An extended challenge-based framework for practice design in sports coaching

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Abstract

The challenge-point framework as a model for thinking about motor learning was first proposed in 2004. Although it has been well-cited, surprisingly this framework has not made its way into much of the applied sport science literature. One of the reasons for this omission is that the original framework had not been encapsulated into a paper accessible for sports practitioners. The framework had mostly a theoretical focus, providing a mechanistic summary of motor learning research. Our aims in this paper were to explain and elaborate on the challenge point framework to present an applied framework guiding practice design. We connect the framework to other theories that involve predictive coding, where information is attended when it disconfirms current predictions, providing a strong signal for learning. We also consider how two new dimensions (learners' motivation and practice specificity) need to be considered when designing practice settings. By moving around the different dimensions of functional difficulty, motivation, and specificity, coaches can optimize practice to achieve different learning goals. Specifically, we present three general "types" of practice: practice to learn, to transfer to competition, and to maintain current skills. Practical examples are given to illustrate how this framework can inform coach practice.

Keywords: Motor learning, practice conditions, skill acquisition, practice scheduling, transfer

Introduction

In this paper, we outline the challenge-point framework as a model of motor learning (Guadagnoli & Lee, 2004) and expand this framework to apply to sports coaching. The original framework outlines how the difficulty of a task ("nominal" difficulty), needs to be considered with respect to how challenging that task is for the individual ("functional" difficulty). The framework was developed based mostly on empirical knowledge garnered through research on practice organization and the contextual interference effect as well as augmented feedback and issues of feedback guidance. In particular, principles developed in the challenge framework were based on distinctions and dissociations noted between immediate gains in practice (i.e., performance effects) and long-term learning, as assessed through retention and transfer designs (for a relatively recent discussion of these distinctions see Kantak & Winstein, 2012). According to the framework, increased difficulty during practice might be detrimental for performance in the short-term, but is ultimately beneficial for learning in the long-term (Guadagnoli & Lee, 2004).

The challenge-point framework nicely complements ideas inherent to deliberate practice theory (Ericsson et al., 1993). This is a theory of long-term skill acquisition where accumulation of playing experiences are eschewed in favour of specific types of practice experiences designed to improve performance). The challenge-point framework is also highly compatible with ideas concerning desirable difficulties for learning (e.g., Bjork, 2017; Bjork & Bjork, 2011) and cognitive load theory (e.g., Paas et al., 2010), developed and researched mostly in educational domains to explain learning and memory effects. In discussing this challenge framework, we also draw upon behavioural-neuroscience ideas concerning predictive coding (e.g., Hutchinson & Barrett, 2019) and reward predictions (Caplin & Dean, 2008; Hikosaka et al., 2008). This helps us to situate the framework with other psychological theories, in terms of the individual as a predictive system who learns when informational expectations are violated. Our goals are therefore twofold; to champion the challenge-point framework as an empirically based philosophy for coaching design and expand upon the original framework with respect to difficulty and the various goals of coaching that impact practice.

In this review, we will start by providing a summary of the challenge point framework as it was originally articulated (Guadagnoli & Lee, 2004). We then have three main points where we elaborate on the original framework, seeking to improve its translation to coaching practice. **First**, with respect to application, we must recognize that although difficulties or challenges in practice can be beneficial for learning, such challenges can also have motivational “costs”. These costs are a product of introducing more errors into practice and performance. There is a vast literature linking perceptions of competence and the meeting of competence needs to motivation (e.g., Deci & Ryan, 1980, 2012; Elliot & Dweck, 2013; Ryan & Deci, 2000), particularly in sports (e.g., Rottensteiner et al., 2015). Reduced motivation has negative effects on learning because learners may stop practicing sooner (Lee & Wishart, 2005) and because reduced motivation might make learning less effective in and of itself (Abe et al., 2011; Wulf & Lewthwaite, 2016).

A **second** point regarding the challenge point framework and coaching is that not all difficulties are equally beneficial for learning (Bjork & Bjork, 2011, 2020; Hodges & Lohse, 2020). It is not difficulty in and of itself which is good for learning but the psychological processes which are engendered by the difficulty. These types of process difficulties have been termed “desirable” because they beneficially enhance encoding of information and its retrieval (Bjork & Bjork, 2011). We suggest that a key factor in determining which difficulties are desirable is practice specificity (Healy & Wohldmann, 2012); that is, do the constraints of practice match those likely to be encountered in competition? For instance, task speed is likely only to be a desirable difficulty if response time is constrained in competition (Hodges & Lohse, 2020). A number of conditions of practice have been shown to impact on learning and transfer based on the match between the two scenarios, such as training under conditions of anxiety (e.g., Lawrence et al., 2014), matching of visual conditions during practice and test (Proteau et al., 1992) and maintaining of perception-action links integral to the task (e.g., Pinder et al., 2009).

