these instances occur (in reality) with little planning. Rather, opportunities arise within sessions for a coach to spend more time dedicated towards one athlete, sometimes if multiple staff are ‘on deck’, or only a few swimmers are in the session (and I am there too of course). In this way, these interventions are not thoroughly systematic in their execution, but instead represent more common occurrences and challenges in the role, where, as an applied practitioner you are often tasked with thinking quickly on your feet. Indeed, for some coaches ‘skill acquisition’ is seen as the domain of the coach (see also Steel et al., 2012; Williams & Hodges, 2023), and if it is not, or someone else professes to be knowledgeable in this area, they want to see evidence of that on demand (this is not always the case and not with all coaches). At the same time, the demands and logistics of the sport make more systematic/controlled or long-term interventions with athletes very challenging, which is in-part what contributed to the aims of the next chapter (study three) and coach education in skill acquisition. If the field *were* to limit itself to documenting only carefully controlled interventions, it limits itself in sharing stories of success and its value as a discipline.

The athletes here were all internationally classified and had competed at international level representing Great Britain. Two were Paralympic champions. Three of the athletes had physical impairments predominantly impacting leg function, and one athlete was intellectually impaired, impacting learning capability.

1. Athlete A (referred to here as Max): ‘Spotting the wall’
- *Constraints-based learning*

Max was struggling with his approach to the wall on both turns and finishes. Specifically, on each turn (in this case on the freestyle stroke) the athlete aims to initiate the tumble (somersault turn) immediately from the last stroke (i.e., as the hand enters the water it pushes through and the head follows round in rotation until the athlete’s feet touch the wall). Similarly for finishes, the athlete should aim to finish (i.e., touch the wall with their hand) as the hand enters the water at the front of the stroke. Thus, in both cases the athlete aims to minimise any *gliding* through the water to reach either the optimum distance from the wall for the turn or to touch the wall for the finish. Specifically, gliding should be avoided because it is associated with the athlete decelerating or not maintaining their speed. If the athlete is gliding too often, it can typically be attributed to the athlete failing to ‘spot the wall’ (i.e., see where they are in relation to the wall when it’s approximately 5-10 metres away) and adjust their stroke accordingly. This was the case with Max.

To try to help with this, I worked with the coach to design a session based around the concepts of implicit learning and variability. In particular, I asked the coach to manipulate the *task constraints* involved in the freestyle stroke (see Newell & Jordan, 2007), whereby the goal in each attempt became to turn or finish leading with either the left or the right hand specifically, as instructed by the coach. For example, Max began by swimming four lengths of a 25 m pool (i.e., 3x turns & a finish) with instructions to turn “only off the left hand on each” (the finish was ignored initially).

With the goal of the task now solely to turn off a specific hand (and without any other focus around technique or target times), the athlete is guided towards finding the intended movement solution themselves (spotting the wall early enough to adjust the stroke accordingly) without any explicit or prescriptive instructions of how to do so.

The decision to try this technique was based on the key concepts of the approach. Specifically, swimmers describe the skill of 'spotting the wall' as an unconscious or automatic one (e.g., "you just *know* where you are on the stroke"; "you can feel it"). That this skill is ideally governed by automatic or implicit control processes makes intuitive sense given the complexity of the task. A split-second readjustment to the stroke must be made based on distance from the wall, approaching speed, and knowledge of your own stroke mechanics. The use of constraints and guiding the learner towards finding their own movement solution encourages acquisition via more implicit (or automatic) learning pathways through a reduction in the accrual of explicit skill knowledge (e.g., Brocken et al., 2020; Winkelman, 2017). Rather than a conscious process per se, the athlete's brain *self-organises* in response to the new external goal. Furthermore, explicit or prescriptive instructions on the fundamentals of the skill should not be necessary for a Paralympic Champion who has previously performed this skill well. In other words, rather than trying to bring the skill back into consciousness in this instance, i.e., an earlier stage of learning (e.g., Fitts & Posner, 1967), we would explore whether the skill could be (re)acquired at the automatic level, given the level of automaticity needed for this skill in the performance setting.

In the initial stages of the session, the level of task difficulty was already quite high, as evidenced by the athlete's failed first attempts. As such, more complex instructions on task manipulation at this stage (e.g., "turn off the left, then the right, then the left hand") may have produced a level of difficulty which would exceed the optimum level of challenge for learning (e.g., *Challenge Point Framework*, Guadagnoli & Lee, 2004). The option to increase task complexity in this way provided the opportunity to incorporate variability into the session contingent on the level of performance displayed by the athlete. More specifically, when the athlete began to execute the turns correctly under more simple conditions (e.g., "right-right-right"), this was taken as an indication that the skill was becoming more automatic and thus less cognitively demanding. As such, we began progressively to increase the complexity of the task (e.g., "left-right-left", or "left-left-right, then finish on the left"), to bring the level of cognitive effort required back up to a more optimal level for learning (see Figure 5.2 for a visual representation of this concept).

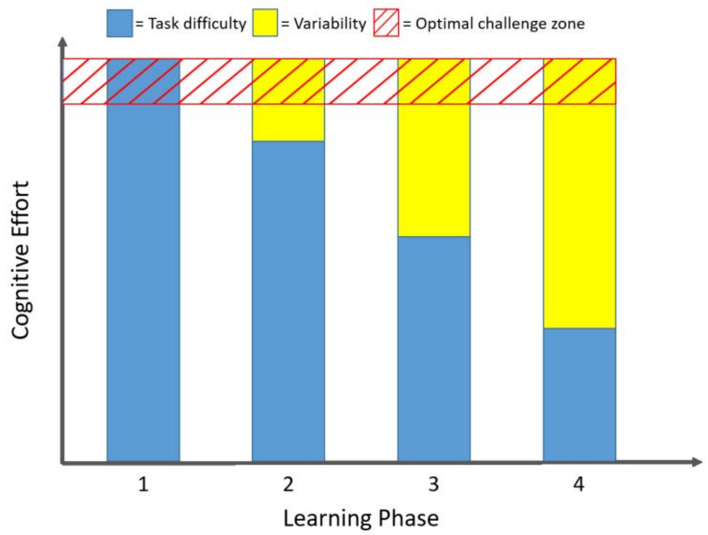

Figure 5.2. A representation of how variability can be used to bring the level of cognitive effort required to perform a task back up to an optimal level of challenge for learning.

These manipulations in task difficulty could be considered a form of *within-skill variability* (i.e., discernible variations of the same overarching skill; Buszard et al., 2017).

Following the apparent success of the first session and once the athlete began to demonstrate more consistent proficiency in spotting the wall, we then also began to incorporate elements of *between-skill variability* into the sessions (Buszard et al., 2017). More specifically, after shorter sets using the task constraint and various levels of within-skill variability, the coach would then change the focus of the session entirely (e.g., work on distinct skills like freestyle or backstroke technique) for a few sets before then moving back to the 'spotting the wall' set. This approach served to facilitate the consolidation of the new skill in memory and in turn the adaptability of the skill to other contexts such as competition (Wright & Kim, 2019). Figure 5.3 provides an illustration of this periodisation process with an adapted version of the Periodisation of Skill Training ('PoST framework'; Otte, Millar, & Klatt, 2019). The PoST framework can be useful as a loose guide for the periodisation of skill change over either micro or macro training cycles (weeks, months, or even single sessions) depending on variables such as the extent of skill change, athlete skill level, or skill complexity. In this instance, Max was already proficient in the movement coordination phase (understanding the movement fundamentals of the skill – i.e., *how* to turn or finish), so we were able to begin the skill change at the within-skill or movement variability phase of periodisation, and move relatively quickly to more complex, between-skill variability training. Performance-based training or competition were used as an indication of skill learning and transfer. In a follow-up meeting with the coach around six weeks after the first session with me, the coach had said they continued these sets roughly twice weekly for four weeks, and he had seen a noticeable improvement in glide reduction on Max's approach to the wall.

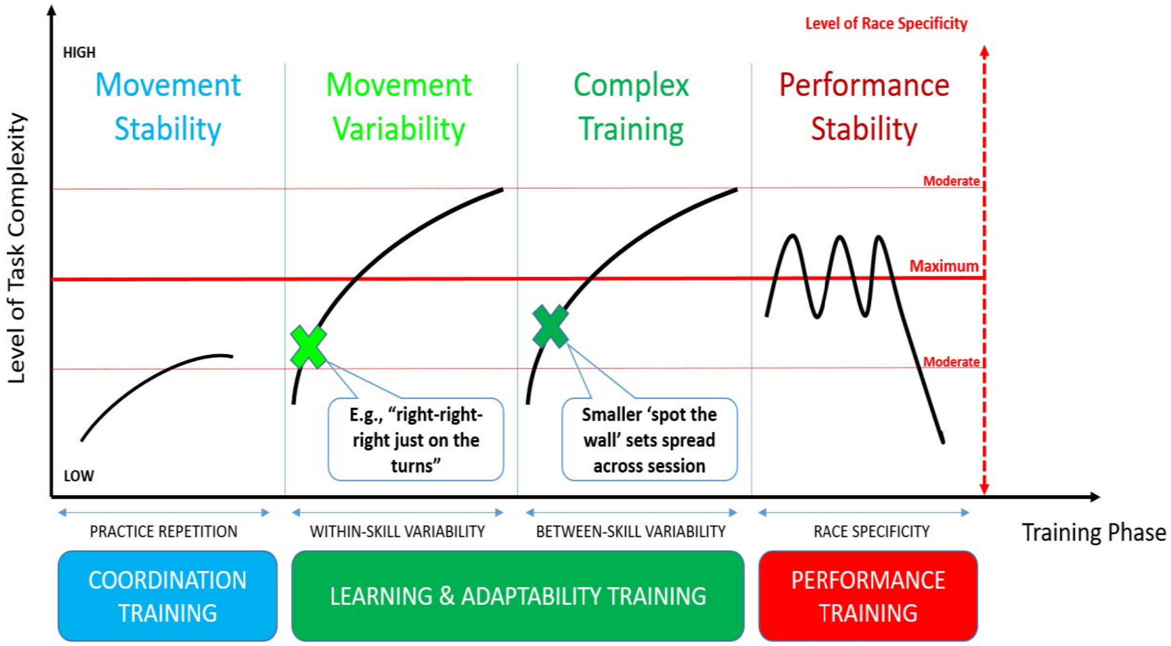

Figure 5.3. Periodisation of Skill Training ('PoST framework'), adapted from Otte, Millar, and Klatt (2019). Examples of the different stages of 'spot the wall' training are plotted.

A key feature of this intervention is that it is high in *representative learning design* (Pinder et al., 2011). In particular, the efficacy of any constraints-based approach to learning is thought to be contingent on the extent to which the practice task is representative of how that skill is performed in a performance setting (*functionality*), and the degree to which the information in the training environment is representative of the information available to the athlete in the performance context (*action fidelity*). As the practice task involved only a manipulation of the task *goal* (i.e., turn off the left or right hand), the skill itself (the tumble turn or finish without any glide) is performed in the same way as in competition, and the information from the environment (e.g., the water, lane ropes, and wall) is also the same as in the competition setting.

2. Athlete B (referred to here as Sean): 'Pacing'

- *Errorless learning*

Sean was having difficulties pacing his event - the 400 m freestyle - effectively. In particular, rather than swimming each length of the swim consistently in the optimal balance between speed and the conservation of energy, Sean was often producing inconsistent lap times – swimming some segments too fast or too slow. This tendency was not restricted to competition, but also often occurred during training sessions, where certain pacing drills were designed to facilitate Sean's general ability to pace. I had noticed that the coach was typically designing sets involving very specific (difficult) target lap times down to the tenth of a second. If and when Sean failed to achieve the target time, or even get relatively close, the athlete would become visibly frustrated, and this often seemed to impact the rest of the set. My suggestion to the coach was that we could experiment with a set based around the concepts of *errorless learning* – an approach also under the implicit learning umbrella (e.g., Poolton & Zachry, 2007).

Errorless learning refers to a technique which involves keeping errors to a minimum during practice (not removing them completely as the name suggests). It is thought that when a learner makes too many errors during practice, they begin to engage more conscious motor control processes, constructing and testing movement hypotheses in an attempt to correct their mistakes, and in turn creating a buildup of explicit skill knowledge detrimental to learning and performance (Lam, Maxwell, & Masters, 2010). As such, reducing the number of errors can help reduce this propensity and promote a more automatic mode of movement control. One way to facilitate errorless learning in practice is to design a set which moves progressively *from easier to more difficult* targets (Capio et al., 2013; Maxwell et al., 2001; Poolton, Masters, & Maxwell, 2007). For Sean, I recommended to the coach that we design a set initially which involves moving progressively from easy to more challenging target time *windows*. For example, the first set could comprise 10x100 m swims. If the optimum 100 m pace for this athlete (as the first 100 m of a 200 m race) was 60 seconds, the target for the first 100 m attempt could be a six second window (i.e., 57-63 seconds; *easy*). The next 100 m target time window would be slightly more challenging (e.g., 57.2-62.8 seconds; 2.6 second window). This would then progress all the way to the final 100 m (e.g., 59.8-60.2; 0.4 second window). If the athlete failed to achieve a target time window they would regress back to the previous window.

From the first errorless learning set with Sean, the benefits were very apparent. Rather than *errorful* pacing sets, characterised by frustration and consciously controlled movements through the water (indicated by “more erratic strokes”, “slapping the water”, or “lacking smoothness” as observed by the coach), the athlete was happier, significantly more successful even in the more challenging trials, and seemingly acquiring more of an unconscious *feel* for how to pace the swim (Sean wasn’t able to verbalise why the success rate had gone up). From there the coach began to explore variations on the sets, sometimes using fewer progression stages, or incorporating the principles of errorless learning into the training of other skills. The coach also reported that athlete Sean’s pacing had improved during ‘stand up’ or race simulation sessions. Importantly for the athlete, Sean was happier and feeling more confident about their ability to pace.

3. Athlete C (referred to here as Becky): ‘Backstroke arm entry & hip rotation’

- *Analogy learning, amplification of error & variability in practice*

As opposed to athletes A and B who were based at the National Performance Centre in Manchester, Becky was based remotely and had visited the Centre for biomechanical analysis. Following analysis of athlete Becky’s backstroke swim, two technical changes were identified and recommended to the athlete and their coach to improve performance. Working in conjunction with the biomechanist and immediately following the analysis, I first spent some time one-to-one with the athlete before supplementing the biomechanical recommendations with skill acquisition recommendations to the coach of how the technical changes might be facilitated in practice.

The first recommended technical change concerned the athlete’s arm entry. Specifically, in the backstroke swim the arms should enter the water in a straight line above the head, thereby maximising propulsion from the arm through the water. For Becky, the left arm entry was performed correctly, but the right arm was entering the water at an angle (150 degrees from the long axis of the trunk rather than 180 degrees) and so the path over which the arm could gain propulsion through the water was reduced.

Becky is internationally classified as an S14 athlete, which denotes an intellectual impairment. This impairment is typically characterised by a deficit in short-term (working) memory, with a relative preservation in implicit or long-term memory processes (Vicari, 2004). As such, intellectually impaired athletes can struggle retaining and processing information in the form of explicit coach instructions (Burns & Johnstone, 2020; Van Biesen et al., 2023). Analogies or metaphors can be used to promote implicit learning (Masters et al., 2019), as they serve to camouflage explicit movement information by coding it symbolically. In this way, provided that the athlete is familiar with the visual representation associated with the analogy (e.g., "kick like a dolphin"), it can be understood (processed) at an unconscious level (implicitly), and working memory capacity is, to some extent, bypassed for more long-term, procedural, or implicit memory mechanisms. I asked Becky to think of their arms like the hands on a clock face. Ideally, both arms should be entering the water at 12 o'clock (see Figure 5.4). I explained to Becky that currently the left arm is entering the water at 12 o'clock, but the right arm is entering the water at 11 o'clock, and that what this meant was that she was, "*giving away one hour per stroke to every one of her competitors in the race*". I further emphasised that, "*your competitors would be very happy to know you're giving them an hour on every stroke*". This gave the analogy additional layers of meaning and associative connections (relating to what her competitors think) which serve to facilitate long-term memory consolidation by creating a more elaborate memory trace (Craik & Tulving, 1975; Eysenck, 2014). I could immediately see that the athlete responded to this approach to language positively, both through observable performance and athlete feedback, where after each trial Becky would refer to how it felt "*not giving that hour away*".

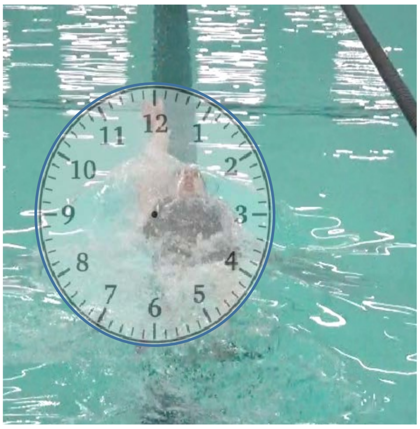

Figure 5.4: The clock face analogy on backstroke for athlete AC. The right arm should enter at 12 o'clock as indicated. Athlete AC's arm was entering at 11 o'clock.

In addition to the arm entry, Becky was also over-rotating her hips on the backstroke (i.e., the hips should roll or rotate during the backstroke, but Becky was over-doing it). To address this, and again taking the athlete's intellectual impairment into consideration, I adopted a technique referred to as the *method of amplification of error* (MAE; Cesari & Milanese, 1995; Milanese et al., 2008, 2016). In contrast to the concept of errorless learning described above, MAE is predicated on the assumption that individuals can learn to correct their own movements through an exploration of their mistakes. In particular, the technique involves exaggerating the error the athlete is making ('poor performance'), before contrasting it with the new corrected technique ('good performance'). In this way, MAE is thought to be useful in the early stages of technical skill correction as a means of destabilising well ingrained, automated movement patterns (Carson, Collins, & Kearney, 2017), as well as providing the athlete with reference points for subsequent movement exploration. To help the athlete in the MAE approach, I again made use of analogy learning instructions. Specifically, I asked the athlete to imagine their belly button was a laser pen pointing towards the ceiling. I told Becky to imagine that currently when the backstroke is being performed, the laser is moving side to side right across the width of the ceiling. On the first practice attempt I instructed Becky to now execute the backstroke by attempting to point the laser *even further* side-to-side (to the walls on the side of the pool on each side) on each rotation (exaggeration is key here – even if that much rotation isn't fully achievable). I also provided a visual demonstration of what I meant. This helped the athlete get a greater *feel* for the impact of hip over-rotation and bring the automated movement back into conscious control. On the second trial I asked Becky to now attempt to keep the laser pointing between the markings on the ceiling in line with the lane ropes (good performance). We then switched between the contrasting poor-good performance trials every 50 m (the length of the pool) in a 300 m swim.

The additional intended benefit of this approach with an intellectually impaired athlete was to further reduce reliance on working memory. More specifically, in addition to the use of analogy learning to promote the use of more long-term implicit memory processes, the MAE would allow the athlete to get feedback from multiple sensory inputs (see Burns & Johnstone, 2020). The efficacy of this approach was immediately observable, as Becky began to feedback to me that she was starting to feel how, "*not* *giving away that hour was affecting the rest of the stroke… my hips aren't rotating as much and my kick also feels better*".

Following a successful trial of these approaches with Becky, I made some further recommendations to her coach around an initial periodisation plan for implementing the skill changes. More specifically, alongside the use of consistent analogies and metaphors in instruction to reduce cognitive load, I reinforced to the coach that the rate of learning typically occurs more slowly for intellectually impaired athletes (Burns & Johnstone, 2020; Van Biesen et al., 2023). That is, the process of moving from consciously controlled to more implicit movements is a more gradual one, and the coach should carefully consider the level of cognitive challenge involved for the athlete. In this way, I suggested that the MAE technique could be used at the start of sets to reinforce the 'good-bad' contrast and increase feedback for the athlete, but that the athlete could then stay in low variability (blocked or repetition) practice performing the 'good' technique for longer. More complex training (see section 3 of Figure 5.3) could then be introduced more gradually with shorter gaps between different skills or sets initially.

The efficacy of this intervention was (gratefully) evidenced to me upon athlete Becky's return to the NPC in Manchester a couple of months later. In particular, Becky approached me immediately to give unprompted feedback on their progress. I promptly made a note as this kind of feedback is invaluable as a practitioner:

"My backstroke has really improved… it was the whole thing about understanding the clock face and what you mean. I'd really like to work with you on my breaststroke now, if (biomechanist's name) can look at what I need to do and you can explain it to me that would really help".