Our **third** point regarding coaching implications of the challenge framework is that the dynamic nature of the competitive environment makes the “optimal” difficulty for an individual (or team) a moving target across practice sessions or across seasons (see also Lohse & Hodges, 2015 where practice decisions are discussed with respect to different timescales of practice). The difficulty of a particular practice scenario can change in the short-term, perhaps due to fatigue or arousal, as well as over the long term as a result of learning. Moreover, goals of practice may change, such that at times it may be beneficial to practice with high functional difficulty to optimize learning and improvement; at other times it may be beneficial to practice with lower relative difficulty, reinforcing successes and promoting competence. We elaborate on and provide evidence for each of these issues below but ultimately, we suggest that coaches can manipulate functional difficulty, motivation, and specificity to optimize different practice goals.

Broadly, we conceptualize these goals as three different “types” of practice: practicing to learn (forsaking short-term performance with the goal of long-term learning), practicing to transfer (maintaining high levels of difficulty and specificity to facilitate transfer of acquired skills to competition), and practicing to maintain (reducing the difficulty to retain existing skills and growing athlete’s perceptions of their own competence). Although retention and transfer are often used interchangeably as “markers” of learning (e.g., Schmidt & Lee, 2019), here we distinguish the two as they may differentially impact practice decisions. There are situations where learning can occur, but that the output of that experience is limited to a narrow set of conditions with no or only partial transfer to other, desirable situations, such as competition. For example, in perceptual-skills training, where individuals are trained to respond to videos occluded in time in order to encourage anticipation, there is evidence of learning (i.e., pre- to post-test improvements on the practised task), but limited evidence of improvements under game-like conditions (e.g., Smeeton et al., 2005). It is likely that for continued learning and transfer, practice conditions need to increase in their specificity to the game, with experiences that scaffold on an initial relatively narrow set of practice/performance conditions. Although transfer may always be the ultimate goal of practice, practice decisions may be more or less skewed to this consideration.

In the final sections of the paper, we discuss some applied examples of how concepts related to our extended challenge framework can be applied in coaching practice.

The Challenge Point Framework for Optimizing Learning

Motor learning research, based on the learner as both an active and passive processor of information, resulted in the challenge point framework back in the early 2000s (Guadagnoli & Lee, 2004). In this paper, the authors provided a conceptual framework for thinking about motor performance (what is seen at the current time or at the end of a practice drill) as different from learning (what is observed at later time points, after time has passed). The framework was based on empirical research from multiple lines of study, in order to give some prescription for effective practice design. In addition to distinctions between present performance and later learning (dissociating between the two with respect to practice conditions), the framework was developed based on evidence showing that a more nuanced approach to consideration of practice effects is necessary, one that is sensitive to individual differences. The optimal challenge point is one that is individually suited to the learner to challenge their current level of performance to maximize opportunities for learning. This challenge is conceived as opportunities for acquiring novel information in the practice environment, whereby new information is viewed as the catalyst for change and ultimately improvement and learning. The challenge framework was formulated based on ideas related to effortful practice and evidence that cognitive effort related to planning, memory, and processing of information is a prerequisite for learning to take place (Lee et al., 1994).

There are three basic principles related to the challenge point framework that can be used to design practice. The first is that new information (or a degree of uncertainty), is needed in practice for long term improvements in the current level of skill. In this way, learning is a problem-solving process where information is used to adapt behaviour and learn over the long term. The second principle is that an "optimal" level of difficulty or challenge is needed to get this information based on pre-existing capabilities. It is not merely new information but useable information that is needed. A learner's information processing capabilities limit the amount of potential information that is interpretable. Related to this last point, is the third principle, that an appropriate level of challenge is dependent on the athlete's skill/experience and their information processing capacity relative to the demands of the task.

Individual differences can make a task more or less difficult for each person, referred to as a task's *functional* difficulty (Guadagnoli & Lee, 2004). Although functional task difficulty was conceived as the task's actual difficulty in relation to the athlete, it could also be thought of as the task's perceived difficulty. Perceived difficulty can vary over attempts within the same athlete or between individuals of similar levels of skill. *Nominal* task difficulty, however, is a more objective property of the task, which remains the same regardless of the person (Guadagnoli & Lee, 2004). Because the same skill or role will be more or less challenging for different individuals, this is why functional task difficulty (actual or perceived) is such an important concept. For similar ideas about individual appropriate cognitive load based on the task demands see Paas et al. (2003).

There are some striking examples of differences between learning conditions dependent on whether the effects are measured during practice or in a retention or transfer test. A well-known example is the contextual interference effect (for reviews see Magill & Hall, 1990; Lee, 2012; Wright & Kim, 2020). In the extreme example of the contextual interference effect, two groups are compared that practice different motor skills (usually three skills, such as different serves in tennis or different shot types in basketball). These skills are practised in either a repeating blocked order, as is typical of many practice drills, or in an interleaved random schedule, more typical of competitive-game like scenarios. The common outcome is that of performance or practice advantages for the easier blocked practice group, in terms of faster improvement on each of the repetitively practised skills. The interleaved group typically takes longer to reach a similar level of attainment as the blocked group by the end of practice. Stated another way, there are typically advantages for the blocked practice group in terms of rate of acquisition and apparent ease of learning and sometimes also advantages in the level of performance attained at the end of a practice bout. However, when performers are brought back for retention testing days, weeks, or months later there is an interesting reversal in the results. The once successful blocked group shows poorer retention than the random practice group. The difficulty of the practice encountered by the random group has led to delayed improvements (also termed offline gains) when this group is assessed at a later date. For a stylized example of this kind of cross-over effect in a motor learning study, see Figure 1. Learning advantages for more randomly ordered practice conditions have also been observed when individuals organize practice of similar actions, but at different distances. For example, Buszard et al., (2017), had tennis players practice the same serve, but at different points on the court in a random order, what they referred to as within-skill variability.

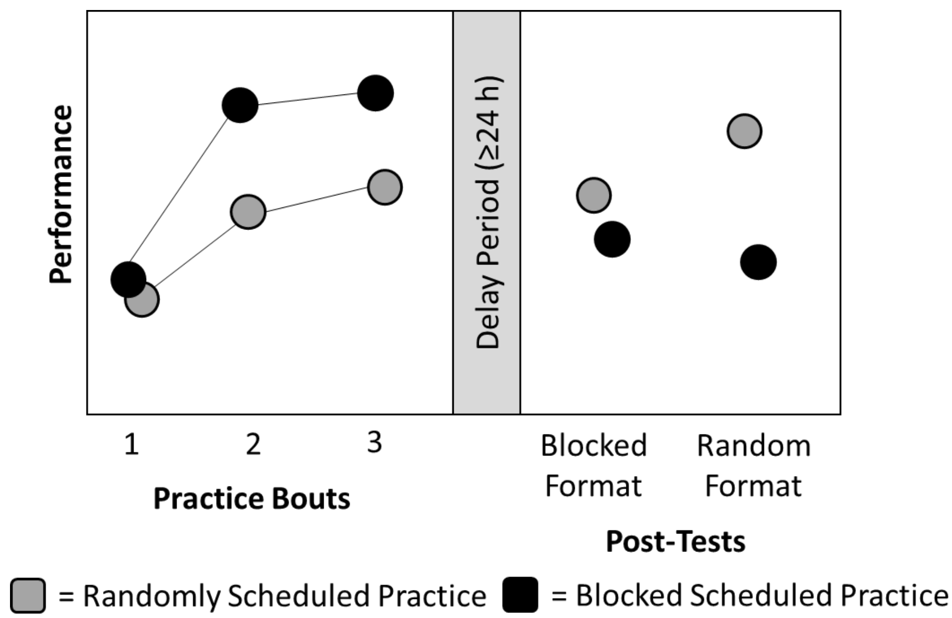

Figure 1. Abstract figure showing the typical reversal effect from a contextual interference study. Randomly scheduled practice is more difficult than blocked scheduled practice, so performance is worse during practice. However, randomly scheduled practice leads to better long-term learning, so there is a reversal in performance on the delayed post-tests (also called retention/transfer tests). Notably, the learning benefit of randomly scheduled practice is seen across both blocked and random formats. However, there is also often a specificity of practice effect such that each group does better in the testing format that matches their practice condition.

What is particularly interesting about these practice order effects is the sense of fluidity and apparent feeling of learning which accompanies people who practice under repetitive, drill-like, blocked practice conditions (e.g., Simon & Bjork, 2001). Fast gains in practice give the impression that learning is taking place, even though faster acquisition is not necessarily good for long term learning (e.g., Farrow et al., 2018; Wadden et al., 2019). When participants who study under blocked conditions are asked how well they will do at a future time, they show optimism in their retention capability, compared to people who study under random conditions. This sense of learning which accompanies rapid gains in practice is despite data gathered from retention tests, which show the opposite pattern (e.g., Koriat & Bjork, 2005; Simon & Bjork, 2001). Performance-learning dissociations between what appears to be the case in practice and what is evidenced at a later practice or in competition are not isolated to challenges in the order in which skills are practised nor to just the learning of motor skills. For example, attempting an action before being shown what to do, spacing out practice of different skills to make them harder to recall, and self-testing, are all methods which serve to bring what have been referred to as desirable difficulties into practice. These methods are often at the cost of slower rates of improvement but to the benefit of learning across multiple settings (Bjork & Bjork, 2011, 2020).

Differences between performance and learning were nicely illustrated in the challenge-point paper by Guadagnoli and Lee (2004) in terms of two different relationships between these concepts and challenge (see Figure 2A-C for a conceptual illustration). When challenge is low performance is good. Of course, as challenge gradually increases, performance starts to drop off. Although this challenge-performance relationship was conceptualized in a curvilinear function with slower decreases at first and more rapid decreases at high challenge, the shape of the function is dependent on both the type of skill and the type of challenge. In general, more challenge equals worse performance and less challenge equals better performance. When learning is considered, however, a different relationship is conceptualized. When there is little to no challenge, then there is little to no learning, which we refer to as “comfortable” difficulty in the grey zone Figure 2A. This does not mean that there is no difficulty or even low difficulty, just low difficulty **relative** to the athlete’s current skills. As relative challenge starts to increase, this is where learning starts to happen, Figure 2B. Importantly, this relationship between challenge and learning is not linear, but is considered to be an inverted U shape, whereby too much challenge is also bad for learning, what we refer to as “punishing” difficulty in Figure 2C.