4. Athlete D (referred to here as Jack): 'Freestyle arm entry & pull'

- *External focus of attention*

Jack is internationally classified as an S6 Para swimmer. Specifically, Jack was involved in accident approximately ten years ago which resulted in a severed spinal cord and paralysis from the waist down. Since joining the British Para Swimming team around eighteen months ago (since the time of writing), Jack has made relatively little progress on their freestyle technique. The NPC Head Coach was becoming concerned and had approached me for assistance. The particular concerns centred on Jack's ability to take on instruction. Having observed Jack several times receiving instructions myself, and having also myself assisted in coaching the athlete, I had suspected that he may also have, or have suffered during his accident, a concurrent neurological condition which was impairing his ability to learn (this had not been diagnosed). In particular, Jack appeared to struggle processing verbal or explicit instructions and exhibited extremely limited short-term (working) memory capacity. As an example, even as few as two pieces of basic instruction prior to skill practice were often too many, and one would be immediately forgotten. Sometimes one would be forgotten! (It should be noted that Jack is a particularly focused and dedicated athlete, so forgetfulness was not a symptom of concentration issues). Furthermore, when instructions were understood and remembered in the short-term, any information or changes in technique were rarely, if ever, retained in the next session. In other words, not only was Jack exhibiting limited working memory capacity, but their ability to consolidate or transfer information from short-term to long-term (implicit or procedural) memory mechanisms appeared to be severely impaired. The NPC Head Coach and I had the opportunity to spend a session with Jack and explore this further.

In relation to his freestyle technique, Jack had an inefficient stroke in that his elbow was entering the water first as opposed to his hand, and once the arm was submerged it was extending out and upwards rather than immediately pushing downwards into the stroke (see the top two images in Figure 5.5). The coach began the session with Jack by communicating instructions using very simple explicit and prescriptive cues. From my observations, Jack appeared visibly to be struggling to process the information, and this was reflected in the swims, which not only weren't improving at all technically, but now looked even more mechanical and disjointed. After each practice attempt, the coach replayed the swim to Jack through a video recording on the coach's phone. Jack appeared to respond well to this during feedback, visibly more at ease and requesting to see more replays. This supported my theory that Jack may have a deficit in processing verbal information, as processing visual information utilises distinct neural regions. Nevertheless, instructions still failed to transfer to the pool. Interestingly, the technique in the pool had not changed at all, but Jack commented that they felt they were executing the movement as instructed. I asked the coach to instruct Jack to exaggerate the movement, to the extent that their arms were entering the water pointing vertically down at the floor. Jack demonstrated the movement correctly to check they had understood, then as soon as the swim began, he reverted to exactly what he had done previously. Amazingly, Jack believed his arms were pointing towards the floor when in fact they were still pointing forwards. In addition to a potential deficit in working memory, this indicated Jack had little somatic awareness, and/or was unable to process proprioceptive information effectively. The potential benefit of more prescriptive, *internal*, or bodily focus cues in swimming is thought to operate as a function of congruence between coach instructions and subsequent proprioceptive task information or feedback (i.e., from the water; Gottwald et al., 2020). This was potential further evidence that the *form* of communication with the athlete needed to change.

After approximately forty minutes of one-to-one coaching nothing had changed. I suggested to the coach that we try to *externalise* the instructions. If Jack did have a deficit in working memory, and thus an impaired ability to process explicit information (a common characteristic in learning disabilities; Vicari, 2004), then external focus cues could be used to reduce the demands placed on working (explicit) memory and instead facilitate more long-term, procedural, or implicit memory processes (Winkelman, 2017; Wulf, 2013). I suggested to the coach that rather than focusing on the hand and elbow position specifically on entry into the water (*internal focus cues*), we could provide an external reference point. Specifically, I suggested instructing Jack that currently on each stroke as the arm enters the water, his elbow-to-fingers are pointing towards the starting block *above* the water on the other side of the pool. Instead, the elbow-to-fingers line should be, "*pointing towards the point where the wall and the floor meet at the other end of the pool*" (*external focus cue*). Jack immediately seemed at ease with these instructions and confirmed he had understood. The results were instantaneous (and quite shocking in contrast!). Technique had transformed on the very first attempt, and the hand was now entering the water first with a high elbow on recovery, and with arms immediately pushing down into the stroke (see bottom two images in Figure 5.5). Furthermore, the movements were *fluid* (vs mechanical), indicating a more automatic (implicit) mode of motor control (Wulf, 2013).

Perhaps equally as surprising as the immediacy of these effects, it appeared that the external cues had facilitated not just short-term performance, but long-term retention and transfer of skills (this had never happened previously with this athlete). In particular, during the next session, Jack mentioned straight away (unprompted) that the cues had really resonated and helped them to understand. The improved technique continued, and just five days later athlete Jack swam a personal best time in the 400-metre freestyle at a national event. He beat his previous personal best by 16 seconds! Jack's technique had transformed so much, and his time improved so dramatically, that this was a rare instance where one could be confident the improvement was a direct consequence of enhanced skill acquisition. The timing of this race and the ability to capture this impact was also quite fortuitous, as sadly due to personal circumstances Jack had to leave the team a short time after. Nevertheless, this had demonstrated to me (and the Head coach at the NPC) more than anything previously, the potential for skill acquisition in the applied setting. What produced the intervention was a synthesis between knowledge of skill acquisition theory and an understanding of the athlete, and it was this kind of work that led to the aims of the next study in the project – coach education in skill acquisition principles (chapter 6).

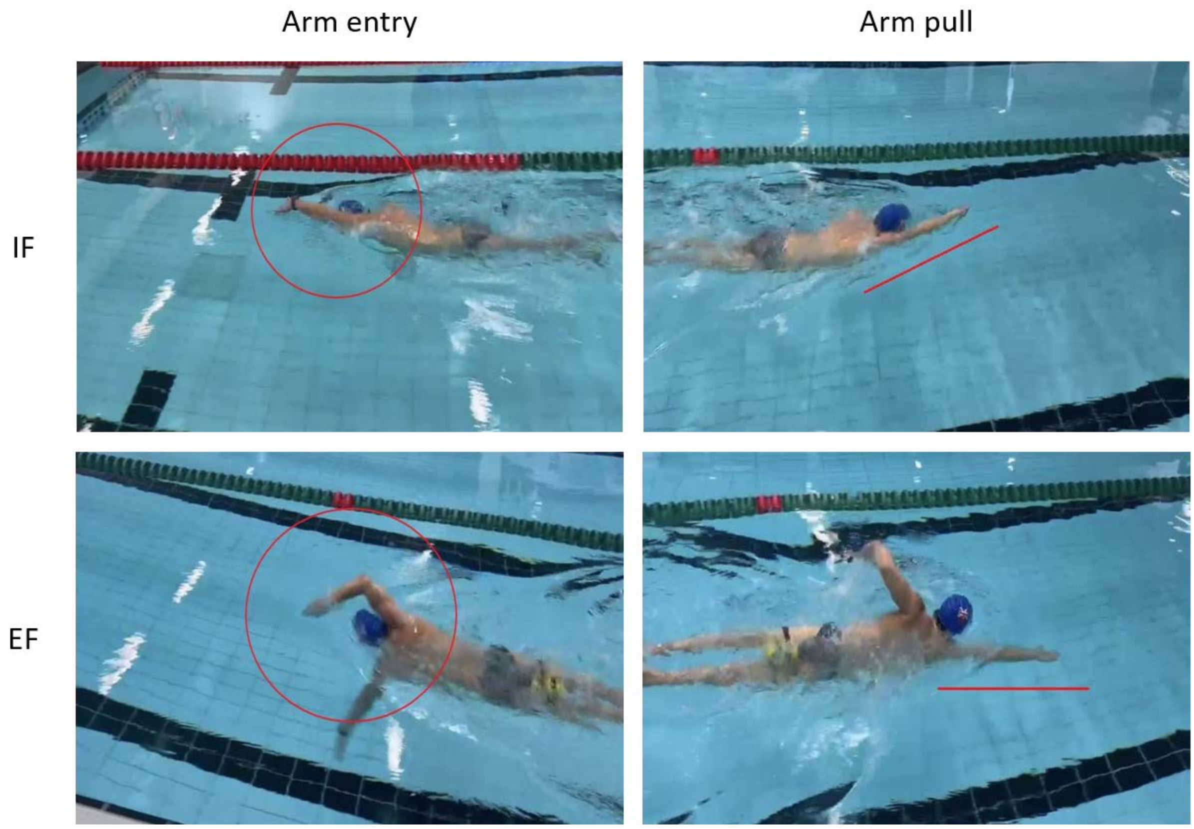

Figure 5.5. Effects of internal focus (IF) and external focus (EF) instructions for both arm entry and arm pull with athlete AD.

5.4 Tokyo 2020(ne) relay race camp

Six weeks prior to the Tokyo 2020(ne) Paralympic Games I was entrusted by the Head Coach of British Para swimming with the role of Performance Communication Lead during a three-day relay race training camp at the National Performance Centre in Manchester. The sole aim of the training camp was to improve the swimmers' changeover times. During a relay race, a swimmer cannot break contact with the block until the previous swimmer's hand (the teammate) has touched the wall. As such, the waiting swimmer must watch their teammate's stroke closely and follow the hand into the wall, attempting to time the initiation of the dive movement such that their feet leave the starting block in as short a time after the hand touch as possible. Hundredths of a second could be the difference between gold and silver. Throughout the camp, I worked closely alongside two biomechanists who filmed and timed every changeover and were able to provide me with instant feedback of performance upon request.

The training camp comprised six sessions over the course of three days – a very short period of time to attempt to facilitate long-term learning of skills. Moreover, each swimmer would only attend a maximum of three of these sessions, and each swimmer would only get the opportunity to practice a changeover with another swimmer a maximum of 4-5 times (swimmers were often practicing changeovers with more than one teammate as the relay race teams had not yet been finalised). In addition, with the Paralympic games so close, and with so many swimmers and coaches typically based in different clubs across the country coming together for the first time, the environment would be somewhat chaotic and highly pressurised. With these time and practice constraints in mind, I had to utilise a range of skill acquisition principles to maximise the opportunities for learning. In particular, I wanted to maximise the swimmers' opportunities to *explore* movement solutions for themselves, and in turn to encourage learning through deeper *levels of processing* (see Craik & Lockhart, 1972), such as problem solving and the creation of meanings, associations, and reference points. At the same time, the learning strategy needed to be one which was amenable to athletes of all ages and disabilities.

Central to my approach was the use of a visual reference for all athletes (visually impaired athletes were not part of this camp), with associated simple cues, and displayed on a large wall next to the pool (see Figure 5.6). Specifically, the visual reference resembled a traffic light system, whereby amber represented a ‘safe’ changeover time – one that would not get a swimmer disqualified but was not particularly fast. Green represented a ‘good’ changeover time, i.e., one which was fast but not so fast that it risked disqualification. Red represented a ‘flyer’, i.e., a disqualification because the swimmer had left the block before their teammate had touched the wall. And finally, an additional purple section which represented a ‘risky’ changeover, i.e., one which was very fast but a little too close to disqualification for liking.

From my time in swimming, I have discovered that one critical factor in learning and performance concerns a swimmer’s level of proprioceptive awareness (i.e., their ability to perceive the location, movement, and timing of parts of the body) (see also Gottwald et al., 2020; Toner & Moran, 2014). The level of proprioceptive awareness among swimmers (and presumably people in general) appears to vary considerably (an extreme example could be seen in Jack described above, who thought he was pointing his hands towards the floor during freestyle when he was in fact pointing his hands towards the wall in front). This may also be amplified among Para swimmers with a range of physical and neurological impairments. As such, a key part of this training camp involved facilitating the swimmers’ ability to calibrate their proprioceptive awareness with their subsequent performance on the changeover (i.e., a swimmer may be leaving the block much faster or much slower than they think – so part of the goal was to enhance the accuracy of this perception).

To achieve this, each swimmer’s first changeover attempt was essentially a ‘free go’ at trying to execute a ‘good’ changeover. Following the changeover attempt, the athlete would feedback to me first where they thought the changeover would be positioned on the traffic light system on the wall (problem solving). I would then mark this down and then make a second mark illustrating where they were actually positioned. The swimmers’ perception accuracy varied widely, ranging from some swimmers who were quite accurate, to others who thought they had executed a ‘safe’ changeover when in fact they had been disqualified. Nevertheless, the swimmers now had some idea of what they were doing versus what they thought they were doing and could adjust accordingly. With this reference point in mind, I then wanted to provide additional reference points on both extremes of the traffic light system. In particular, the swimmers were instructed to exaggerate or amplify their performance by executing a ‘very risky’ changeover and a ‘very safe’ one. Again, they would feedback to me first on each attempt.

The purpose of this learning strategy was not only to encourage the swimmers to explore their perceptual-motor landscape more freely, but to provide new intrinsic feedback, stimulating the functions of *perceptive categorisation*, and in turn enhancing error detection capability (Milanese et al., 2016). This forced exaggeration is also a form of within-skill variability, providing the swimmer with useful comparisons between the exaggerated changeovers and their initial and subsequent attempts, thereby facilitating their ability to modify movements accordingly (Shea & Morgan, 1979). Furthermore, the exaggerated targets guide the learner towards focusing their attention on movement *effects* rather than the movement itself (i.e., an *external focus of attention*; Milanese et al., 2016). Not only was it hoped that this would facilitate learning and performance, but in generating a more external focus for the athletes, cognitive demands and explicit processing requirements would be reduced for those athletes with intellectual impairments (Wulf, 2013). In other words, the approach was also an inclusive one. Following these exaggerated changeovers and knowledge of results, the swimmers were instructed to use these reference points to attempt to achieve a ‘good’ changeover.

Some additional learning strategies were also incorporated throughout the camp. Firstly, feedback was mostly restricted to changeover times, and more specifically to where athletes were placing on the traffic light system, rather than any additional feedback on, for example, diving technique – an approach referred to in skill acquisition literature as *bandwidth feedback* (Sherwood, 1988). This bandwidth feedback was accompanied by questioning the athletes around how times might be improved – a technique designed to increase perceived self-control and enhance learning through deeper information processing (Janelle et al., 1997). The combination of bandwidth feedback and questioning has previously been shown to be an effective learning strategy in swimming coaching (Chambers & Vickers, 2006). Finally, peer-to-peer learning was encouraged throughout the camp (see Jenkinson, Naughton, & Benson, 2014). Specifically, as only one changeover was practiced at a time, the rest of the swimmers in the group were encouraged to watch each other’s practice trials and to discuss between themselves if they could identify any potentially effective strategies. Overall, the camp was a very successful one, with all the swimmers improving their changeover times, and these improvements (vs. the initial practice attempts) held in the Paralympic Games, where one of the British teams won Gold in the mixed relay. With so many other variables in play, it is difficult to put any of that success down to the camp, but some of the athletes did feedback to me that they had really enjoyed the training, and that by the end they had a better ‘feel’ for their changeovers, which was particularly pleasing.

Figure 5.6. Traffic light visual cue system used to aid feedback and learning during the Tokyo 2020(ne) Paralympic relay race camp.

5.5 Challenges and summary

Within this chapter I have presented several examples of working specifically with athletes on the BPS team. While this is of course an essential part of working as a skill acquisition practitioner, as well as an invaluable learning experience, it comes with many challenges. A considerable challenge is that while I may be able to identify effective learning strategies for some athletes, I am not their coach, and it is their coach who designs and delivers training twice a day, six days a week. Effective implementation of many of the strategies I’ve described, or at least the justifications for their use, require some understanding of the related processes. While some coaches at BPS display an intuitive grasp of skill acquisition principles, approaches are not underpinned by an understanding of the key concepts of the approach (Pinder et al., 2022; Powell et al., 2021 – chapter four). Techniques or approaches are in lots of cases quite different from what a coach might normally do. Indeed, *any* change in approach to coaching is significant when you've been coaching a certain way for 10 or more years. Moreover, skill acquisition is typically viewed as the domain of the coach (Steel et al., 2012; Williams & Hodges 2023). Getting buy-in from coaches to facilitate understanding of skill acquisition principles is less challenging (although still very challenging) when you work daily with a coach. However, most coaches at BPS are based remotely at different clubs around the country. Making recommendations on how to train an athlete based on one or two interventions is a big ask even of the most open-minded coach, particularly as ecologically valid research in the elite athlete sample to evidence the impact of skill acquisition is relatively scarce (Buszard et al., 2017; Wulf, 2013). These logistics also presents significant challenges for monitoring athlete progress beyond feedback from the athlete or coach.

Additional challenges are present in Para sport. In particular, each individual athlete disability, whether physical, visual, or intellectual, has unique implications for movement capability and/or learning. From my time at BPS, I have learned that the athletes are incredibly empathetic towards a lack of understanding of their disability, and the best approach is usually to have very open discussions around learning and communication preferences. However, disability implications for practice are so nuanced it can take a long time to understand an athlete well. Furthermore, for athletes with visual or intellectual impairments especially, trust is often required in the relationship which is only built over time. Again, those best positioned are the coaches themselves. I felt therefore that what was needed, particularly in a programme such as this where coaches are based remotely around the country, was development of the coaches' understanding of skill acquisition principles in a way which also harnessed their existing knowledge of the sport and of the athletes, such that they were better able to identify and implement more effective learning strategies (with additional guidance) as they saw fit. It was this endeavor that led to the next study (chapter 6), and coach education in skill acquisition.

In summary, it is hoped that in presenting some of my experiences, and part of my journey from novice to skill acquisition practitioner with the British Para Swimming team, I provide a small contribution to a framework of understanding which might help other prospective practitioners and facilitate future collaborations with coaches and athletes. The opportunities for skill acquisition practitioners to be embedded in an elite level sport are scarce (Dehghansai et al., 2020; Pinder & Renshaw, 2019), and as much insight should be gleaned from these experiences as possible. The examples I have presented here were of course interspersed by many examples which were not so effective, but I was afforded perhaps the even rarer opportunity to be facilitated by an open-minded and generous team who allowed me the chance to learn from my mistakes, and for that I am eternally grateful.

CHAPTER SIX

6. Study Three: A six-week coach education intervention enhances the skill acquisition knowledge and practice design of coaches in elite level swimming

6.1 Introduction

The skill acquisition practitioner has been described as a sport scientist who examines the theories and processes underpinning motor learning and control and works closely with coaches and athletes to help translate research into practice (Williams et al., 2012). Despite potential for skill acquisition to inform coaching and enhance athlete development, there is a disconnect between scientific theory and applied practice (Anderson et al., 2021; Powell et al., 2021 – chapter four). At the same time, there remain significantly fewer skill acquisition practitioners collaborating with coaches than there are practitioners from any other sport science field (Dehghansai et al., 2020; Williams & Hodges, 2023). To bridge theory and practice, researchers have called for more examples of successful collaborations between skill acquisition practitioners and coaches in sports settings (Williams & Hodges, 2023). In response to this call, here we document two case study examples of such collaborations in elite Para swimming.

A major challenge for skill acquisition practitioners is to identify the gaps between existing research and current applied practice to provide context to begin to impact learning design (Pinder et al., 2022 – chapter five). In our investigation into coaching practices at British Para Swimming (Powell et al., 2021 – chapter four) discrepancies were highlighted in relation to three established lines of enquiry in skill acquisition literature, (i) *focus of attention*, (ii) *contextual interference*, and (iii) *implicit learning*. Consequently, the focus on these skill acquisition principles will now form the basis of the design, delivery, and evaluation of a four-week coach education intervention for elite coaches on the British Para swimming programme.

Focus of attention research reports that performance (i.e., immediately observable, short-term behaviour) and learning (i.e., long-term retention and transfer) of motor skills are enhanced as a function of encouraging athletes to focus their attention *externally* towards the environment or movement effects, as opposed to focusing attention *internally* towards component parts of body movements (Wulf, 2013). This effect has been explained through the constrained-action hypothesis, which suggests internal focus generates conscious control processes that disrupt the automatic processes typically governing skilled movement. In contrast, external focus facilitates automatic processes via neural self-organisation in response to the external goal (Kal, Van der Kamp, & Houdijk, 2013). In relation to swimming, research reports that external focus cues (e.g., ‘push the water back’) enhance performance relative to internal cues (e.g., ‘pull your hands back’) (Freudenheim et al., 2010; Stoate & Wulf, 2011). Research has also identified alternative focus cues thought to confer a similar learning benefit to external focus. For example, *holistic* focus cues conceptualise the *feeling* of the overall movement (e.g., ‘a *smooth* rotation’), in contrast to internal cues which direct attention to *component parts* of the movement (e.g., ‘*head tucked* on rotation’). In this way, holistic cues serve to code explicit (conscious) movement information kinaesthetically, thereby facilitating more automatic control processes (Mullen et al., 2015).