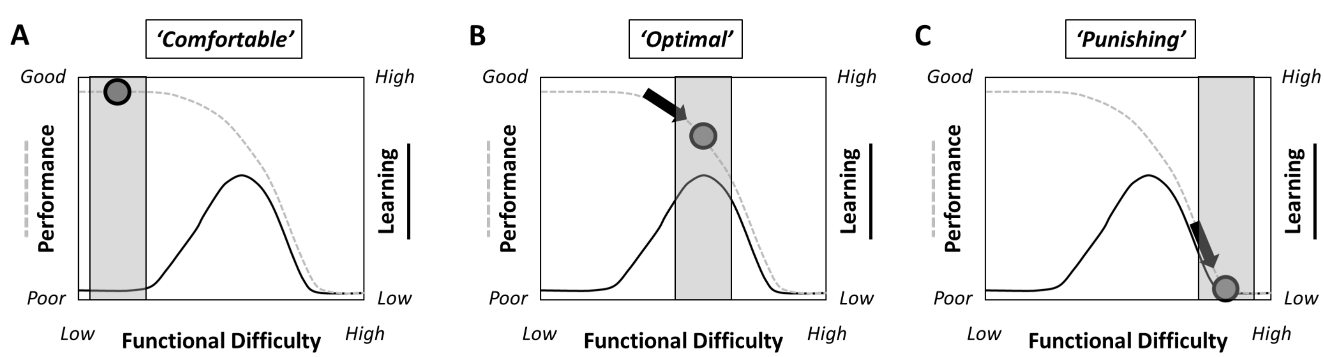

Figure 2. A conceptual illustration of the challenge point framework (Guadagnoli & Lee, 2004), at three different levels of functional difficulty and performance (A, B and C). As functional difficulty increases (panels from A-C), performance (dashed line) decreases monotonically. This potential decrease in performance is denoted by the grey dot in the three panels. In contrast, the relationship of functional difficulty to amount of learning is denoted by the solid line displaying an inverted U shape. There is a theoretical “optimal” point or zone of difficulty at which learning is maximized (panel B), but learning is low when functional difficulty is too low (A) or too high (C). Note that the terms, “comfortable”, “optimal”, and “punishing” (A-C, respectively) are our own terms for qualitatively describing different levels of functional difficulty relative to learning.

What is desirable for learning is what is referred to as the optimal challenge point, but might be better conceptualized as an optimal challenge “zone”. The term “zone” is more encompassing of a range where difficulty and performance are optimal for learning. The zone where learning is (hypothetically) maximized is when performance has started to drop-off, termed “optimal” difficulty in Figure 2B. Importantly, there is some decrease in performance, but not too much that the challenge overburdens the learner. Conceptually at least, by adjusting the difficulty of practice, we can find the optimal place at which learning will be greatest. It is in this new zone where learning can now take place because of the availability of new, unexpected information. Before and after this place, challenge with respect to learning is sub-optimal, not difficult enough so that no new learning is taking place, or too difficult and overwhelming in terms of the demands on the athlete such that it is difficult for learning to take place. Although the challenge point framework is one that is based on the individual learner, we think it could also be considered at a team-level. Practice can be structured for the team, such that the team is challenged and errors occur to create team learning opportunities (although of course ultimately the learning occurs at an individual level). Moreover, the learning effects may be related to both the physical acquisition of skills or the learning of perceptual-cognitive skills related to anticipation and decision making (e.g., Broadbent et al., 2015).

The general goal of the challenge framework is helping people in motor skill acquisition to appreciate the role of difficulty in learning. If athletes are to do more than maintain their current level of skill, then there is a need to get them out of their comfort area, where they know what to expect and how to respond and where there is little-to-no new information to be gained from practice. For beginners, the availability of new information is high at relatively low levels of challenge. Even a low amount of difficulty for beginners will create uncertainty and lead to situations where new information is available for learning (as illustrated in Figure 3 for the hypothetical novice). In order to help make this new information useable, the coach often provides a valuable role in helping direct attention and determine key information. This help may be through adapting of task-specific constraints, changing rules or augmenting practice through verbal instruction or video (e.g., Hodges & Franks, Renshaw et al., 2010, 2019).

As individuals increase in their skill, the amount of information available for learning starts to shrink. For skilled individuals, a relatively high degree of difficulty is needed to bring new information and uncertainty into the practice environment (as illustrated for the intermediate and skilled hypothetical performer in Figure 3). For more skilled performers, situations need to be created which stretch the players capacities, so that they gain new "information" to improve and learn (the green triangle on the far right of Figure 3).