Contextual interference describes the inverse relationship between motor performance and learning as a function of practice scheduling. Specifically, repetition or ‘blocked’ skill practice (e.g., AAA BBB CCC) improves performance, while task-switching or ‘random’ practice (e.g., ACBABCACA) enhances learning (Hodges & Lohse, 2022). This learning benefit through practice variability is explained via cognitive mechanisms which operate as a function of switching *back and forth* between skills or skill variations involving either the repeated (re)construction (Lee & Magill, 1983) or elaboration (Shea & Morgan, 1979) of memory traces. The efficacy of the contextual interference effect in sport remains under-explored, and literature emphasises the importance of contributing factors such as relative task difficulty and representative learning (e.g., Czyż & Coker, 2023). Acknowledging such factors, Porter et al. (2020) reported the learning benefit of variable (vs. blocked) practice scheduling in basketball shooting.

Implicit learning refers to the acquisition of skills in the absence of explicit information about how the skill should be performed (Masters & Maxwell, 2008). This is contrasted with explicit learning, where acquisition is accompanied by a conscious understanding of skill rules. Findings indicate implicitly learned skills are less susceptible to performance breakdown (or ‘choking’) under pressure, as attempts to consciously control or ‘reinvest’ movements are inhibited by lack of access to explicit skill knowledge (Masters & Maxwell, 2008). Consequently, performance is reliant upon more adept automatic (or implicit) control processes. In the sport or performance context, metaphor or analogy learning cues have been shown to facilitate implicit learning. Specifically, analogies are thought to camouflage explicit movement information by coding it symbolically. In this way, ‘chunking’ allows analogies to carry rich information while requiring fewer working memory resources (Andy, Wong, & Masters, 2017). In swimming, the adoption of a more automatic mode of motor control as a function of analogy instructions was demonstrated by Komar et al. (2014), who reported analogies improved movement efficiency during the underwater phase of the breaststroke.

In our analysis of coaching practices at British Para Swimming in relation to these learning principles (see Powell et al., 2021 – chapter four), we reported that in contrast to recommendations of best practice, coaches emphasised predominantly internal focus cues, incorporated relatively low levels of variability, and utilised mostly more traditional explicit approaches to coaching. Interviews revealed coaches had no formal knowledge of skill acquisition principles, which is perhaps unsurprising given the lack of skill acquisition information or guidance in formal swimming coach education or certification resources (e.g., Scottish Swimming, 2016). The findings then provided a framework for subsequent interventions with coaches at the National Performance Centre and facilitated the skill acquisition practitioner’s ability to influence coaching practice and bring learning strategies more in line with theory-informed approaches (see Pinder et al., 2022 – chapter five).

In previous examples of successful skill acquisition interventions, changes to practice design have been implemented by embedding a skill acquisition practitioner in the daily training environment – an approach suggested as necessary to develop appropriate working relationships and sport-specific knowledge (Pinder & Renshaw, 2019; Dehghansai et al., 2020). However, many Olympic and Paralympic organisations, including British Para Swimming, operate on a de-centralised programme, where most coaches and athletes are based remotely in clubs across the home nations. In this context, embedding a skill acquisition specialist in the daily training environment is not possible.

A potential solution to address barriers to the integration of skill acquisition expertise across such programmes lies in coach education. However, formal education processes, such as coaching workshops, have been shown ineffective in changing practice (Stodter & Cushion, 2014), and coaches report a preference for learning 'one-to-one' (Fullagar et al., 2019) and informally via experiential learning (Greenwood et al., 2014).

To this end, the current study explored the effectiveness of a coach education intervention which acknowledges these learning preferences. Specifically, in a follow-up to our practice analysis (Powell et al., 2021 – chapter four), two senior coaches from British Para Swimming with no knowledge of skill acquisition principles participate in a one-to-one educational approach conducted by a skill acquisition practitioner with experience in the sport. Emphasis was placed on developing the coaches' understanding of the theory underpinning focus of attention, contextual interference, and implicit learning, and encouraging coach experiential learning between sessions. In this way, it was hoped coaches will be facilitated in harnessing their own experiential knowledge in their approach to practice design and begin to identify and implement learning strategies more aligned with the scientific recommendations of best practice, when and how they see fit.

6.2 Method

6.2.1 Participants

Two experienced male ASA level 3 qualified swimming coaches were recruited to take part in the study. Coach 1 (C1) was a senior coach from the British Para Swimming (BPS) World Class Programme and was part of the team at the Tokyo Paralympic Games in 2021. Coach 2 (C2) was a national level Para swimming coach with experience of coaching several internationally classified Para swimmers and Paralympic medallists through the talent development pathway. As part of the current analysis, C1 coached a non-disabled 16-year-old nationally competitive male swimmer during pre-intervention, and another non-disabled 16-year-old nationally competitive male swimmer during post-intervention. C2 coached an experienced 20-year-old internationally competitive male Para swimmer during pre-intervention, and a 24-year-old Paralympic champion male swimmer during post-intervention. Both of C2's swimmers were internationally classified as S14 athletes – denoting intellectual impairment, and both were matched for the severity of their impairment as a function of their psychometric testing during classification. Consistency in experience level and disability classification across athletes for both coaches was a selection criterion to account for potential differences in coaching and learning strategies as a function of individual differences.

Ethical approval to conduct the study was provided by Manchester Metropolitan University Faculty Ethics Committee. All participants gave written informed consent before data collection.

6.2.2 Procedure

Coach observation

Coaches were observed delivering a one-to-one coaching session with their athlete both pre- and post-intervention. The pre-intervention observation was conducted as part of the practice analysis presented in Powell et al. (2021 – chapter 4). On both occasions, coaches were asked to design and deliver a session, lasting anywhere between 60-90 minutes (i.e., the typical duration of a training session at BPS minus the warm-up and 'swim-down'), with a focus on learning technical skill/s. Sessions were video recorded using a Sony Handycam camera and coaches were fitted with a WM8S UHF Wireless Lavalier microphone. Recorded sessions were transcribed using Youtube's video transcription service. The transcripts were then checked for accuracy and coach dialogue was coded as either instructions or feedback.

Coach Education

Coaches each participated in four 'one-to-one' online development sessions covering theory and applied practice relating to key principles of skill acquisition research. One session took place every two weeks, and each lasted approximately two hours. Sessions were facilitated using basic PowerPoint slides designed by the principal researcher. Slides contained minimal text and simple visuals to assist learning (see Appendix E for baseline slides. (Note, slides made use of multiple animations to keep text presentation to a minimum). The sessions were titled as follows: session 1 '*focus of attention: the science of coaching cues and language*', session 2 '*contextual interference: variability in practice and the learning-performance distinction*', session 3 '*Implicit learning: analogies, cognitive processing demands, and performance under pressure*, and session 4 '*recap and reflections*. Central to the sessions was the dissemination of the coaches' own observed practices in relation to these skill acquisition principles, obtained from the pre-intervention analysis of practice. The use of the coaches' own data served as a means of identifying the gaps between research recommendations and applied practice. In this way, the coaches' own practice examples provided practical relevance and meaning to the sessions. The individual sessions followed a basic and flexible structure of: (i) introduce the broad theory of the skill acquisition principle and the broadly associated underlying mechanisms, (ii) describe the coaches' own observed practices in relation to the skill acquisition principle discussed, (iii) provide examples of effective skill acquisition techniques used previously by the skill acquisition specialist in swimming, and (iv) key takeaways. Coaches were encouraged to ask questions and share ideas whenever possible to tailor discussion towards their own specific needs (Stoszkowski & Collins, 2016). Throughout the sessions, coaches were reassured that there was no right or wrong approach per se, and that this process was as much about informing research through the knowledge of expert coaches as it was about informing applied practice.

Coach interview

The pre-intervention coach interviews were conducted and recorded as part of the initial practice analysis (see Powell et al., 2021 – chapter four) and are not described in the current study, other than a reiteration that the coaches reported no knowledge of skill acquisition principles immediately prior to the intervention. For the post-intervention, a semi-structured interview was designed to allow flexibility in questioning (see Appendix D). Clarification, elaboration, and detail orientated probes were used throughout to elicit richer data (Smith & Sparkes, 2016). Questions included asking the coach what specifically they were asking or encouraging their athlete to focus on or think about during skill execution and why; how the session and practice blocks within were structured and why; what the purpose/rationale was behind any analogy learning cues which may have been used; how their approach to coaching and practice design both in the session and generally may or may not have been influenced by participation in this process; and what aspects of the coach education process they did or did not find to be effective and why. Coaches were reassured that there were no right or wrong responses/approaches and that their own subjective insights were valuable and would serve to inform research. Interviews were recorded with a video camera and wireless microphone for transcribing.

6.2.3 Measures

Focus of attention and implicit learning

To analyse the coaches' use of focus of attention (FOA) cues during instructions and feedback, a table of definitions for FOA cues was designed and adapted from previous FOA observation research (Powell et al., 2021 – chapter four) (see Table 6.1). The FOA cues were categorised as internal focus (IF), external focus (EF), mixed focus (M), holistic focus (H), ambiguous focus (A), and outcome focus (O)[5]. Cue frequencies were converted into proportions for each set of instructions and feedback. In this way, proportions reflected the likely swimmer FOA generated by the coach immediately before or after any given skill practice. For example, a coach could be recorded using 20 IF cues and no other focus cues during two minutes of instructions, and only 1 IF cue with no other cues during another ten seconds of instructions. However, it would be interpreted that on both occasions the coach is encouraging 100% internal focus in their swimmer prior to attempting a skill. As such, the total number of each cue observed was not considered in the overall analysis. Three members of the research team initially coded the first recorded session independently to reach consistency in assigning codes and an inter-rater reliability check produced an agreement level of 85%. Where discrepancies occurred, discussions were held until a consensus was reached (Pope et al., 2000). The second transcript was then coded by the primary researcher.

[5] Outcome cues are externally focused in that they convey information relating to movement effects. However, the information pertains only to knowledge of results (e.g., time to 15 m), as opposed to knowledge of performance (Magill, 2001). As such, more outcome cues are likely to be observed during coach feedback (vs. instructions). A separate measure for outcome cues helps to distinguish external cues in the pure form (e.g., 'push away from the wall').

Table 6.1

Cue definitions & examples for internal (IF), external (EF), holistic (H), ambiguous (A), outcome (O), and mixed (M) focus cues.

Cue	Definition	Example
IF	Directs attention towards component parts of the movement	'Keep your head down'
EF	Directs attention towards movement effects and/or aspects of the external environment	'Accelerate into the wall'
H	Conceptualises the feeling of the movement as a whole	'Smooth rotation on the turn'
A	Cues which are ambiguous and/or carry no clearly definable explicit meaning	'You're slipping around'
O	Cues relating to overall performance outcome measures	'That one was 6.2 seconds'
M	Encourages attention to be distributed equally between any two or more of internal, external, and holistic focus	'Arms straight and pointing at the floor"

For implicit learning, any examples of analogy learning techniques (e.g., 'like a torpedo off the wall'; 'a windscreen wiper action') used by the coaches were recorded and described. Although focus of attention and implicit learning were distinct sections in the coach education, overlap exists in their analyses. That is, in line with previous research (e.g., Poolton & Zachry, 2007; Powell et al., 2021 – chapter four; Wulf et al., 2002) analogies were also recorded as external focus cues. Analogies which conveyed some element of *feel* (e.g., 'imagine the wall is red hot') were still recorded as external (vs. holistic) cues because the explicit information would still be expected to be coded symbolically (vs. kinaesthetically).

Contextual interference

Each practice session was video recorded and mapped out chronologically onto an Excel spreadsheet recording pool length and lengths swam, skills practiced (stroke type, start, turn, finish), any equipment used (e.g., snorkel, fins, paddles), and brief descriptions of any coach instructions prior to skills practiced. Spreadsheet content was corroborated through a triangulation of coach observations, interviews, and session plans. CI was calculated as the percentage of opportunities taken to change skill (or skill variation) practiced versus the percentage of opportunities not taken. Opportunities taken to change skill were coded as '1' and opportunities not taken were coded as '0'. Thus, the first skill practiced in each session was not coded as there was no preceding skill practice. Opportunities to change *not* taken (i.e., repetition) were categorised as *blocked* practice. Opportunities taken to change skill were categorised as either *between-skill variability* (i.e., changes between fundamentally different skills) or *within-skill variability* (i.e., discernible variations in the execution of the same overarching skill). For example, changes between swimming strokes (e.g., breaststroke to butterfly) were recorded as between-skill changes, whereas variations in the same overarching skill of the freestyle stroke (e.g., freestyle with or without a snorkel) were identified as within-skill changes. In this way, each session produced a proportion of CI in the form of blocked practice (low CI), between-skill variability, and within-skill variability. Coach instructions helped guide the analysis and identify changes within-skills which might otherwise be difficult to discern (e.g., 'this time dive a little deeper'). Coach instructions also served to highlight the focus of the skill practice. Specifically, skill changes which were simply a by-product of the constraints of the pool (e.g., the turn halfway through a 100 m backstroke swim) but were not part of the intended learning focus, were not recorded as skill changes. For a detailed description of the measurement of FOA, implicit learning, and contextual interference, see Powell et al. (2021 – chapter four).

6.2.4 Qualitative Analysis

For the analysis of qualitative data, recurring patterns of meaning ('themes') were identified using Clarke and Braun's six-phase approach to thematic analysis (Clarke & Braun, 2013), which served to provide the researcher with a descriptive account of the concepts investigated. This approach to qualitative analysis provides a comprehensive story of the interpretations and experiences of the individuals under study (Clarke & Braun, 2013; Smith & Sparkes, 2016). The process of thematic analysis involved first the researcher familiarising themselves with the interview transcripts by reading and re-reading them several times to identify broad statements of interest. The researcher then began coding the data to identify larger patterns and themes. Finally, the themes were reviewed, refined, and named to capture two overarching themes which each had three suggestive sub-themes. The thematic analysis was initially conducted by the lead author and subsequently shared with two other authors who acted as 'critical friends', questioning themes and assumptions to generate reflection among the research team (Sparkes & Smith, 2015). Discussions were continually assessed for alignment with the dataset to ensure themes were reflective of the transcripts.

6.3 Results

Two overarching themes were identified that represented the coaches' interpretation and experience of the coach education and their subsequent approaches to practice design: (1) *less is more*, and (2) *beyond performance*. The main theme of less is more pertained to the learning principles of both focus of attention and implicit learning as the coaches discussed their interpretation and experience of these interchangeably, resulting in both quantitative and qualitative overlap in the analyses of these principles. This theme was associated with the sub-themes, *relatable*, *self-discovery*, and *simplicity*. The main theme of beyond performance was associated with the sub-themes *recap*, *doing something different*, and *psychology not physiology*. In the following section, the main themes will be discussed in detail with supporting excerpts from both C1 and C2, alongside quantitative findings from the related learning principles.

6.3.1 Focus of attention and implicit learning

Both coaches emphasised predominantly *internal* focus cues during the pre-intervention coach observation (coach 1 = 62.9%, coach 2 = 45.2%), whereas they switched to more holistic focus cues (C1) or external focus cues (C2) post intervention (see Figure 6.1).

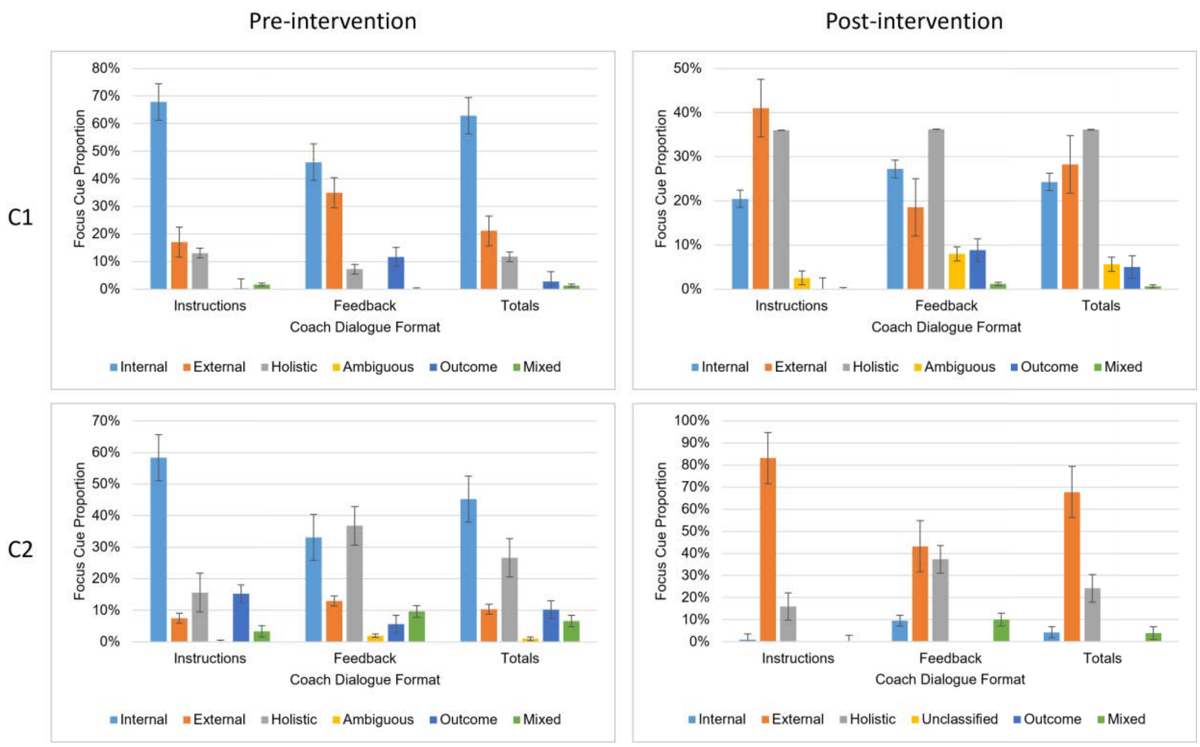

Figure 6.1. Focus of attention cue emphasis during coach session observations both before (left) and after (right) the skill acquisition coach development process for coach 1 and coach 2.

Of the external focus cues recorded in the post-intervention, C1 made use of three analogy learning cues (‘Imagine squeezing a tennis ball between your ankles’), whereas C2 placed a large emphasis on analogy learning cues. Specifically, of the total number of FOA cues used across C2’s session, 66.3% were analogy or metaphor-based cues.

Less is more

In the interview, C1 described the shift in focus cue emphasis as a deliberate learning strategy, developed through participation in the coach education process, and aimed at encouraging athlete learning through exploration and guided discovery:

This is one of the bits I’ve taken on board from this whereby a bit less and not too much all the time. Maybe previous years I’d be sort of constantly giving instructions… like you’ve seen he’s picking things up for himself, and sort of self-discovery is really important. (C1)

Although C1 used predominantly more holistic FOA cues in the observed session (e.g., ‘it’s got to be *explosive*; it’s got to be *powerful*, but it’s got to be *neat and tidy* alright'), it was the benefits of using analogies and metaphors which had resonated most following the intervention:

It's become more about making it relatable to the athlete - sometimes the simplest form of instructions can be the most beneficial. For example, I could see (athlete's name) legs were crossed on the start. I could talk about angles, they need to be six inches apart etcetera, but I said, 'imagine you're squeezing a tennis ball between your ankles'; not being too technical – they can relate to it. On one of his jumps he was crouched forward so I said to him, 'imagine you've got a pole going through your body from fingers to legs'. After that he was in a much better line. (C1)

C2 used a small range of different FOA cues overall, each linked to a boat metaphor, but used these cues repeatedly (e.g., 'kayak body', 'propeller legs', and 'paddle arms'). This more focused and non-prescriptive approach was a deliberate learning strategy developed through participation in the education process, and in response to the individual needs of the athlete and their intellectual impairment:

I was trying to be very short in my communications, I didn't want him to get lost in my words… as part of the recap it was two key words: one was torpedoes, and one was kayak… he understood it and it just simplified quite complex movements.

I started trying to use more and more analogies and that seemed to stop me talking as much and helped him get it straight away and helped him visualise what I'm looking for… I was conscious of confusing him with too much information. (C2)

C2 further explained that even in the short space of time since beginning the process, they had noticed the benefits of analogy learning with other athletes with intellectual impairments in their home training programme:

The S14s in particular have been really responsive to it, and their (subsequent) movements are way less mechanical… With (athlete name) today too I found the use of analogies or metaphors and summarising complex movements like that just hits home really well. (C2)

C2 also reflected that prior to the intervention, as their own knowledge and interest in the biomechanics of swimming had grown over time, so too had their use of more prescriptive internally focused cues during training:

I think as my knowledge increased, I started to use more internal focus cues… I like to know how the anatomy should work through the water, like how the arms link to the legs and so on, so I think I've become naturally more internally focused with my cues to athletes… whereas now I think I've realised the importance of external cues and analogies as well in summarising movements to get the movements going. (C2)

6.3.2 Contextual interference

As can be seen in Table 2, C1 incorporated no between-skill variability into the practice session in the pre-intervention observation, while C2 incorporated low levels of between-skill variability (12.5%). Coaches made use of higher levels of within-skill variability in practice during the pre-intervention observation (C1 = 44.7%, C2 = 53.1%). In the post-intervention observation, C1 incorporated moderate levels of both within-skill (17.9%) and between-skill variability (20.5%). C2 incorporated relatively low levels of within-skill variability (15.2%) and relatively high levels of between-skill variability (41.3%)

Table 6.2

Levels of within-skill variability, between-skill variability, and blocked practice both before and after the skill acquisition development process for coach 1 and coach 2.

	Coach 1		Coach 2	
CI %	Pre	**Post**	Pre	**Post**
Within-skill	44.7	**17.9**	53.1	**15.2**
Between-skill	0	**20.5**	12.5	**41.3**
Blocked	55.3	**61.6**	34.4	**43.5**

Beyond performance

In the interview, C1 described their reflections on variability following the intervention both as a means of assessing and enhancing athlete learning. In doing so, C1 also alluded to their attempts now to design practice underpinned by an understanding of the learning-performance distinction:

It's one of the techniques we've been trying out since we started (this process)… your brain is processing all of the information and now we're going back to what we've done - I want to see if you can put it into practice without me giving you the information…

it's realising that just because someone has done something well for thirty minutes, it doesn't mean it's ingrained. If I were to learn how to introduce myself in Japanese, I could do it for thirty minutes and regurgitate it but in a week, I'd have forgotten it.

So now it's do a skill, do something different, go back to it, do something different, so you're mixing it up. This season in particular I've seen some good results using that system, and to be honest when I think back before (this process) some of my best sessions were the unstructured ones. (C1)

In reflecting on the process in general, C1 described how the concept of variability in practice had resonated with them, but also how the approach to education, with an emphasis on coach *understanding* of scientific theory (as opposed to prescriptive guidance on the implementation of skill acquisition techniques), had been crucial to influencing practice design and harnessing the coach's existing knowledge and expertise:

One of the things I view differently now is there's a difference between how you want to work physiologically and how you want to work psychologically - some coaches get it the wrong way round, and I think I was one of them.

It's important to understand the science but you shouldn't be led by the science because you need to figure things out for yourself. As soon as we discussed the idea of variability; doing a bit here and a bit there and changing things, that made a lot of sense to me, so I'm able to then think about how I can play around with that myself. (C1)

C2 described their approach to variability in the session and more generally across training cycles following the intervention, again with an emphasis on an increased understanding of the learning-performance distinction. The practice structure adopted was also accompanied by bandwidth feedback techniques (see Chambers & Vickers, 2006), and together formed part of a learning strategy designed with the athlete's intellectual impairment in mind:

We purposely put some switch off swims of something completely different just as a bit of a spacing effect… then revisited the movement as a recap and the second time I gave less direction. I think previously I would work on AAA and progress to BBB and then CCC, whereas today in the first part of the main set I kind of did AB, stayed there, *reinforced it, had a bit of a gap doing something else, and then went back to AB. Then the second part of the main set was ABC, stay there, change, then recap it. I kept it very focused. I didn't want him to get confused with too many things.*

I think understanding the difference between performance and learning has influenced planning and periodisation for the whole season. In training I'll do a performance session rather than a learning session now so I get the opportunity to see what's been learned because how much have they actually learned… Looking back I'd go through loads of drills and skills and go through every detail and come away going that's amazing they've done that really well, then after a period of time I'd come back to it and it looks terrible and I'm having to repeat everything… adding more variability through the week with focus points I'm seeing less of a breakdown in technique… there's definitely an upward trend in efficiency and that's evidence of what we're doing. (C2)

6.4 Discussion

The study examined the efficacy and impact of an education intervention with two coaches from the British Para Swimming Team. Following an initial analysis of practice (see Powell et al., 2021 – chapter four), coaches with no formal knowledge of skill acquisition principles had adapted their approach to practice design to incorporate theory-informed approaches. The purpose of the intervention was to develop the coaches' understanding of the theory underpinning key principles in skill acquisition research. In this way, the intention was to provide coaches with a framework of understanding, through which they could harness their own experiential knowledge of effective coaching practice and incorporate new ideas and techniques as they saw fit. As such, the study did not set out with any specific or quantifiable hypotheses in mind, but rather to explore what, if any, concepts resonated with the coaches, and in turn *how* skill acquisition theory might be interpreted and applied by the coaches themselves in a high-performance setting.

Through the education process, coaches had shifted from emphasising predominantly internal focus cues to more holistic (C1) or external focus (C2). The coaches' interpretations and experiences in relation to FOA and implicit learning development were encapsulated in the theme of *less is more*, and for C1 this manifested in the utilisation of more holistic focus cues to encourage learning through guided discovery.

In this way, holistic focus cues (e.g., 'nice, neat line') served to camouflage more explicit (prescriptive) movement information by coding it kinaesthetically (Mullen et al., 2015). Interestingly, C1 was still utilising a large proportion of internal cues. Initial alternative findings suggest internal focus cues could benefit learning in sports such as swimming, where a somatic focus prior to skill practice can improve processing of relevant proprioceptive task information through increased congruence between instructions and feedback (Gottwald et al., 2020). Nevertheless, that informed coaches are still choosing to use multiple internal cues perhaps calls into question the rigidity of the constrained action hypothesis (i.e., external focus equals optimal and internal equals suboptimal).

For C2, the emphasis had shifted to more analogy or metaphor-based cues (66.3%) - an approach influenced by their athlete's intellectual impairment. That is, as part of the coach education, the skill acquisition practitioner had described the potential benefits of analogy instructions for athletes with intellectual impairments, facilitated by anecdotal evidence from applied practice and underpinned by the theoretical implications of the approach. Specifically, intellectual impairments typically involve a deficit in short-term working memory capacity, with a relative preservation in more long-term, implicit memory processes (Vicari, 2004). Consequently, intellectually impaired athletes can struggle retaining and processing information presented in the form of explicit (or internal focus) coach instructions (see also Burns & Johnston, 2020). Analogies can be used to promote the use of more implicit (long-term) memory structures as they serve to camouflage explicit movement information by coding it symbolically (Mullen & Hardy, 2010). As such, provided that the athlete is familiar with the visual representation associated with the analogy (e.g., 'flat like a soldier standing to attention'), it can be understood (processed) at an unconscious level (implicitly) and working memory can to some extent be bypassed for more long-term, procedural, or implicit memory mechanisms. This facilitation of more implicit (or automatic) motor control as a function of analogy cues was evidenced in C2's reflections that their intellectually impaired athletes' subsequent movements (both in the observed session and with athletes in their home club) were 'way less mechanical'. 'Mechanical' movements are indicative of a more conscious form of motor control, as opposed to a more automatic mode of control which would typically be characterised by *fluidity* in movement (Wulf, 2013). It is possible that any detrimental effects of explicit coach instructions, and in turn any beneficial effects of more implicit, non-prescriptive instructions such as analogies, are exaggerated in the coaching of intellectually impaired athletes. Given the large proportion of intellectually impaired athletes on the British Para Swimming Team (34% at the time of writing), this offers a promising opportunity for future skill acquisition research. Indeed, external focus cues, thought to operate through similar mechanisms to analogy cues (i.e., reduced conscious or working memory processing), have already been shown to benefit learning for children with intellectual impairments (Chiviacowsky, Wulf, & Avila, 2013). However, the extent of this benefit relative to individuals without learning impairments has yet to be explored and could have important implications for disability sport.

In relation to contextual interference, coaches incorporated lower levels of within-skill variability and higher levels of between-skill variability following the intervention. However, the within-skill variability recorded in the pre-intervention took the form predominantly of part-task training drills, whereby athletes progressed *through* various stages of practice drills in which the focus of learning changed at each stage throughout – thus in the absence of any process of switching *back and forth* between skills or skill variations to facilitate acquisition via either memory (re)construction (Lee & Magill, 1983) or elaboration (Shea & Morgan, 1979). In the post-intervention, the coaches were still utilising part-task training techniques, however, stages of drills were now interspersed by short sets of alternative skill practice, thereby incorporating a process of switching back and forth between the same to-be-learned skills. This approach to variability allowed the coaches to revisit or 'recap' the to-be-learned skills later in the practice block, session, or even training week. The shift in practice design appeared to result from an increased awareness and understanding of the *learning-performance distinction* (see Kantak & Winstein, 2012), and manifested in a form of variability which could be more closely associated with psychological research into the *spacing effect* (Cepeda et al., 2006). That is, whereas the contextual interference effect in skill acquisition literature emphasises enhanced learning as a function of switching randomly and repeatedly between skills on each skill practice attempt (Hodges & Lohse, 2022), the spacing effect emphasises the learning benefit of temporal spacing between learning events. In adopting this approach, the coaches reported seeing less of a breakdown in technique over the season. As such, if this is the type of variability that informed coaches are choosing to adopt in practice, and given the inconsistencies previously reported in relation to the contextual interference effect in the applied setting (Barreiros et al., 2007; Farrow & Buszard, 2017), perhaps more research is needed into the potential learning benefits of temporal spacing in sport.

6.4.1 Limitations

Potential limitations with the current study should be noted. First, coaches were observed (pre- and post-intervention) coaching their athlete one-to-one. Although one-to-one coaching often forms part of swimming practice sessions (e.g., if an athlete requires specific attention and/or if multiple coaches are on deck), it does not represent a more typical full swimming session, whereby a large group of swimmers are coached simultaneously. Nevertheless, one-to-one coaching would reasonably be considered a more concentrated representation of a coach's approach to coaching and learning design (i.e., the *type* of language used would be expected to be the same, along with the type of variability). Second, due to logistical and time constraints, and the nature of elite level sport (e.g., injuries and training cycles) different athletes were used for the pre- and post-interventions. However, for each coach, athletes were matched for age, gender, experience level, and disability classification. The intellectually impaired athletes were also matched for the extent of impairment through psychometric test results, and consequently, coaching approaches would not be expected to differ as a function of the athlete coached.

6.4.2 Conclusion

Overall, the skill acquisition coach education appeared to be effective in influencing practice design. In particular, coaching practices had been adapted to align more closely with established recommendations from prominent lines of skill acquisition research. More importantly, coach interviews indicated new perspectives and approaches were being incorporated into the daily training environment in a way which was natural to them. This included novel strategies in elite sport, including the use of holistic cues, variability through temporal spacing, and the use of analogies to facilitate learning among athletes with intellectual impairments. Key to this was the development emphasis on the coaches' *understanding* of skill acquisition concepts and the mechanisms which underpin learning effects. The purpose of this approach was to harness the coaches' own experiential knowledge in practice design (see also

Greenwood et al., 2014). More specifically, just as athletes do not learn as effectively when movement solutions are prescribed by a coach, a coach should be guided towards finding their own coaching solutions by the skill acquisition specialist. In acting as a reflective practitioner, the aim for the skill acquisition practitioner was to guide and facilitate coach experiential learning between sessions, to enhance the coaches' own toolbox of skills, refine their coaching philosophies, and to help synthesise scientific knowledge with the essential knowledge they have already acquired through years of experience. The significance of this experiential knowledge is further amplified in the coaching of Para athletes, for whom a range of disabilities each have unique implications for learning. Furthermore, given there remain significant unresolved areas of debate in skill acquisition research, providing expert coaches with the information for themselves, and seeing what resonates and what works in practice for them, should provide as useful an avenue for furthering our understanding of skill acquisition principles as any other.

CHAPTER SEVEN

7. General Discussion

7.1 Summary and implications

The project had set out originally to gain a broad understanding of coaching practices pertaining to *start and turn* techniques specifically and in relation to focus of attention and contextual interference learning principles. The next stage was to be an examination of the impact of research informed external focus and contextual interference interventions on various learning and performance parameters of starts and turns. However, in addition to reasons highlighted in section 1.7, through a process of immersion in the sport, of gaining an understanding of the complexities of coaching and the skills involved, and an increased awareness of the nuances and individual athlete needs in Para sport, it became apparent that this was not enough. Instead, what was required was a much deeper understanding of current coaching practices. Some of the coaches had spent 20 or more years honing skills through experiential learning, producing Paralympic champions among athletes with unique learning constraints. Previous research has highlighted that the experiential knowledge acquired in this way not only comprises an intuitive grasp of techniques described in skill acquisition literature (Lindsay & Lenetsky, 2020; Powell et al., 2021 – chapter four), but effective learning strategies not yet identified by research (Greenwood et al., 2012, 2014). To attempt to harness this knowledge and to provide greater context to begin to impact learning design, the more precise gaps between research and applied coaching practice in swimming needed to be understood.

Alongside an investigation into current coaching practices relative to established principles in skill acquisition, there was acknowledgement that coach education and certification resources involve no formal training in skill acquisition (e.g., Scottish Swimming, 2016). Specifically, while swimming coach qualifications involve a base level of education in various sports science disciplines, including physiology, biomechanics, and nutrition, there is little-to-no understanding required on skill acquisition, and information which is provided to coaches is outdated and does not pertain to any of the learning principles discussed in this thesis. This is reflective of swimming coaching research, which has typically concerned performance improvement through an understanding of physiological or biomechanical perspectives (McGowan et al., 2016; Mooney et al., 2016; Nugent et al., 2017). Furthermore, in line with previous research in other sports and nations (Cregan et al., 2007; Pinder & Renshaw, 2019), coaches at British Para Swimming (BPS) receive no formal guidance on coaching athletes with disabilities. In working as a practitioner with the team, a significant challenge lay in making recommendations to coaches without an understanding of the key concepts of approaches in skill acquisition. To exacerbate this, like many Olympic and Paralympic organisations, BPS is a de-centralised programme, where most coaches are spread around different swimming clubs across Britain. Consequently, as the project evolved, it was decided that a more sustainable impact for skill acquisition could be facilitated by a next step in coach education.

The findings from across the three studies in the current thesis have several implications for coaching, skill acquisition, and Para sport. First, through investigations into current coaching practices (chapters three & four), and in line with previous research (Cregan et al., 2007), it was reported that coaching practices did not differ significantly between disabled and non-disabled athletes, nor as a function of the disability classifications themselves. This finding makes intuitive sense in relation to athletes with physical disabilities, where adaptations are likely to pertain to movement capabilities rather than learning strategies per se. However, recent research has begun to highlight the more precise learning and coaching implications for performers with intellectual impairments in the sporting context (Burns & Johnstone, 2020; Van Biesen et al., 2023). Broadly, intellectual impairment is characterised by a deficit in short-term (working) memory, with a relative preservation in implicit or long-term memory mechanisms (Vicari, 2004). This results in a slower rate of learning and difficulties retaining and processing information (e.g., in the form of explicit coach instructions). In line with this, recommendations for coaching intellectually impaired athletes include first, among other things, the use of short, simple terminology and dialogue (accompanied where possible by visual demonstrations), and second, a greater level of repetition in practice, at least in the initial stages of learning (Burns & Johnstone, 2020). From my own observations of practice, I could see coaches were often demonstrating the former of these approaches. However, the findings from studies one and two provide initial indications that levels of repetition in practice did not differ for intellectually impaired swimmers. Moreover, although coaches were making use of simple cues and terminology, the *type* of cues used did not differ between athletes (see Powell et al., 2021 - chapter four). The use of external focus or analogy learning cues specifically in relation to athletes with intellectual impairments has not yet been recommended within formal coaching guidance or research. However, the efficacy of such an approach was supported by findings from my own athlete interventions at BPS (see chapter five), underpinned by an understanding of the key concepts of the approach, i.e., reduced working memory demands in favour of more implicit memory mechanisms. This was further supported by the now informed coaches in study three (chapter six), who suggested their intellectually impaired athletes were responding particularly well to the use of analogy learning cues, stating their subsequent movements were 'way less mechanical'. Given the growing number of intellectually impaired athletes in Para sport (34% of athletes at BPS at the time of writing), these findings could have important implications for coaching and skill acquisition provision more generally.

In relation to the learning principle of focus of attention (FOA), findings from study one (chapter three) contrasted with previous research in skill acquisition literature. Specifically, whereas previous studies report coaches in a range of sports make use predominantly of internal versus external focus cues (Dieffuss & Raisbeck, 2016; Halperin et al., 2016; Porter et al., 2010; van der Graff et al., 2018), no significant difference was found at BPS. It is suggested that this is likely to be at least in part due to methodological limitations highlighted in previous research. However, the current thesis also highlights for the first time that differences in the use of FOA cues may be a function of the skills being coached. In particular, little difference was reported in studies one and two for coaches' use of internal and external cues in relation to coaching *start and turn* skills. In contrast, coaches in study two were observed using significantly more *internal* focus cue emphasis during the coaching of swimming strokes. This may be because starts and turns offer more opportunities to interact with the environment (e.g., the wall or starting block), and coaches are taking advantage of this. Equally, the complexity of start and turn skills (movements involving multiple degrees of freedom executed both through the air and underwater *at speed*) may be less amenable to skill breakdown, which forms the basis of internal cues (Mullen & Hardy, 2010). Conversely, *because* swimming strokes are more amenable to skill breakdown, coaches may be taking advantage of the opportunity to use more *internal* focus cues. Specifically, coaches in study two described consistently the importance in swimming of body (or somatic) awareness. This notion is in line with literature purporting the benefits of 'somaesthetic awareness' (i.e., a heightened sense and mastery of body movement) among elite athletes to facilitate *continuous improvement* once a certain level of skill has been reached (Toner & Moran, 2014, 2015a, 2015b). Indeed, there are initial suggestions that internal focus cues may be optimal in sports such as swimming due to an enhanced ability to process pertinent proprioceptive task information through increased congruence between instructions and feedback (Gottwald et al., 2020).

Perhaps a more logical conclusion on what constitutes optimal FOA cue use based on literature and the findings from the current thesis lies somewhere in between. Specifically, coaches in study three (chapter six) who had undergone an online coach education intervention and engaged in deliberate experiential learning in FOA strategy were still using internal focus cues, but using them in conjunction with alternative cues, such as external, holistic, ambiguous, and analogy learning cues. Although coaches were also using these alternative cues in study two (to a lesser extent), they did not appear to be aware, and/or to view them as significant. A goal in the coach education intervention in study three was to build coach awareness around practices they were already adopting (using the findings from study two) as well as to develop their understanding of the underlying associated processes, with an emphasis on no right or wrong, to see what worked in practice for them. That the now informed coaches were choosing to use internal *and* external focus cues, along with a range of others, calls into question the rigidity of the constrained action hypothesis (e.g., Wulf, McNevin, & Shea, 2001) and the idea that external focus equals skilled movement and internal focus equals unskilled or suboptimal movement (see also Toner & Moran, 2021). Instead, what became optimal was knowing *when* and *how* to use different cues, as the coaches themselves described (e.g., holistic, or external focus cues to encourage self-discovery, or analogies to convey complex movement information). Additionally, the findings highlight that the dichotomous nature of much of the FOA literature (i.e., internal vs. external focus) is insufficient when attempting to translate findings to the applied settings, where coaches are adopting a range and complex interaction of various FOA cues.

With regards to contextual interference, findings from study one revealed coaches at BPS incorporate significantly more blocked than variable practice in training design, but also significantly more within-skill variability than between-skill variability. A similar pattern was recorded during coach observations in study two, but results were non-significant, potentially due to the smaller sample, and so must be approached with caution. However, study two revealed that the within-skill variability observed typically took the form of part-task training, whereby skills were broken down into component parts (e.g., the freestyle stroke is reduced to the kicking, arms, or breathing element) before being built back into the full skill or stroke. This is a common approach in swimming coaching (e.g., Brackley et al., 2020), and its merits as a learning strategy have been debated in skill acquisition literature (Brison & Alain, 1996; Davids et al., 2017; Schmidt & Lee, 2011). In relation to contextual interference theory, the part-task training observed involved athlete progression *through* training drills, whereby the focus of learning changed at each stage throughout. In other words, practice sessions did not involve any process of switching *back and forth* between skills or skill variations to facilitate the consolidation of movements via either memory (re)construction (Lee and Magill, 1983) or elaboration (Shea and Morgan, 1979). In line with this, and notwithstanding the proposed processes underpinning the contextual interference effect which are still debated (e.g., Farrow & Buszard, 2017), it became apparent through observations and interviews that practice design was not underpinned by an understanding of the concepts of the *performance-learning distinction* (Kantak & Winstein, 2012). In other words, without a process of switching back and forth between skills within or even across multiple sessions, coaches were less often incorporating a mechanism for distinguishing between immediately observable or temporary performance and more long-term skill retention. This perhaps carries heightened significance for athletes with intellectual impairments given the learning constraints previously highlighted.