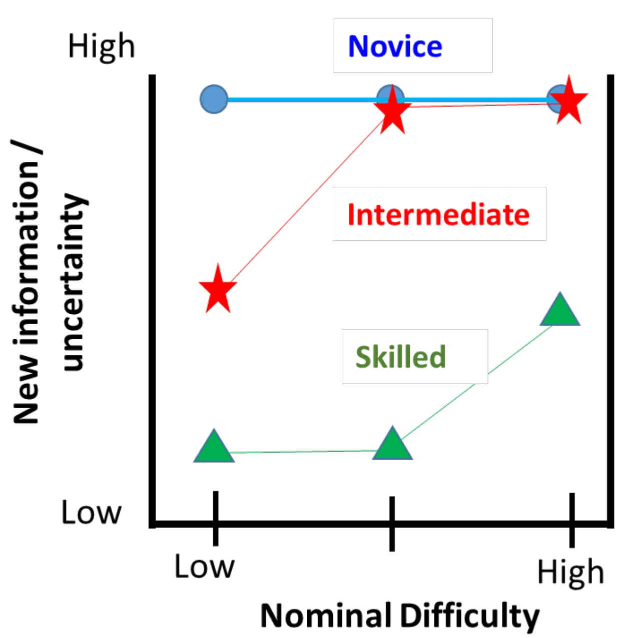

Figure 3. Illustration of the hypothetical relationship between information availability, or what we refer to as task uncertainty, and task difficulty, as a function of skill level. For novices, even low levels of nominal task difficulty create rich learning situations where information and uncertainty are both high under these relatively low difficulty conditions. For intermediates, less information or uncertainty is available when difficulty is low, but as difficulty increases the amount of potential information from the situation to learn should rapidly increase. For a more skilled individual, low and medium difficulty practice conditions do not create situations of uncertainty where information is available for learning. High levels of difficulty are needed to garner such situations, where there is novelty and a degree of uncertainty.

The relationship of challenge to the concept of (novel) information is critical to the challenge-point framework. It underlines how challenges should be considered with respect to the availability and usability of information and how this will differ between individuals. Information should be considered in its broadest terms and may be something intrinsic to the environment or the learner. For example, if we think about the simple motor act of jumping, jumping a particular way results in a particular height or kinesthetic feeling. These information sources can also be supplemented by the coach, such as video feedback of the jump or instructions about aspects of the jump. As such, information can be naturally occurring or augmented. Information can also be processed at various levels, with and without awareness on the part of the learner (e.g., Janacsek & Nemeth, 2012; Taylor et al., 2014). When we act there is thought to be a corollary of this action plan (termed efference copy), which enables 'forward model' predictions about the action's expected sensory consequences operating largely outside of awareness (Kawato et al., 2003; Wolpert & Flanagan, 2009). Expectations (and forward models) improve with practice and we become better at generating accurate predictions about how a movement will feel, look or sound. Before this point, action plans and associated predictions are poor, with a high tolerance for variability and low attunement to key sources of sensory information for accurate execution (Shadmehr et al., 2010).

Under conditions of uncertainty, information is sought and attended because it is *new* or *unexpected* and gives value to the performer. In the challenge-point framework, this uncertainty was linked to both the action plan (i.e., what to do) as well as to the sensory consequences (i.e., what will happen/how will that feel). When there is uncertainty in what is being performed, information matters and opportunities for learning are enhanced. There is a considerable amount of empirical research linking learning to expectations and in particular the violation of expectations (e.g., Hajcak & Foti, 2008; Hutchinson & Barrett, 2019; Miall & Wolpert, 1996). When our expectations are violated, particularly expectations about how a movement will feel and look, the motor system detects such violations and uses them as a signal for learning. When our expectations are met, our internal models of the world are reinforced and no change is needed. Note that people do not need to be explicitly aware of this constant prediction, but errors in prediction can lead to awareness, especially if these predictions are more outcome/target focused rather than on incoming sensory information (e.g., Huberdeau et al., 2015; Meijs et al., 2018; Pinto et al., 2015).

We can take the example of the jump one step further (so to speak) to illustrate the relation between information and uncertainty. For a relatively novice long jumper, who is learning to relate their technique to their outcome, there is considerable uncertainty in how they execute the jump and in what they expect a successful jump to look and feel like. Because of the uncertainty at many levels and the high potential for new information as expressed through variability in the execution and outcomes, optimal conditions may be those that serve to reduce the uncertainty or challenge. This reduction can be through focused instructions or simplified task conditions (perhaps a wider take-off zone), narrowing attention to other aspects of the jump. Similarly, a coach's feedback can help with what has been termed the "credit assignment problem" (an important component of motor learning identified in reinforcement learning models, Sutton & Barto, 2018). The coach can help a learner make sense of the multiple information sources, attributing a particular outcome to a particular facet of the take-off technique for example.

For a more experienced long jumper, uncertainty is lower in both the movement parameters and the kinematics of the jump they produce. Thus, creating new information to promote learning may require introducing variability (e.g., varying approach distance), or elaborating on current information about their landing footfall in relation to the take-off board (providing more detailed mechanical feedback than intrinsic proprioception alone provides). We can consider this latter situation as one of increasing challenge as the learner now needs to learn how to interpret and translate self-referenced video feedback to the actual adaptations they make when jumping. Because such feedback about footfall is not available in competition, the performer will need to learn how to interpret for themselves whether they have taken off at a desired point (and what they need to do to achieve this goal). In this way, reducing feedback from the coach, providing it sparingly or intermittently, serves to guide the learner to new sensory information, where they are forced to attend to other naturally available information to determine how to step and take-off for a successful jump. This principle of reducing external feedback to facilitate learning is heavily grounded in years of empirical research related to the guidance hypothesis (Salmoni et al., 1984; Liu & Wrisberg, 1997; Winstein & Schmidt, 1990). Instruction or feedback is often needed at certain points in the learning process, but its presence can distract attention from other sources of information and processing activities necessary for long term learning and independent performance.

In many ways, the challenge point framework could be considered a meta-theoretical framework of motor learning, which encompasses theoretical explanations for a broad range of practice effects; ranging from contextual interference, to physical and feedback guidance effects as described, to distributed practice and self-directed learning benefits (Donovan & Radosevich, 1999; Sanli et al., 2013 respectively). It also aligns with a more global theory of skill acquisition applied to expert performance, that of deliberate practice (Ericsson et al., 1993). In the deliberate practice framework, the acquisition of high-performance skill is thought to be a result of many hours of highly effortful and attention demanding practice, designed with the primary purpose of improving performance beyond the current level (i.e., learning). This type of practice is not necessarily inherently enjoyable, though it is frequently judged as satisfying and rewarding (Coughlan et al., 2014; Hodges et al., 2004; Ward et al., 2007). Although deliberate practice theory is mostly agnostic to the specific types of methods which best bring about high performance, beyond specifying the need for (coach-designed) feedback, it is based on the empirical study of skill acquisition and principles of practice which are inherently mentally effortful (for recent reviews see Ericsson & Pohl, 2016; Ericsson, 2020).

In applying the challenge framework to coaching, we have taken the liberty of extending this framework and notions of challenge to additional goals of *transfer* and *maintenance*, where challenge can be conceived of more broadly than that related to cognitive effort. We are not suggesting that transfer is not an inherent goal of practice to learn, but it may not be the primary goal, or it may be sacrificed when difficulties associated with meeting competition demands exceed current capabilities. With respect to the goal of transfer, demands and challenges are primarily designed to match those encountered in competition. This matching may or may not result in similar types of practice to those based on the goal of learning. Moreover, because learning is not always the goal of practice, we also consider the challenge framework with respect to the need to *reinforce* current skills and *maintain* current performance. Although these three goals of learning, transfer and maintenance are rarely independent and should be thought of in terms of priorities, rather than either/or decisions, the different goals are likely to have different implications for structuring practice. Hence, being cognizant of the primary goal when designing practice matters for design.

Informational Benefits versus Motivational Costs

By increasing the functional difficulty of practice, we expect to see a decrease in performance (Figure 2A-C). This decrease may come in the form of reductions in accuracy, slower and more variable movements, or both (e.g., Schmuelof et al., 2012). These potential errors are definitely a valuable learning signal (Sanli & Lee, 2014; Albert & Shadmehr, 2016), as the information gleaned from unsuccessful attempts can be used to adjust and refine future movements. However, we also need to consider the potential motivational costs of errors for both the learner as a person with psychological and safety needs and for learning as a physiological process.

Referring back to Figure 2 where we discuss three types of practice difficulty, some parallels to motivation can be made. Clearly punishing difficulty is likely to bring about frustration, confusion and be demotivating for an individual. Both comfortable difficulty and optimal challenge can be motivating or not motivating, but likely for different reasons. In the former case, comfortable difficulty can help to meet the needs for competence, but it also has the potential to be boring, especially if no new learning is taking place and individuals are under-challenged (e.g., Acee et al.,2010; Krannich et al., 2019). In the latter case, optimal difficulty can bring about unexpected rewards or close misses, serving to engage the learner (e.g., Clark et al., 2009; Lazzaro, 2005). However, failing or making errors has motivational costs in terms of persistence (e.g., McAuley et al., 1991), especially as the optimal zone for learning approaches punishing difficulty. We speculate that small challenges for small periods of time can keep motivation high, balancing the benefits of errors for learning against their costs in motivation.

Performance errors can have both psychological and physiological costs (e.g., Hajcak & Foti, 2008). In a group setting (like team sports), this aversion can be compounded by the social consequences of making errors in front of peers, which can create tremendous psychological pressure (e.g., Sagar et al., 2007). As noted earlier, feelings of competence are important for keeping athletes engaged in the short and long-term. In many sports, there is also real danger of pain or injury from making errors (e.g., skiing, skating, gymnastics), so athletes may shy away from errors to avoid risking both psychological and bodily harms (e.g., Chase et al., 2005; O'Neil, 2008). Awareness of these potential trade-offs when introducing challenges and their associated performance dips is important. We discuss some examples of how to balance informational benefits with motivational costs below. One step that is likely to be important for this balance is in creating a culture where athletes feel comfortable exposing their weaknesses, performing under novel conditions where successes are not guaranteed, and engaging in practice conditions which are challenging (see "Practice-to-Learn" below and also Yan et al., 2020 who discuss growth mindsets as important precursors to engaging in difficult practice). Additionally, physical safety of the athletes is always paramount, so coaches need to take extra steps to ensure that precautions are taken when increasing difficulty can increase risk of injury.