Through utilising these observations alongside theoretical explanations for the contextual interference effect in the coach education intervention in study three, coaches became more aware of the performance-learning distinction in their approach to practice design. Following the intervention coaches were still utilising part-task training techniques, however, stages of drills were now interspersed by short sets of alternative skill practice, thereby incorporating a process of switching back and forth between the same to-be-learned skills. The coaches described the benefit of being able to ‘revisit’ or ‘recap’ skills at different points in the session or training week to assess ‘what had actually been learned’. In essence, coaches were introducing structure to variability. This form of variability more closely resembles psychological investigations into the *spacing effect* (Cepeda et al., 2006). That is, whereas the contextual interference effect in skill acquisition literature emphasises enhanced learning as a function of switching randomly and repeatedly between skills on each skill practice attempt (Hodges & Lohse, 2022), the spacing effect emphasises the learning benefit of temporal spacing between learning events. Coaches indicated they were already witnessing the benefits of this approach, ‘seeing less breakdown in technique’. As such, perhaps the parameters of what constitutes contextual interference in experimental research should be revised. Either way, if this is the type of variability that informed coaches are choosing to adopt in practice, and given the inconsistencies previously reported in relation to the transferability of the contextual interference effect to the applied setting (Barreiros et al., 2007; Farrow & Buszard, 2017), more research is needed into the potential learning benefits of temporal spacing in sport.

In relation to implicit learning, previous research pertaining to non-linear or *non-explicit* approaches to pedagogy has highlighted coaching practices in swimming through the use of constraints and the concept of *ecological dynamics* (Brackley et al., 2020; Junggren, Elbæk, & Stambulova, 2018). However, coaches in studies two and three demonstrated that the use of *language*, and in particular the adoption of FOA cues which are less explicit in nature (i.e., reduce conscious processing and the accrual of explicit knowledge) such as external, holistic, or analogy learning cues, can be a powerful instrument for coaches who wish to utilise a more non-prescriptive, or implicit approach to coaching and learning. For example, one coach in study two reported the deliberate strategy of adopting more *ambiguous* focus cues (e.g., ‘you’re slapping’), in the hope that the athlete would ‘figure it out for himself’. Along similar lines of encouraging problem solving and self-exploration, the now informed coaches in study three increased their use of holistic cues (e.g., ‘keep it clean and tidy, but still explosive’), describing that ‘self-discovery is really important’. And as previously described, one coach reported the benefits of analogy learning cues, particularly for athletes with intellectual impairments, in helping to summarise complex movements and facilitate understanding.

Coaches in study two appeared also to be intuitively learning the benefits of constraints-based approaches to learning, however, their implementation of techniques was not underpinned by an understanding of the key concepts of the approach (i.e., self-organisation through the adaptation to constraints). Instead, coaches would provide explicit movement information or knowledge alongside the exploration of skills (e.g., 'the reason we're doing this drill like this is I want you to keep your head still because that's key here'). In the coaches' explanations of their rationale for more implicit approaches, they described terms more closely associated with *explicit* processes, such as *awareness* and *understanding*. Interestingly, regardless of *how* skills were being learned (i.e., through implicit or explicit learning pathways), and whether analogy cues or constraints were adopted, coaches often followed each practice block or skill attempt by asking athletes to describe what they felt, what they learned, or what had gone well/less well and how. According to theory, skills learned implicitly (unconsciously) may not be amenable to verbal (explicit or conscious) reflection, as while the skill may have been learned it is likely to have been learned in the absence of explicit movement information (also known as procedural or non-declarative memory, as opposed to declarative memory) (Masters et al., 2019). In other words, rather than viewing implicit and explicit techniques as mutually exclusive approaches to learning, coaches, including those following the skill acquisition education intervention, viewed them as complimentary methods which could be used in conjunction. While this approach may not be supported by experimental, mostly laboratory-derived skill acquisition theory, it *is* supported by theoretical recommendations which have emerged from case studies in the applied setting. More specifically, in an approach described as *learner-centred pedagogy for swim coaches*, Light (2014) suggests that optimal learning of swimming skills occurs via the interaction between non-reflective (implicit or unconscious) learning arising from the adaptation to constraints, and subsequent reflective (explicit or conscious) learning facilitated by dialogue between athlete and coach. This idea of the need for successful elite athletes to be able to switch flexibly between conscious (explicit) and more automatic (implicit) states is also supported by other lines of research in skill acquisition (see Toner & Moran, 2014, 2015a, 2015b). Nevertheless, the contradictions indicate more ecologically valid testing is needed to elucidate the optimal strategies for the implementation of implicit learning techniques in the applied setting.

Overall, the project demonstrates the importance of understanding coaching practices in individual sports and identifying the gaps between skill acquisition research recommendations and applied practice to provide context to begin to impact learning design. In utilising this knowledge, coach education interventions which encourage learning through coaches' preferred means, i.e., 'experiential learning', or learning by 'doing it' (Bates, 2007; Gilbert & Trudel, 2001; Greenwood et al., 2014; Maclean & Lorimer, 2016; Nash & Sproule, 2009; Rynne, Mallett, & Tinning, 2010; Sawiuk et al., 2018) can provide a more sustainable impact on coaching and athlete development. What's more, in focusing on coach understanding of the principles underpinning motor learning theory, and in emphasising no right or wrong approach, we are better able to harness coaches' own experiential knowledge and see what works in practice for them. Given the current challenges facing the uptake of skill acquisition provision in sport (Steel et al., 2014) this should provide as useful an avenue for furthering our understanding of skill acquisition principles as any other. It is hoped that in sharing some of these examples of practice, the current thesis contributes to a framework of understanding which facilitates future collaborations between coaches and skill acquisition practitioners.

7.2 Impact

In addition to the academic implications of the research in this thesis, the project has also had several real-world impacts. As highlighted in chapter five, skill acquisition principles have now become a prominent part of the coaching process at the National Performance Centre in Manchester, and these new approaches are not just restricted to the pool but utilised in areas such as strength and conditioning and physiotherapy. Skill acquisition now forms a key part of Individual Athlete Process goals for athletes across the Great Britain Team. In particular, priority athletes are routinely analysed by the biomechanics team, and the skill acquisition practitioner will then work closely with the athlete and their coach to identify appropriate learning strategies to implement recommended technical changes. A particularly beneficial impact has been made in the coaching of athletes with intellectual impairments (making up 34% of the team), where an understanding of the neurological impact of the disability, coupled with an understanding of the underlying neural mechanisms in skill acquisition theory, has led to the design of coaching approaches which have at times been transformative (see chapter 5 and 6 for examples).

With regards to coaching across the BPS programme (i.e., across the UK), the project research has contributed to the delivery of skill acquisition coaching workshops which have been very positively received, as well as a national coaching podcast. The coach participants from study two have since reported that skill acquisition principles have become fundamental to their approach to coaching. More specifically, coach 1 has reported particular successes with the use of constraints with two blind athletes, while coach 2 has been upskilling a group of coaches within their club, stating that "the office is now filled with examples of focus cues and analogies". In the spring of 2022, the Head Coach of British Para Swimming requested the delivery of a three-part online Webinar series entitled, 'Key Principles of Skill Acquisition in Swimming'. A central aspect of the series involved disseminating and sharing the findings from study two, and, as with the approach to study three, making skill acquisition ideas relevant and accessible (the slides from the series can be found in Appendix E, and were adapted to include individual coach observations for study three). The series went out internationally and over 200 coaches and practitioners registered and viewed. It was positively received and many coaches subsequently contacted British Para Swimming wanting to find out more. One coach had contacted to say they were now delivering the series to other coaches at their club. As a consequence of these impacts, skill acquisition provision is now moving to the other disciplines at British Aquatics. In particular, coach education and development are now underway with British Olympic Swimming, and specifically the coaching team at the National Performance Centre in Bath. Plans for British Diving are due to commence in 2023.

7.3 Limitations

A number of potential limitations with the research in this thesis must be acknowledged. Firstly, in study one, the nature of the survey may not have been sufficiently accessible for some respondents with intellectual disabilities. More specifically, although the primary researcher guided these respondents, where possible, through the questions, and those which had clearly not understood the questions had been removed from the analysis (e.g., answered all questions with '0%' or '100%), upon reflection it could be said that not enough was understood at the time on the part of the research team with regards to the impact of this impairment on processing this type of information. Secondly in study one, the survey only investigated focus of attention in relation to internal and external cues. Subsequent research –

namely the findings from study two – has demonstrated that coaching language can comprise a whole range of cues thought to be beneficial for learning and performance, including holistic cues, ambiguous cues, and analogy learning cues. Furthermore, given that external focus cues are associated with implicit memory mechanisms (Winkelman, 2017; Wulf, 2013), it may be that they are less accessible to explicit memory retrieval processes, when, for example, an athlete is responding to a questionnaire.

In relation to study two, a potential limitation pertains to its ecological validity. In particular, the coaches were asked to conduct sessions on a one-to-one basis with their swimmers, which is not typical of interactions in most training sessions where a number of swimmers are coached simultaneously. Furthermore, during the interviews two coaches (who recorded high within-skill variability) indicated that they would typically progress through the stages of drills more slowly, and thus incorporate higher levels of repetition (i.e., lower variability) when not being observed for the purposes of the research. As such, some of the practices observed may in part stem from the coaches' desire to demonstrate a range of skills in one session rather than for pedagogical purposes. The sessions also provided only a snapshot of coaching practices for each coach at any given time of the swimming season and with any given athlete. Although these factors were to some extent accounted for by the coach interviews, the practices observed should not be considered wholly representative of coaching on the British Para Swimming Team. The same limitations apply for study three, with the additional possibility that the now informed coaches might shape their practice design and interview responses in line with what they view as 'correct' for the purposes of the research. It is hoped that this possibility was mitigated by the continual emphasis on no right or wrong approach, and that the purpose of the study was more weighted towards coaching practices and perspectives informing research, than vice versa. In addition, upon a subsequent visit to one of the coaches' clubs, I was introduced to some of the constraints which were now built into the daily sessions for the swimmers.

7.4 Future research

The research in the current thesis is the first of its kind to provide an extensive quantitative and qualitative analysis of coaching practices within a sport in relation to a range of key learning principles in skill acquisition. As every sport has unique coaching and learning requirements, it is imperative that further research of this kind is conducted to identify the gaps between scientific research recommendations and current applied coaching practices to provide context and relevance to impact learning design. Given the barriers to the integration of skill acquisition expertise which already exist (Steel et al., 2014), it is essential that prospective applied skill acquisition researchers and practitioners can enter a sport with as much information as possible, and with guidance around how they might carry out their own practice analyses where necessary. In line with this, practitioners who *are* involved in a sport must be encouraged to share their experiences beyond publishable interventions, given the challenges in controlling experimental variables in the applied setting.

Future research should also continue to seek clarity on the optimal learning strategies recommended to coaches and athletes. For example, there remain areas of debate on the merits and implementation of internal versus external focus of attention cues (e.g., Collins, Carson, & Toner, 2016; Wulf, 2016), and, with particular relevance to swimming, on the efficacy of task decomposition or part-task training (e.g., Davids et al., 2017; Magill & Learning, 2007; Seifert et al., 2013; Whelan, Kenny, & Harrison., 2016). In addition, current theory presents a challenge for coaches attempting to reconcile best practice approaches where the associated underlying learning mechanisms are conflicting or unknown. For example, traditional explanations for the contextual interference effect infer a cognitively demanding explicit learning process in working memory (via reconstruction or elaboration), whereas FOA and implicit learning techniques are designed to reduce working memory involvement. A practical solution may lie in an alternative theory for the contextual interference effect, which proposes that the excess demands placed on cognitive resources through task switching actually *prevents* explicit processing in working memory, and instead promotes learning via implicit pathways (Rendell et al., 2010). Nevertheless, more ecologically valid testing of scientific theory is needed to provide clarity on skill acquisition research recommendations.

Finally, based on the theory and observations described in the current thesis, two additional areas of potential future research present themselves. Firstly, and as described in greater detail in section 6.4, given intellectual disabilities are typically characterised by a deficit in short-term working memory processes and a relative preservation in implicit memory (Vicari, 2004), it may be that learning strategies thought to reduce working memory involvement and facilitate learning via more implicit pathways, such as external focus cues or analogies, are particularly beneficial for this cohort. Such findings would carry significant implications for Para sport and warrant further exploration. Secondly, as described in study three and section 7.1 above, theoretically informed coaches were implementing a form of variability more closely resembling the *spacing effect* described in psychological research (Cepeda et al., 2006). That is, variability which emphasised *temporal spacing* and *reduced* cognitive effort, as opposed to variability as described in skill acquisition literature which emphasises repeated task switching and *increased* cognitive effort (Farrow & Buszard, 2017; Magill, 2011). As the coaches in study three were already reporting the benefits of this approach, future research should further explore the learning benefits of temporal spacing in sport.

7.5 Final personal reflections

When I began this project, I had no previous experience or knowledge of the field of skill acquisition. However, with a background in psychology and sport psychology (I completed an undergraduate degree in psychology and master's in both experimental cognitive psychology and sport psychology), I had always been fascinated with the mechanisms which contribute to learning, and with the ability to perform learned skills on the biggest stage. I think in many ways this background has shaped my approach to skill acquisition – one which emphasises a deeper understanding of the underlying mechanisms in associated theory, and one which acknowledges the complexities of the human brain; one which isn't bound by rules laid out in academic research. At the same time, my approach as an applied practitioner has focused on trying to provide that same level of understanding to coaches and athletes so they are better able to incorporate ideas themselves into their own complex worlds. As it turns out, having an open mind when entering the world of high-performance sport is more important than I thought. For Para sports, where every athlete has a disability with unique learning and performance implications, it is essential.

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APPENDIX A: Athlete Survey (Study One)

(The original survey was online only via SurveyMonkey so the below is not as exactly what the participants would see. Questions 5-7 which form the basis of study one are presented in the way participants would see. Each question appeared one at a time).

Please tick the box below if you agree to participate

Please provide your name in the box below

Q1. What is your freestyle impairment classification group?

Q2. How often do you get time in training devoted to working on improving specific aspects of your *starts* together with your coach?

Q3. How often do you get time in training devoted to working on improving specific aspects of your *turns* together with your coach?

Q4. How often do you spend time working on improving specific aspects of your *starts* in training on your own?

Q5. How often do you spend time working on improving specific aspects of your *turns* in training on your own?

Q5. Just *before* practicing my starts or turns, my coach will tell me to focus on:

c) What I am doing with my body. For example, how I position my body; how I swing my arms; how I move my head; or how I use my legs, feet, or hands:

(drag the slider to the preferred position or enter a numerical rating in the text box)

Never ——————————————————————— All the time

d) Areas <u>outside</u> of my body in the <u>environment</u> around me. For example, how I should use the wall or the starting block; areas I should look or aim towards; the effect I'm having on the water:

Never ——————————————————————— All the time ☐

Q6. Just *<u>after</u>* performing a start or turn in training, if my coach then gives me feedback on how I performed, the focus of the feedback is around:

a) What I am doing with my <u>body</u>. For example, how I position my body; how I swing my arms; how I move my head; or how I use my legs, feet, or hands:

(drag the slider to the preferred position or enter a numerical rating in the text box)

Never ——————————————————————— All the time ☐

b) Areas <u>outside</u> of my body in the <u>environment</u> around me. For example, how I should use the wall or the starting block; areas I should look or aim towards; the effect I'm having on the water:

Never ——————————————————————— All the time ☐

Q7. When working on improving my starts or turns with my coach in training, my coach will:

d) Get me to experiment with different approaches to practising that skill. For example, changing starting positions; switching left/right hands/feet; speeding something up or slowing it down; or using different apparatus:

Never ——————————————————————— All the time ☐

e) Get me to try to execute the skill in the same way a number of times before moving on to something else:

Never ______________________________ All the time ☐

f) Get me to practice that skill alongside other skills and switch randomly between them. For example, if I'm working on my start, my coach might get me to do one or two starts, and then switch to a turn or a stroke, and then continue to switch between 2 or 3 skills so that no skill is repeated in a block of sets:

Never ______________________________ All the time ☐

Q8. Can you describe any examples of things you feel have worked well for you in training when trying to improve starts or turns? For example, types of instructions, feedback, cues, things to focus on, use of apparatus, or other types of training exercises? (Optional)

Q9. And finally, can you describe any examples of things which you feel have not worked well for you in training when trying to improve starts or turns? Or things you feel you struggle with, or prevent you from learning effectively? (Optional)

APPENDIX B: Study 1 Extended Descriptives

Table A1

Extended descriptive statistics for focus of attention cues and impairment classification.

	Classification	N	Mean	SD	Skewness Z Score	Shapiro-Wilk W	Shapiro-Wilk p
Internal instructions	Physical impairment	20	63.5	33.7	-1.254	0.893	0.030
	Intellectual impairment	10	68.0	30.5	-1.776	0.869	0.097
External instructions	Physical impairment	20	63.0	29.5	-1.074	0.937	0.207
	Intellectual impairment	10	52.3	23.6	-1.109	0.889	0.164
Internal feedback	Physical impairment	20	65.3	27.1	-0.668	0.935	0.191
	Intellectual impairment	10	75.4	26.2	-0.758	0.848	0.055
External feedback	Physical impairment	20	63.9	23.7	-1.189	0.938	0.219
	Intellectual impairment	10	64.1	21.0	0.719	0.905	0.250
Total Internal	Physical impairment	20	64.4	26.5	-1.303	0.936	0.204
	Intellectual impairment	10	71.7	21.4	0.147	0.814	0.022
Total External	Physical impairment	20	63.5	20.3	-1.146	0.959	0.530
	Intellectual impairment	10	58.2	14.2	2.443	0.795	0.012

Table A1

Extended descriptive statistics for practice type and impairment classification.

	Classification	N	Mean	SD	Skewness Z Score	Shapiro-Wilk W	Shapiro-Wilk p
Blocked	Physical impairment	20	58.1	27.3	-1.771	0.907	0.055
	Intellect impairment	10	75.4	23.0	-0.520	0.897	0.201
Within	Physical impairment	20	48.0	26.9	-0.502	0.909	0.061
	Intellect impairment	10	48.4	24.1	-1.006	0.960	0.787
Between	Physical impairment	20	30.6	22.7	0.596	0.936	0.203
	Intellect impairment	10	37.9	31.1	0.537	0.924	0.396

Appendix C: Coach Semi-Structured Interview (Study Two)

Some of these questions may be quite difficult to answer, therefore you don't **need** to have an answer, just try to answer where you can.

There are also no right or wrong answers. The purpose of this exercise is purely for me, as a research student, to try to get some idea about some of the practices and approaches used in training by expert coaches on the programme.

1. In relation to the technical aspect within the session, what areas were you working on today?
2. What sort of things were you encouraging the athlete to focus on/think about during this technical aspect of the session, and was there any specific thinking around this?

   (Probes: so encouraging focus on this… can you give any specific examples of how you might do that? Types of cues/language? Okay, so you have described cues which help focus on body movements – are there any other types of cues you use?)
3. During the rest of the session, outside of the technical element, was there anything else you were working on with the athlete, and if so, what kind of things were you encouraging the athlete to focus on/think about for these? (Again, any reason why if appropriate).
4. In terms of the session as a whole, how did you structure it and what was the thinking behind this?
5. How did you structure the technical part of the session or the practice blocks specifically, and what was the thinking behind this?
6. If you were working with an athlete who was of a different age, or skill level, or disability, would you have adapted any aspect of the way you coached the session, or structured the session?
7. (We may have already covered this). Were there any other approaches or techniques used in the session which might not be easy to spot in the video in relation to, for example, how you interacted with the athlete, using apparatus, or organising and structuring the session, and if so what was the thinking behind it?
8. Are there any examples, from either this session or a previous technically focused session, of techniques or approaches you have used which you feel have worked well for an athlete in terms of helping them to learn a skill? (Why?).
9. Are there any examples, from either this session or a previous technically focused session, of techniques or approaches you have used which you feel have <u>not</u> worked well for an athlete in terms of helping them to learn a skill? (Why?).
10. Is there any other comment that you would like to make in relation to coaching and learning skills?

Appendix D: Coach Semi-Structured Interview (Study Three)

Some of these questions may be quite difficult to answer, therefore you don't **need** to have an answer, just try to answer where you can.

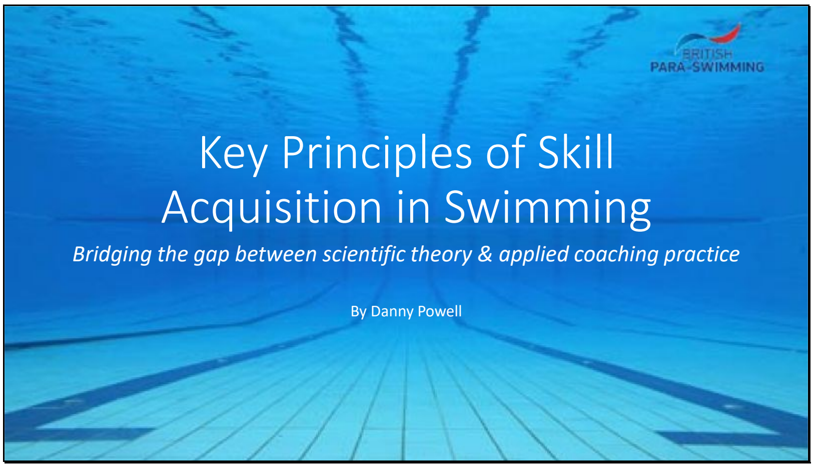
There are also no right or wrong answers. The purpose of this exercise is purely for me, as a research student, to try to get some idea about some of the practices and approaches used in training by expert coaches on the programme.