For learning as a process, there is also growing evidence to suggest that reduced motivation can have a direct negative impact on learning (e.g., Wulf & Lewthwaite, 2016; Ma et al, 2017). Thus, when practice difficulties increase, it is important to take protective steps to ensure motivation by promoting competence, autonomy, and social relatedness (Deci & Ryan, 2012). For instance, when practice is more difficult and errors more common, coaches can promote competence by providing feedback specifically after relatively good attempts rather than poor attempts (e.g., Chiviacowsky & Wulf, 2009). Coaches can also focus on self-comparisons (i.e., how is an athlete improving relative to themselves a month/ year/ season ago, perhaps through video feedback) and try to minimize social-comparative feedback to teammates (e.g., Avila et al., 2012). Coaches can also promote autonomy by allowing and encouraging athletes to have some control over their practice environment. This may be letting athletes choose when/ how to increase difficulty (Leiker et al., 2016; Leiker et al., 2019) or receive feedback (Abbas & North, 2017; Carter & Ste-Marie, 2017; Ste-Marie et al., 2020). It is also important to develop the right mindset for engagement in practice, such that failures do not lead to athletes giving up (Dweck, 2008; Yan et al., 2020). When individuals believe that improvements come about through hard work and not innate talent (i.e., growth mindsets), individuals persist under challenging conditions for longer (e.g., O'Rourke et al., 2014) .

Much of the recent thinking about motivational impacts on motor learning are influenced by research into the effects of rewards on learning and physiological processes that take place between practice sessions (Robertson, 2019). The term "consolidation" refers to the long-term process of strengthening memories created in practice into longer more durable forms which can be recalled at a later date (e.g., McGaugh, 2000). Consolidation is more than just instantiating information, but actually transforming information through the continued learning which takes place once practice has stopped (e.g., Robertson, 2019) and it is particularly sensitive to long periods of rest involving sleep (e.g., Diekelmann & Born, 2010; Walker et al., 2003). Rewarding activities through feedback, praise and physical incentives helps to promote the consolidation of motor skills, which is thought to be mediated by increases in dopamine during the practice session (e.g., Abe et al., 2011; Galea et al., 2015; Schultz, 2017). Because dopamine is implicated in memory consolidation, designing learning situations which create opportunities for success/reward, particularly unexpected success, should be an important consideration. Unexpected successes appear to be especially rewarding and are strongly linked to behaviour change (Lohse et al., 2020; Tobler et al., 2006). However, it is unclear how "unexpected" successes need to be. There is no simple percentage of how often individual learners need to succeed (or fail) to maximize learning benefits and/or sustain motivation. Interestingly, some research suggests that video game players can fail at their nominal objectives much more often than they succeed while sustaining motivation (McGonigal, 2011).

We know that the nature of the error also impacts motivation, with near misses or falling just short of success motivating players to stay engaged (Lazarro, 2005), which seems to marry well with ideas of optimal challenge falling just outside an individual's "comfort zone". In video game environments, designers do a great job of progressively increasing challenges because the same action or outcome no longer produces the same level of reward (Lohse et al., 2013). This progressive increase in challenge has been related to increased learning and brain plasticity (e.g., Christiansen et al, 2020) and resilience across time, stressors and general attentional demands (e.g., Poolton et al., 2005). Progressive increases in difficulty as a way to bring about skill acquisition in beginners is nothing new to sport practitioners, but as should be apparent, this progressive increase is also important for sustained learning in more experienced athletes.

In summary, difficulty presents informational benefits but it can also have motivational costs. Therefore, steps are needed to promote motivation when athletes are performing in the optimal challenge zone. Some challenge is likely motivating, especially if challenge is progressively increased (also termed “scaffolding”, e.g., Rosenshine & Meister, 1992) and intermittent (e.g., Wang & Chen, 2010). The exact balance of these costs/benefits is likely individual, based on cognitive load, motivational disposition and prior experience (e.g, Kanfer, 1990; Paas et al., 2010), as well as potentially the relationship that coaches have with specific athletes. Below, we make broad recommendations for how to balance these trade-offs when the primary goal is practice to learn versus practice to maintain.

Before presenting these practical recommendations, we also need to consider another broad principle of practice related to specificity. Difficulties that reflect the demands of competition, in terms of cognitive-perceptual processes (e.g., Lee, 1988), as well as physical (e.g., Morgan et al., 2014) and psychological demands (e.g., Lawrence et al., 2014; Pijpers et al., 2006), will better promote transfer to competition. These difficulties might not always be compatible with task challenges designed to bring about learning, illustrating the need to consider the various goals of practice when creating difficulties.

Practice Specificity

Transfer across situations, particularly from practice to the game or competition environment, is a fundamental aspect of coaching practice and a critical aspect of effective test performance. For a long time, cognitive psychologists (e.g., Roediger, 1990; Schacter & Graf, 1989; Schacter, 1992) and motor learning theorists (e.g., Lee, 1988; Lee et al., 1994) have espoused the importance of matching practice conditions to those of the test in order to best achieve high performance in the test environment. Even those conditions which seem superfluous to the material being acquired make a difference to retrieval processes. For example, if you want people to be able to perform a task under water (even if this is just learning numbers or letters, not action dependent on water interactions), then practising performing underwater leads to better transfer (Godden & Baddeley, 1975; for more recent ideas on this context specificity in cognitive tasks see Karpicke, Lehman & Aue, 2014, Lehman & Malmberg, 2013 and for motor learning; Krakauer et al., 2006).