1. In relation to the technical aspect within the session, what areas were you working on today?
2. What sort of things were you encouraging the athlete to focus on/think about during this technical aspect of the session, and was there any specific thinking around this?

   (Probes: so encouraging focus on this… can you give any specific examples of how you might do that? Types of cues/language? Okay, so you have described cues which help focus on body movements – are there any other types of cues you use?)
3. During the rest of the session, outside of the technical element, was there anything else you were working on with the athlete, and if so, what kind of things were you encouraging the athlete to focus on/think about for these? (Again, any reason why if appropriate).
4. In terms of the session as a whole, how did you structure it and what was the thinking behind this?
5. How did you structure the technical part of the session or the practice blocks specifically, and what was the thinking behind this?
6. (We may have already covered this). Were there any other approaches or techniques used in the session which might not be easy to spot in the video in relation to, for example, how you interacted with the athlete, using apparatus, or organising and structuring the session, and if so what was the thinking behind it?
7. How, if at all, has the skill acquisition development process influenced your approach to the use of language or coaching cues?
8. How, if at all, has the skill acquisition development process influenced your approach to how you structure sessions, practice blocks, or training weeks?
9. How, if at all, has the skill acquisition development process influenced your approach to the use of more implicit techniques such as the use of constraints?
10. What aspects of the skill acquisition development process did you find to be effective and why?
11. What aspects of the skill acquisition development process did you find to be ineffective and why?
12. Is there any other comment that you would like to make in relation to coaching and the skill acquisition development process?

Appendix E: Skill Acquisition Education Intervention 1

Slide 1



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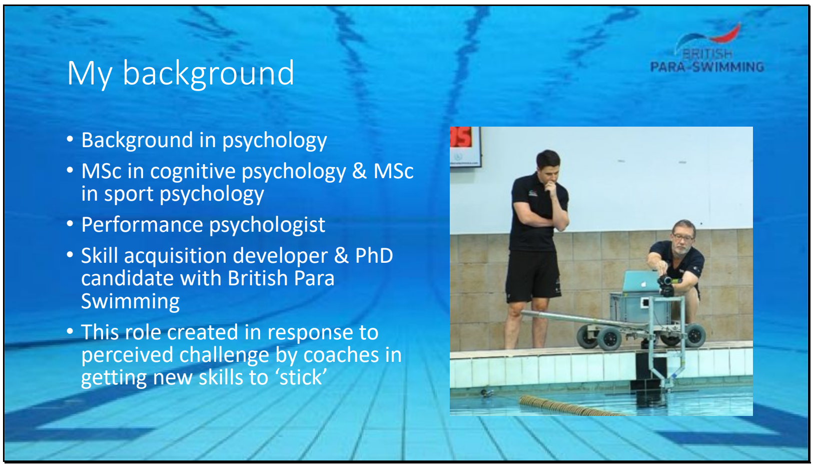

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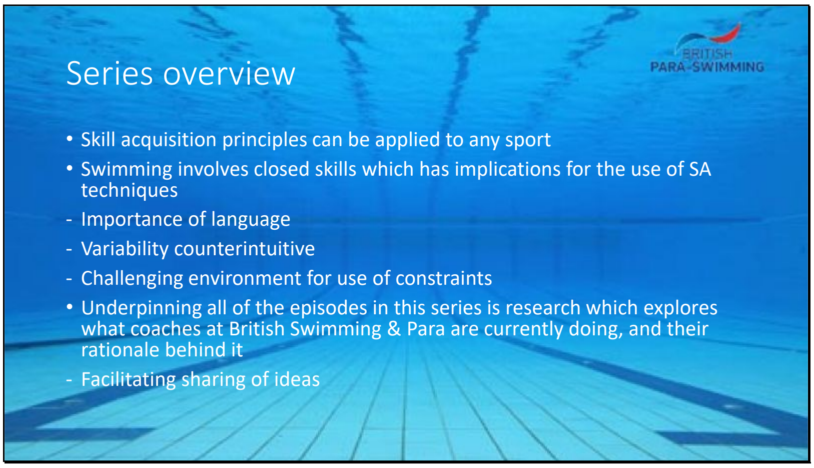

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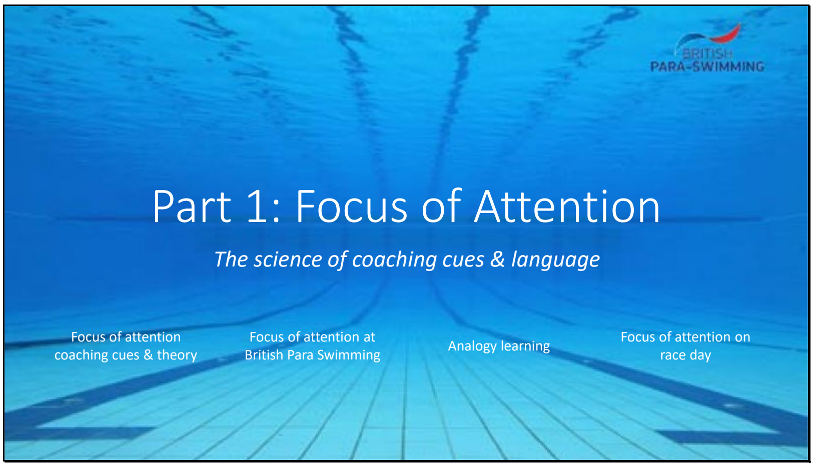

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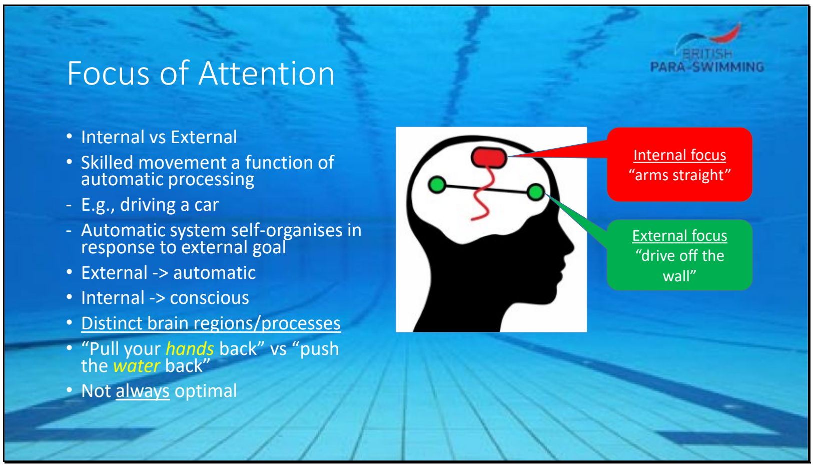

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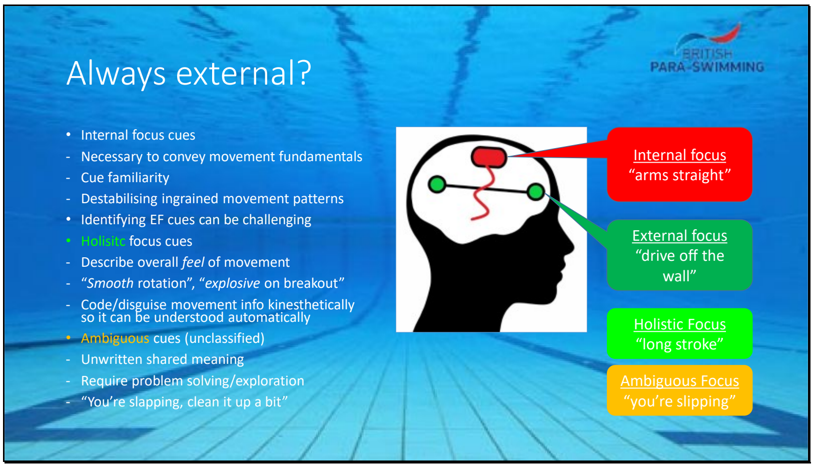

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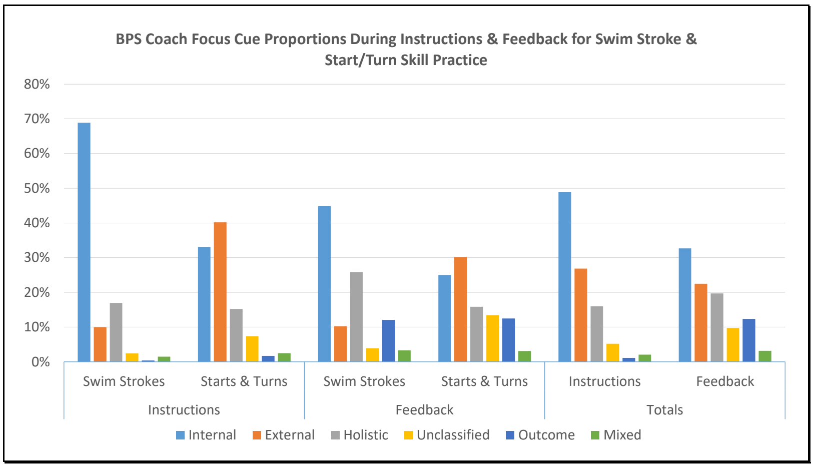
Slide 10



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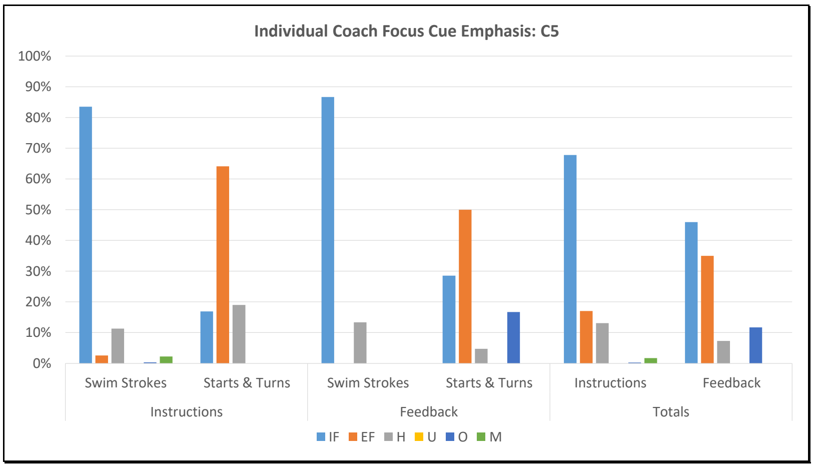
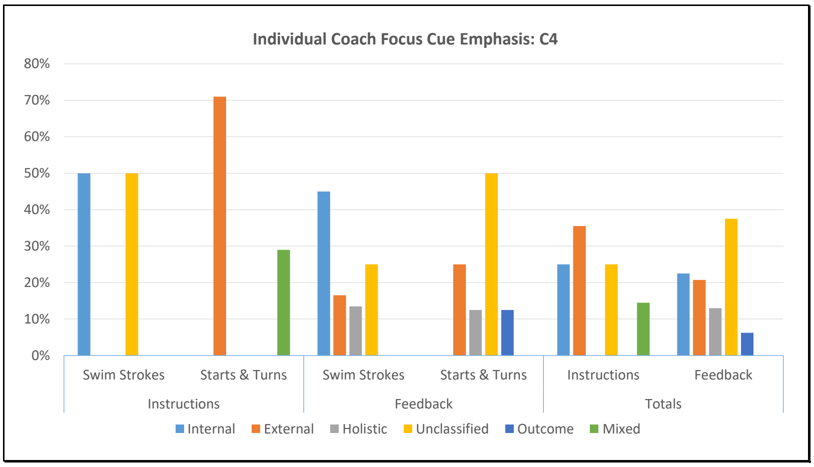
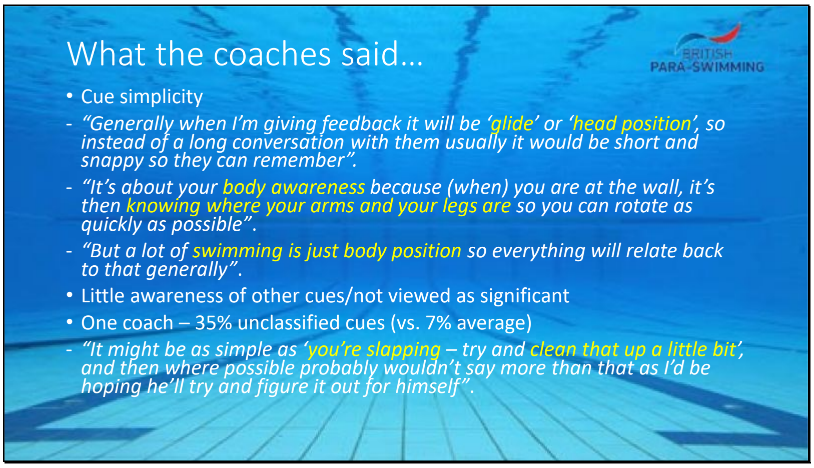


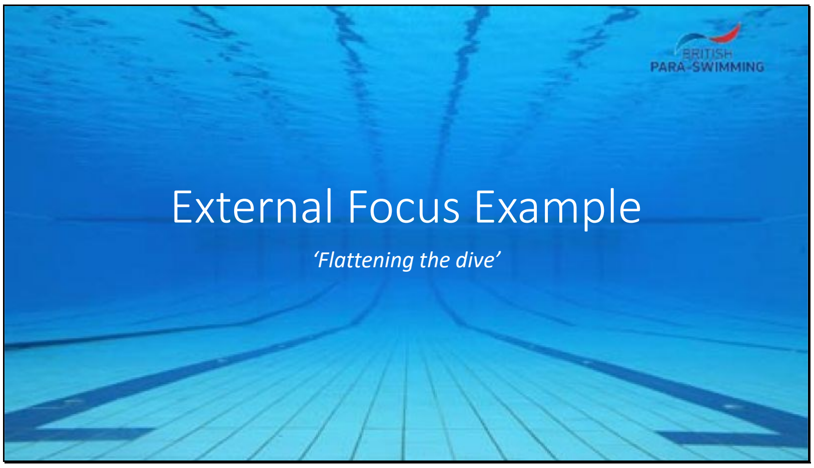
Slide 12



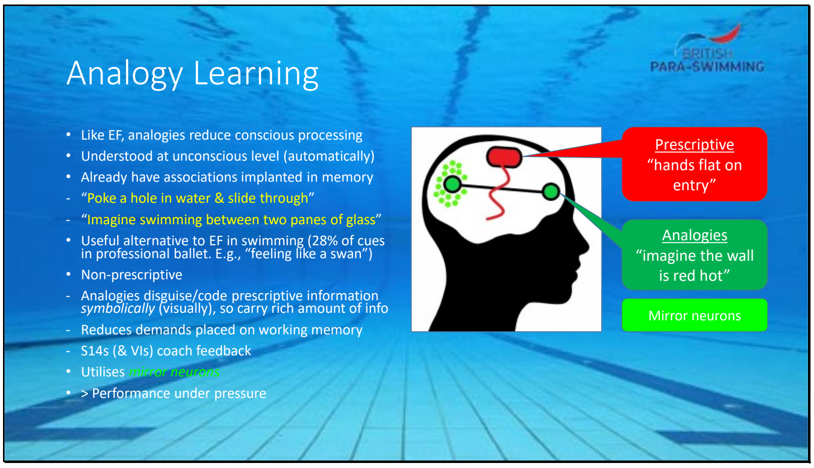
Slide 13



Slide 14



Slide 15



Slide 16

Coach analysis: analogy learning

BRITISH PARA-SWIMMING

- 5 coaches observed using at least one example of analogy learning
- *"It's almost like a windscreen wiper action". "So I want you flat like a soldier standing to attention".*
- None could be said to be the main focus of instructions
- E.g., C7 used two analogies during one set of freestyle instructions but these were used alongside 22 other FOA cues (many prescriptive) during two minutes of dialogue

Slide 17

Focus of attention on race day

BRITISH PARA-SWIMMING

"Make sure your leg is straight on the block" ✗	"Drive off the block" ✓
"Watch that hand on entry" ✗	"Explode on breakout" ✓
"Six underwater leg kicks" ✗	"Controlled on the first 50" ✓
"Think about that arm on recovery" ✗	"Clean on every turn" ✓

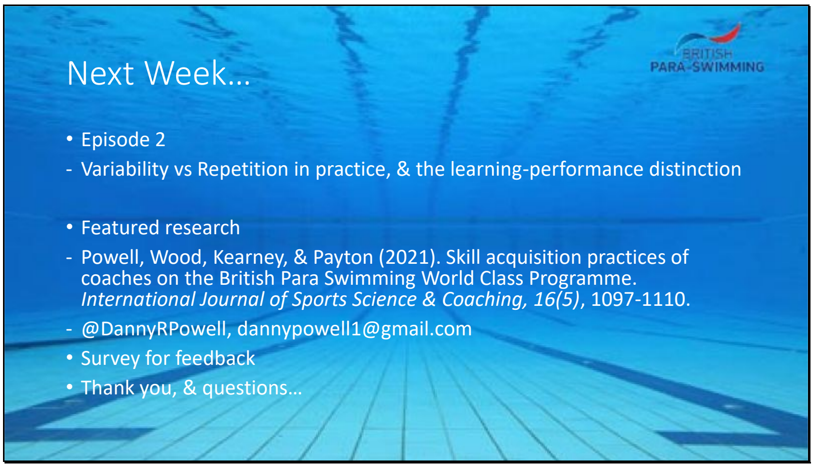
Slide 18

Key Takeaways

BRITISH PARA-SWIMMING

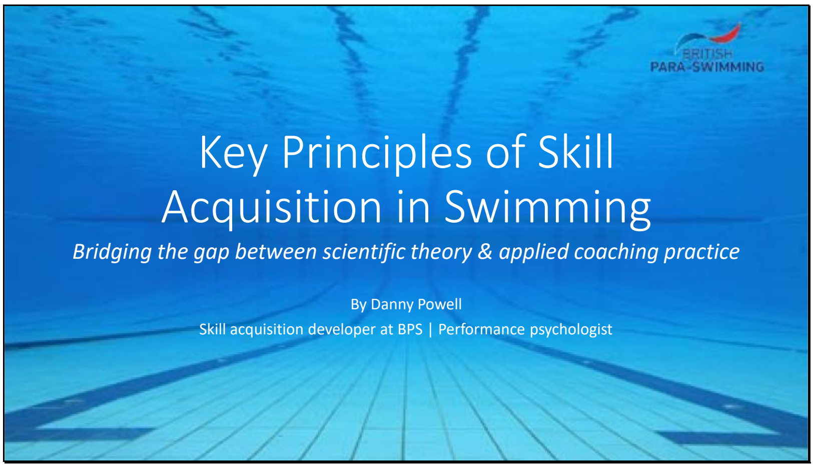
- Awareness of internal & external focus & their effects
- Internal, holistic/ambiguous cues also beneficial
- Analogy learning
- Learning vs performance cues

Slide 19



Appendix E: Skill Acquisition Education Intervention 2

Slide 1



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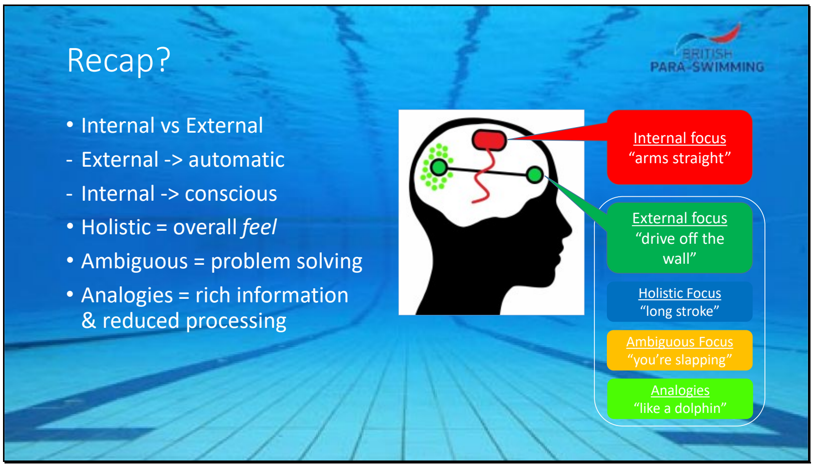

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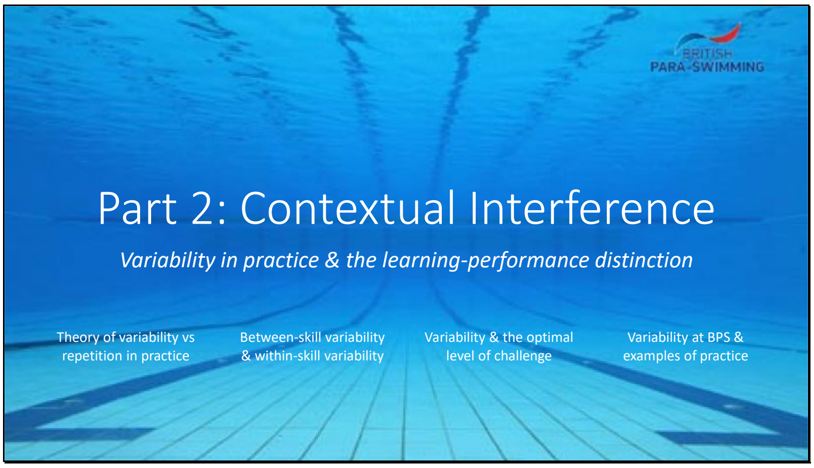

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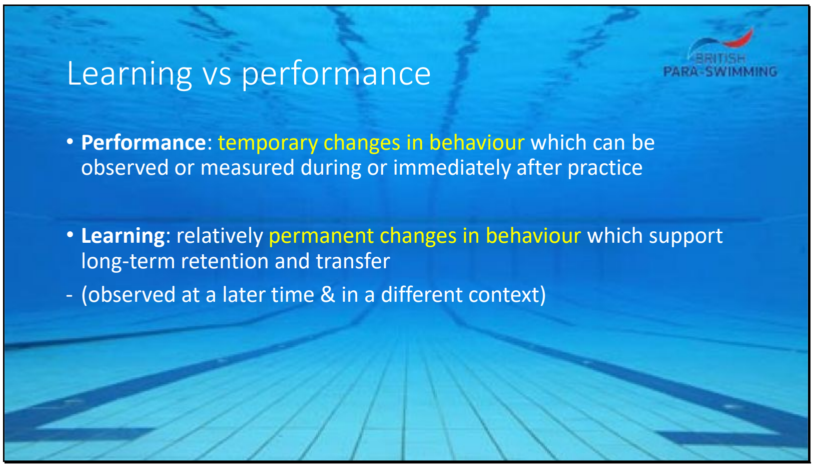

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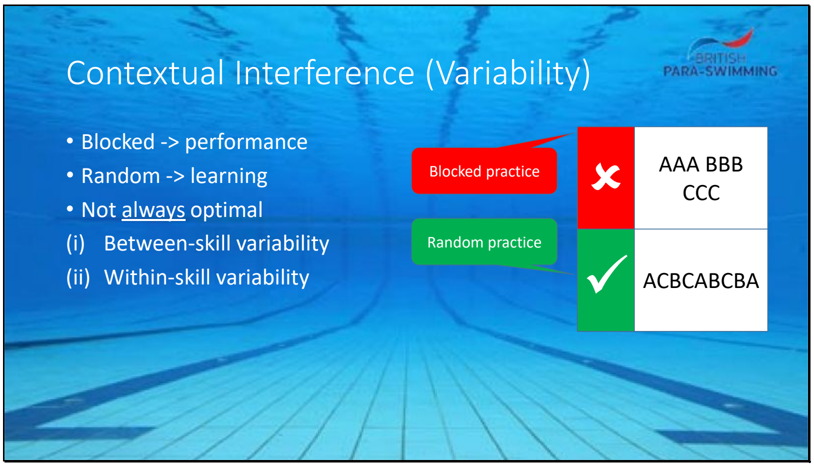

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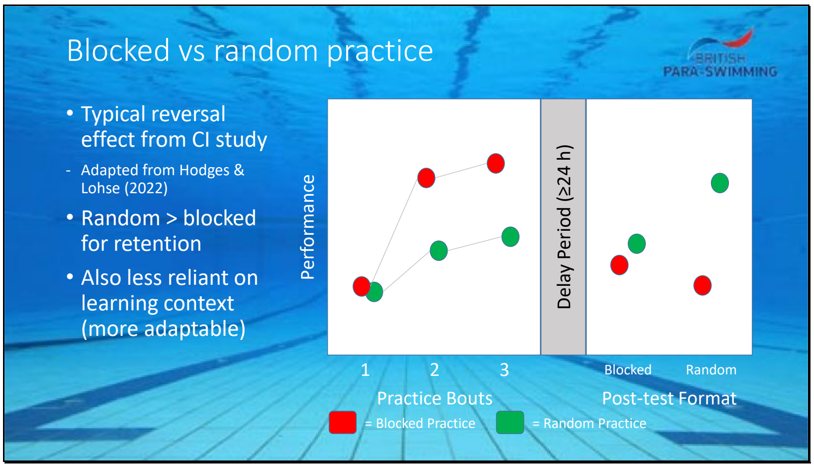

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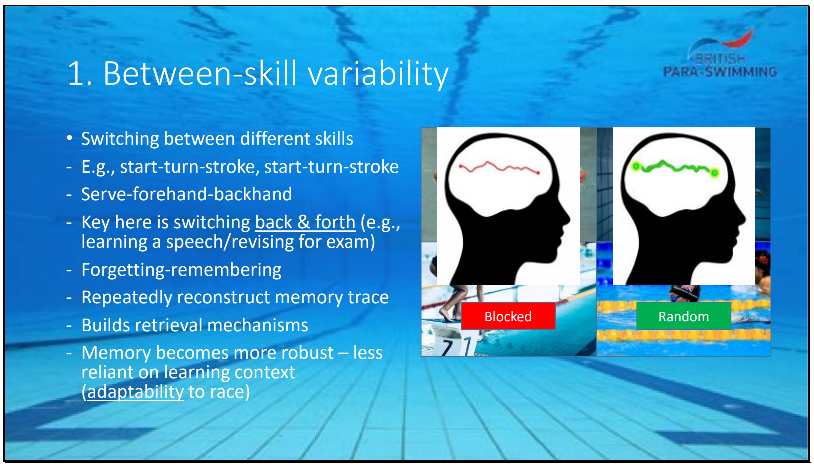

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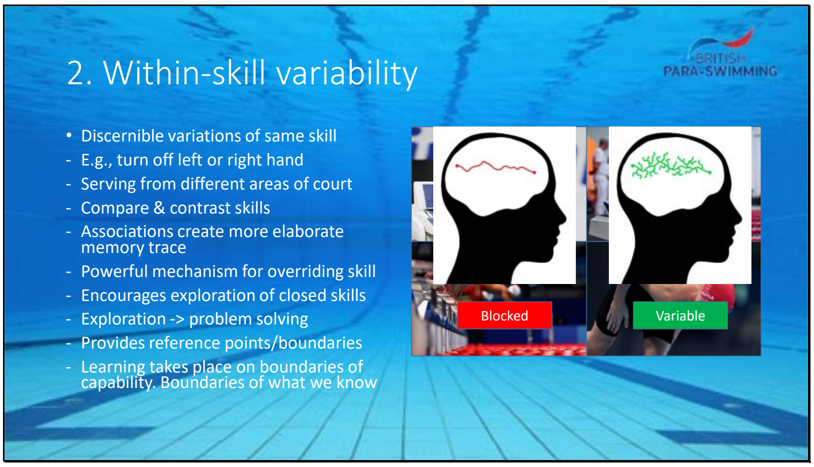
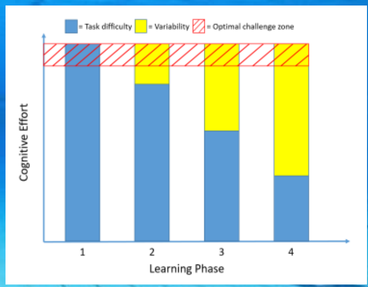


Slide 9

The influence of task difficulty

BRITISH PARA-SWIMMING

- Initial findings for complex skills mixed
- Suggestions that certain level of skill required to reap benefits of variable practice
- Challenge Point Framework (for learning)
- Learning influenced by cognitive effort
- Optimal level of challenge
- Task should be difficult but not too difficult (≈85% new research)
- Complexity + CI potentially exceeds optimal level for learning
- Learning stage
- Skill level
- Task complexity



Slide 10

Gradual increase in variability

BRITISH PARA-SWIMMING

- Idea that a certain level of skill required supported by findings that a gradual increase in variability enhanced learning
- Blocked -> serial -> random
- Serial practice involves less uncertainty
- E.g., golf & basketball skills
- Gradual inc. > blocked & random
- Through repetition athlete is able to perform skill & level of challenge reduces
- Increase challenge & build skill memory
- Potential limitation is difficulty level predetermined - not linked to athlete skill level

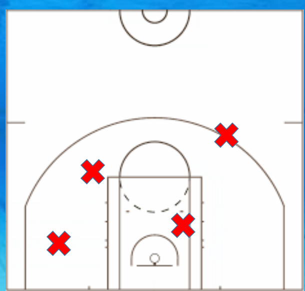
Blocked	AAA BBB CCC
Serial	ABC ABC ABC
Random	ACBCABCBA

Slide 11

Win-Shift/Lose-Stay

BRITISH PARA-SWIMMING

- Practical application of CI effect
- Variability contingent on performance
- Execute the skill (win) = shift
- Fail to execute (lose) = stay



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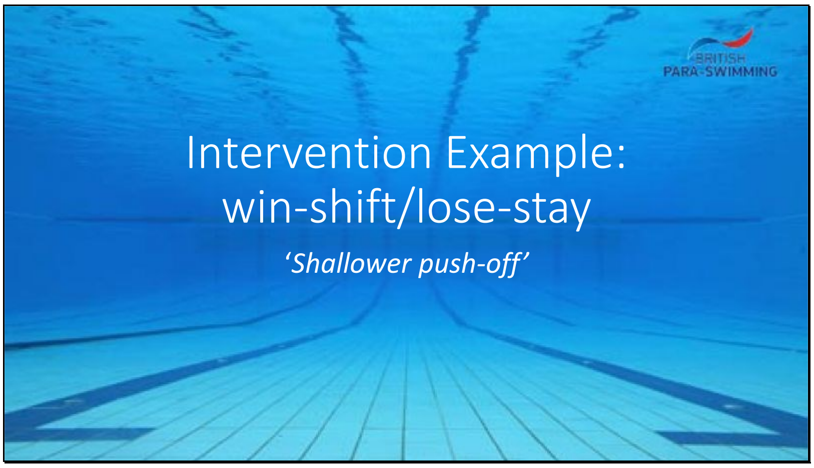

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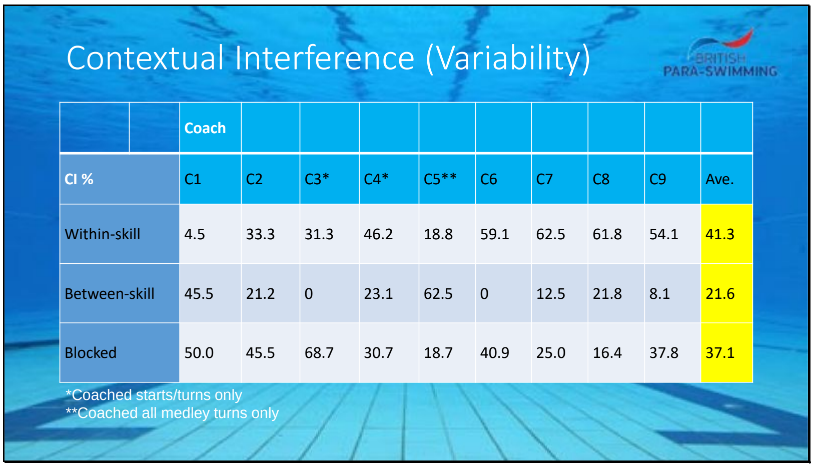
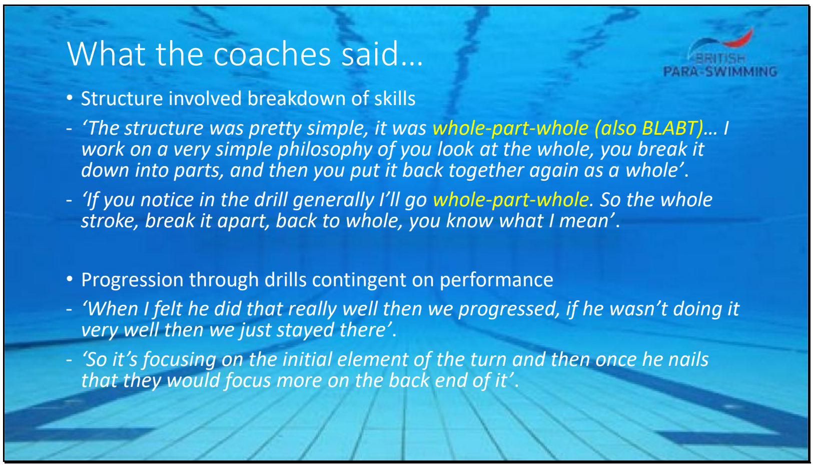


	Coach									
CI %	C1	C2	C3*	C4*	C5**	C6	C7	C8	C9	Ave.
Within-skill	4.5	33.3	31.3	46.2	18.8	59.1	62.5	61.8	54.1	41.3
Between-skill	45.5	21.2	0	23.1	62.5	0	12.5	21.8	8.1	21.6
Blocked	50.0	45.5	68.7	30.7	18.7	40.9	25.0	16.4	37.8	37.1

*Coached starts/turns only
**Coached all medley turns only

Slide 15



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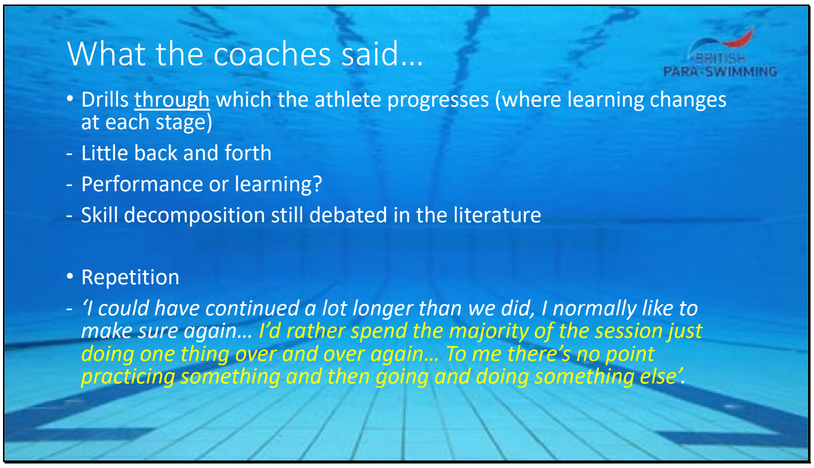

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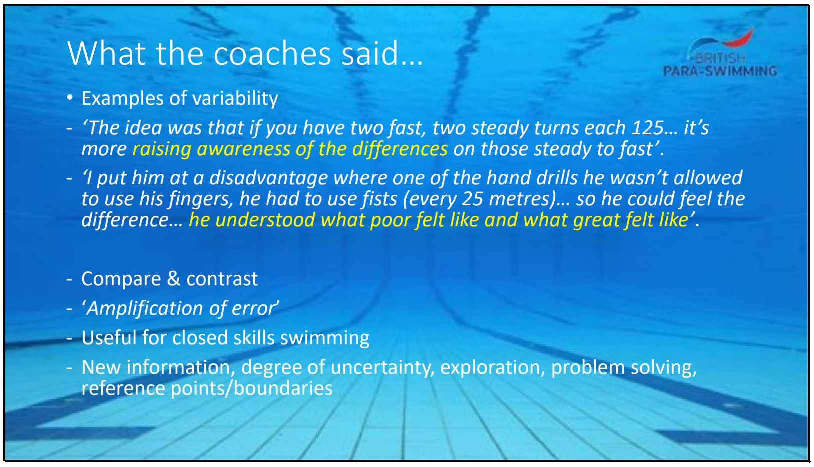

Slide 18

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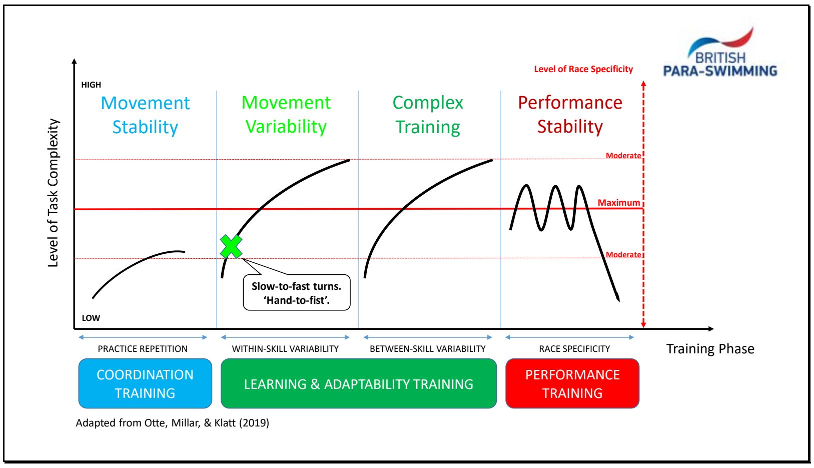

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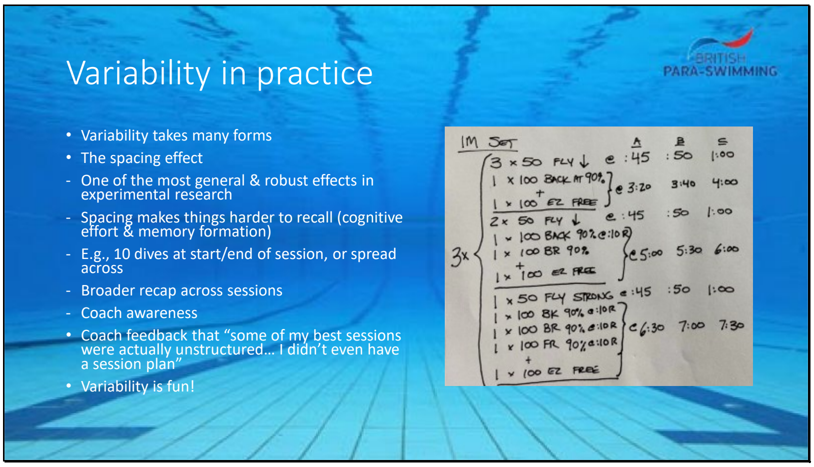

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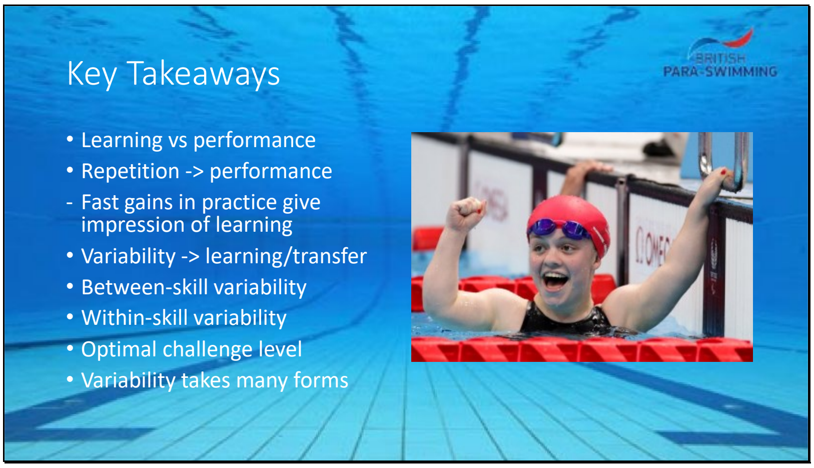

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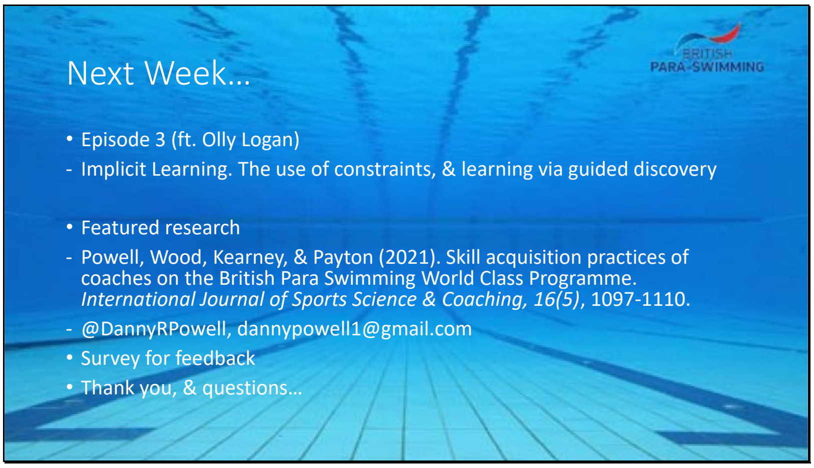
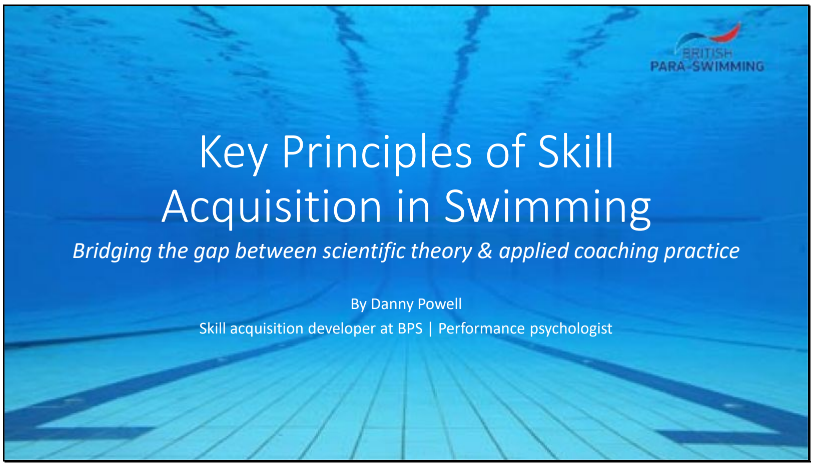


Appendix E: Skill Acquisition Education Intervention 3

Slide 1



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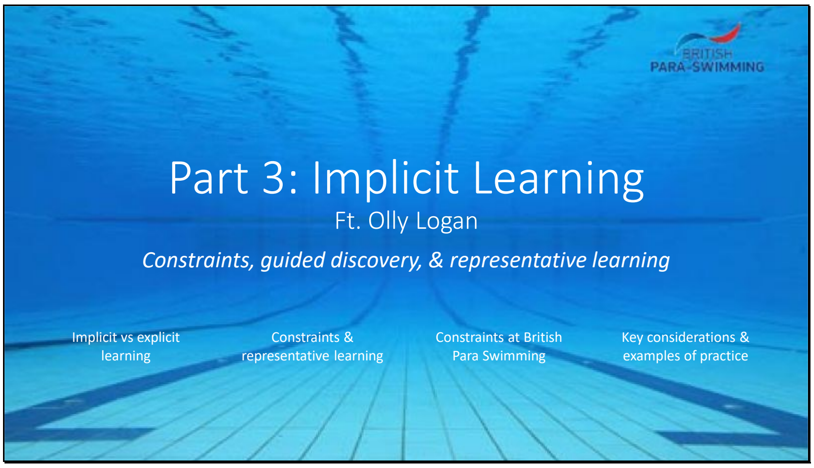

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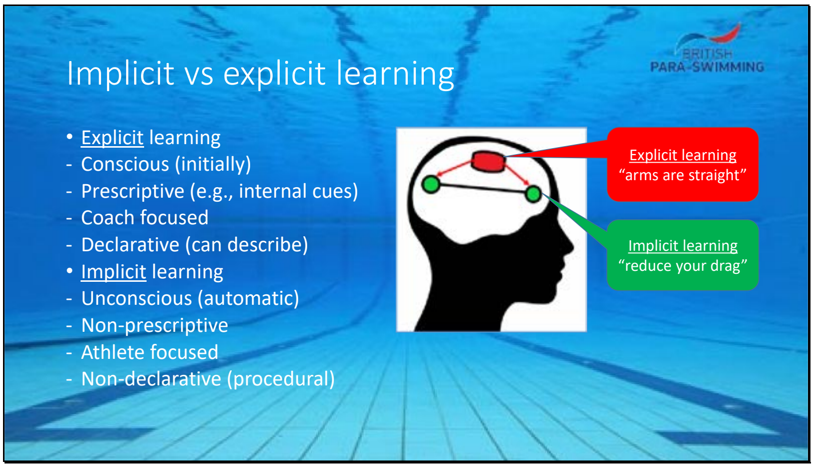

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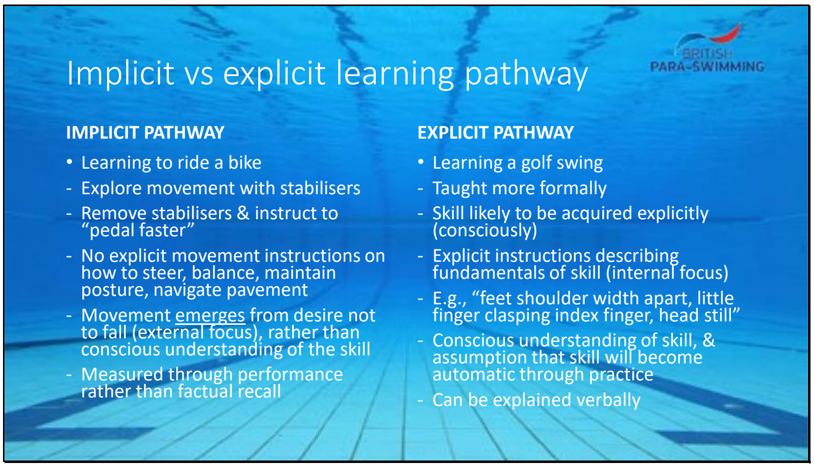

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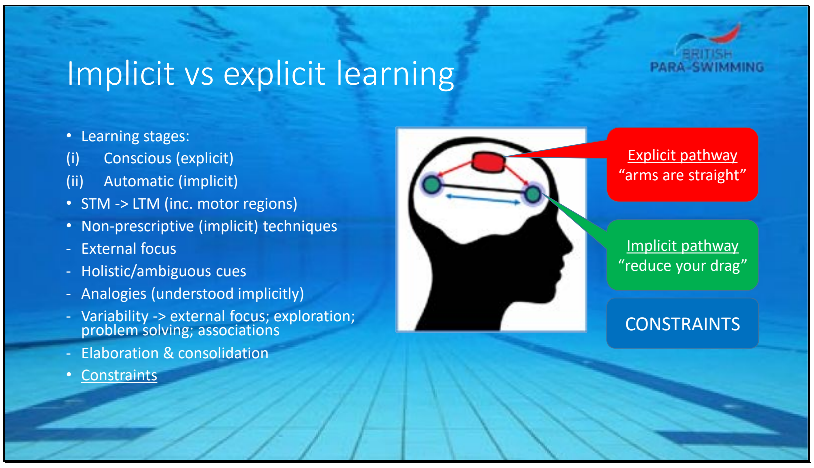

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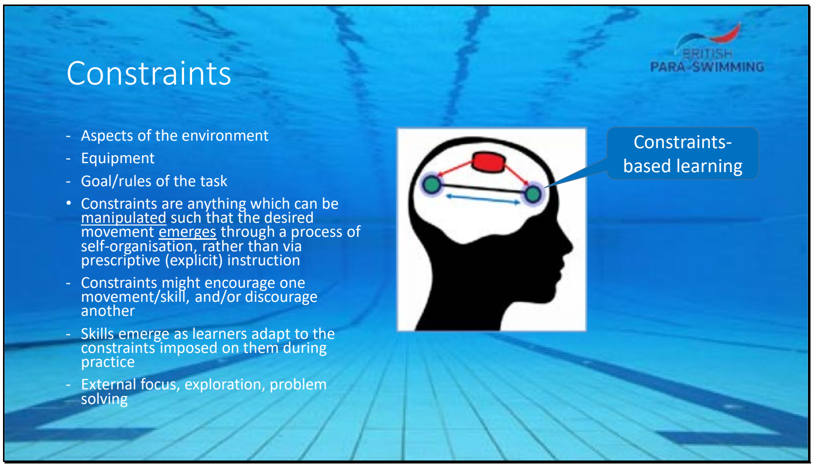

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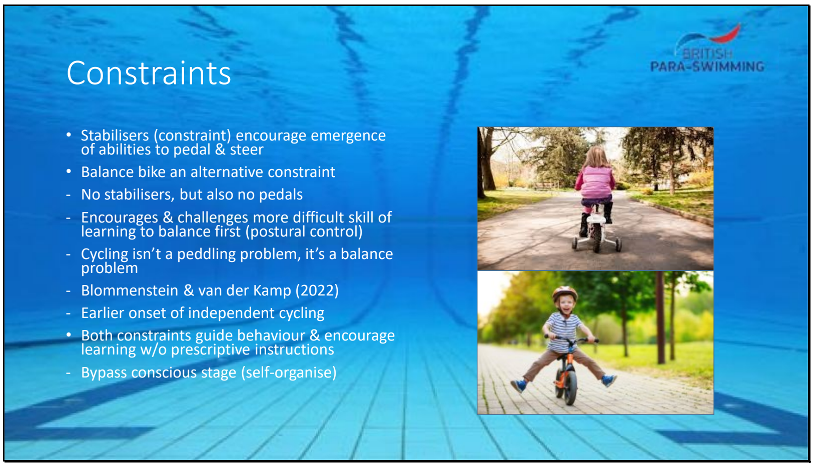

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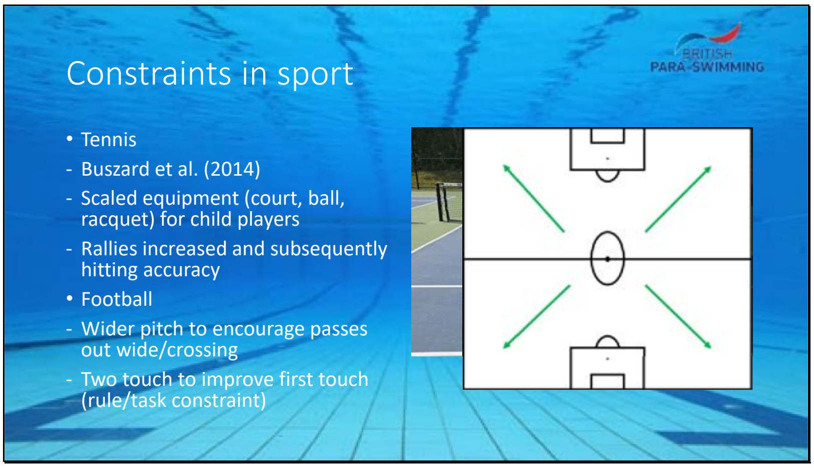

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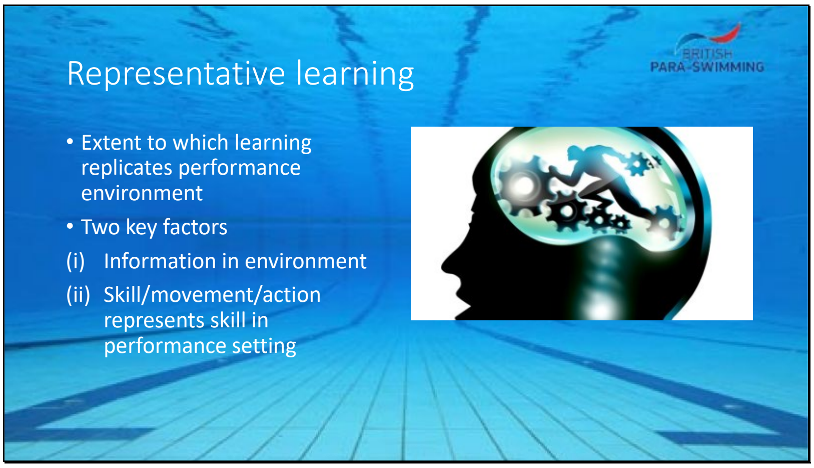

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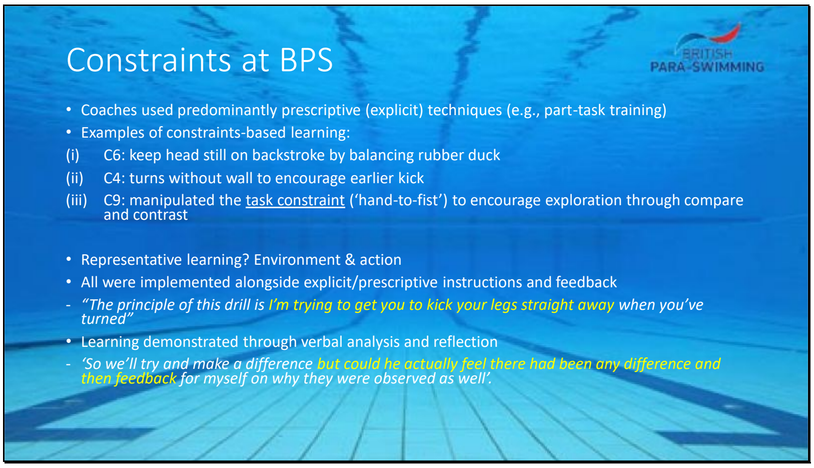

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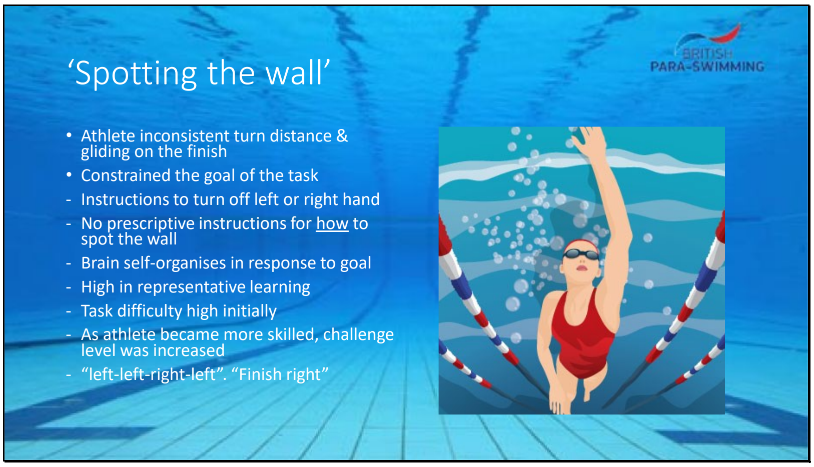

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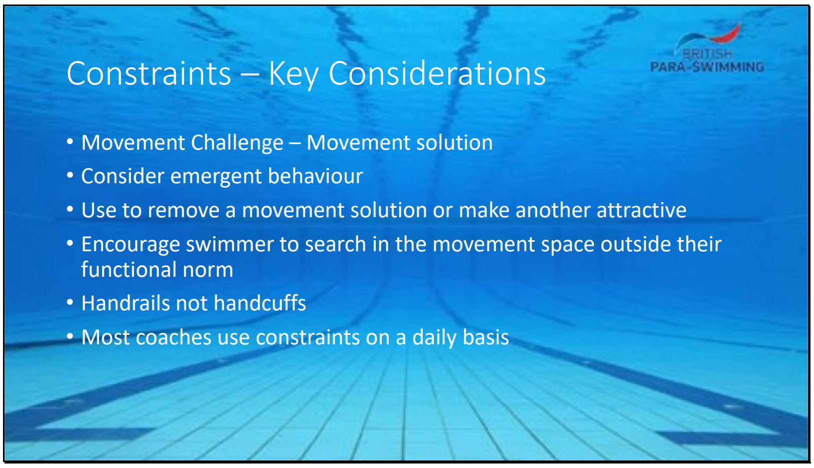

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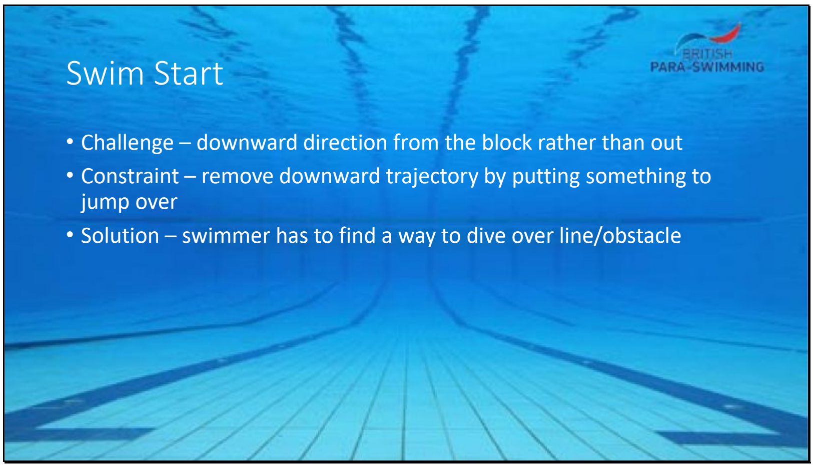

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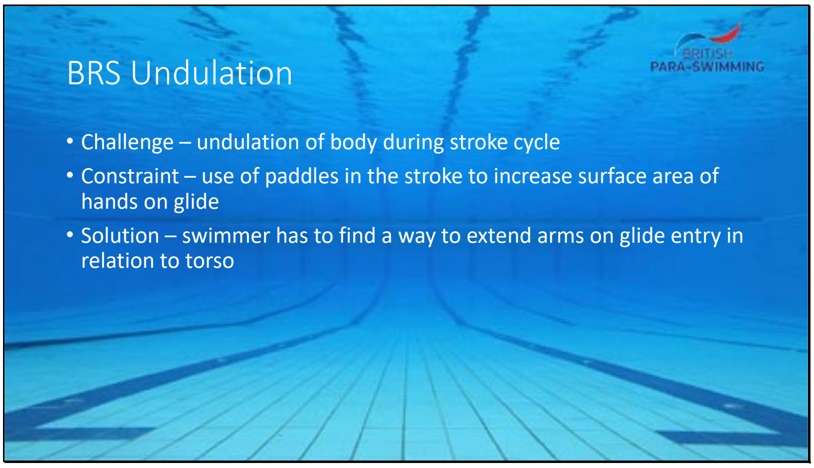


Slide 17

Other examples

- Encouraging underwater fly kick on key sets – band across the lanes
- Depth off start or turn – pullbuoy tied to a weight
- Increase upbeat on fly kick – vertical kick or power tower
- Dive entry effectiveness – dive and glide for distance
- BRS underwater – Dive, kick, pullout and recovery for distance
- Turns practice spotting – variable start distance

Slide 18

Skill Interventions

- Destabilisation
- Search phase (explore degrees of freedom to achieve task goal)
- Discovery phase (explore task solutions and stabilise them)
- Exploitation phase (test execution at varying degrees of context)

Exploitation phase (test execution at varying degrees of context)

Discovery phase (explore task solutions and stabilise them)

Search phase (explore degrees of freedom to achieve task goal)

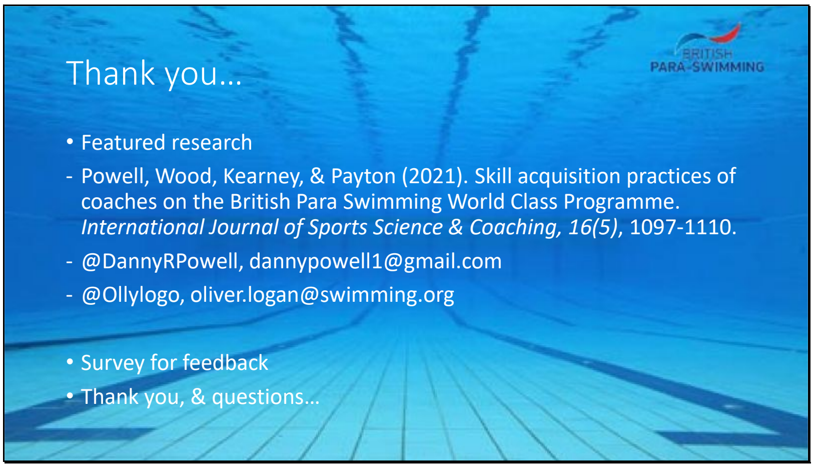
Destabilisation

Slide 19

Key Takeaways

- Implicit vs explicit learning
- Conscious -> automatic stage
- Constraints non-prescriptive
- Manipulate constraints to encourage emergence of skills
- Representative learning
- Consider how & why, & what emergent behaviour you want to encourage

Slide 20


Thank you…
BRITISH PARA-SWIMMING
• Featured research
- Powell, Wood, Kearney, & Payton (2021). Skill acquisition practices of coaches on the British Para Swimming World Class Programme. *International Journal of Sports Science & Coaching, 16(5)*, 1097-1110.
- @DannyRPowell, dannypowell1@gmail.com
- @Ollylogo, oliver.logan@swimming.org
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• Thank you, & questions…