The encoding specificity principle is a fundamental learning principle which has stood the test of time, helping to explain why learning is enhanced when the cognitive processes during study (i.e., encoding) are similar to those which are required during the actual competition or test phase (i.e., retrieval; Thomson & Tulving, 1970; Tulving & Thomson, 1973). Designing practice to maximize transfer is heavily embedded within a cognitive processing account of learning. Memory for pictures, words and actions, is underscored by the need to ensure overlapping processes between conditions of practice and assessment (e.g., Anderson, Wright & Immink, 1998; Gupta & Cohen, 2002). However, specificity of practice is not limited to cognitive processes and has been demonstrated for sensorimotor processes as well (Proteau, 1992). One of the most striking examples of this effect was the finding that an extended period of practise without vision had negative consequences in a retention period when vision was subsequently available (Proteau & Marteniuk, 1993). Individuals had not learned to use an information source which would be highly beneficial for response accuracy (for similar effects in basketball free-throw shooting see Moradi et al., 2014). This reversal highlights the strength of the specificity effect: by all accounts having vision should be beneficial, but if visual information was not available during training, then the presence of visual information during testing can actually degrade performance.

With respect to coaching, an important principle of practice is simulating the demands of competition in order to facilitate transfer. For example, much has been written about and applied in practice with respect to physical matching of competition stressors within a practice session (e.g., Morgan et al., 2014). Specificity of practice to the competition environment has also been referred to in other literature as “representative design” (e.g., Davids et al., 2013; Pinder et al., 2011). The emphasis in representative design is in maintaining the key perceptual and motor couplings which are present in the game in practice (for example, batting against balls thrown from a live pitcher, as opposed to a ball machine where body cues are absent; e.g., Renshaw et al., 2007).

In addition to transfer of processes which are likely to be encountered in practice and competition (e.g., thinking under pressure, making decisions based on multiple sources of information and choice), transfer is maximized through practice conditions with psychological fidelity (e.g., Lawrence et al., 2014). So, it is the cognitive, sensory, and emotional thoughts, demands, and feelings of impending competition which are desired in practice, or at least in aspects of practice, for transfer to be maximal. When fidelity is high there is a strong match between these processes during practice (or parts of practice) and the game. Although the environmental context matters, things like playing surface, temperature etc., it appears that the processes promoted in practice matter more than the environmental context for facilitation of transfer (Schmidt & Lee, 2019). This means that practising passing skills with challenges that impact on accuracy, such as smaller balls, without time pressures which will be encountered in the game, will likely aid learning and improvement of these skills, but not necessarily aid or best promote transfer to the game environment.

In the example of passing, in open sports such as hockey, soccer or basketball, another consideration for transfer is the decision process itself. In tournament play for example, there are high decision demands, where a performer is often required to make fast decisions, under situations where there are a number of potential choices. People are often playing in different positions, there are new/different players, new patterns of play, different opponents and higher anxiety, than in regular games. The demands on working memory associated with such situations have been noted by sports' researchers (e.g., Furley & Memmert, 2013; Furley & Wood, 2016). Working memory is the process which requires of the performer to hold/remember and manipulate information to arrive at a decision (Baddeley & Hitch, 1974, 2007 for a review). Therefore, the conditions of practice which mimic the demands on an athlete during competition (practice-to-transfer) need to be considered alongside goals of learning. Goals of competition transfer both complement and supplement learning goals, facilitating the transfer of already acquired skills. This prioritizing of goals might be particularly important for new learners, where the capacities (and hence optimal challenge) associated with making an accurate pass would be exceeded if the passing was immediately practiced under time or opponent-pressured situations. In these final sections we discuss in more detail the practice implications of these ideas and explicitly relate practice difficulty to practice specificity and the various goals of practice.

Practice Goals and Choosing Difficulty

We consider there to be three separable, though not mutually exclusive goals of practice design in coaching. In considering these goals we draw on the main ideas related to the challenge point framework with respect to practice designed to improve performance over the long-term; what we refer to as “practice-to-learn”. This is the most important goal and probably should underpin the majority of practice-based decisions in designing practice and instructing athletes. We expand on these initial ideas from the challenge point framework and also consider two other practice principles which intersect with this framework and potentially change how practice difficulties are considered. We also consider practice goals related to maintaining current skills, which we call “practice-to-maintain”, where the emphasis is more on developing automaticity in skills and keeping athletes motivated through high competency expectations and relative successes. As well, the goal of “practice-to-transfer” is considered, where the emphasis is on creating challenges which simulate game demands required in competition. Although this last transfer goal is most highly related to issues of practice specificity, for all goals, practice specificity must be considered in the design of optimal task challenges. In Figure 4 we have illustrated these various goals of practice with respect to competition specificity and functional task difficulty.

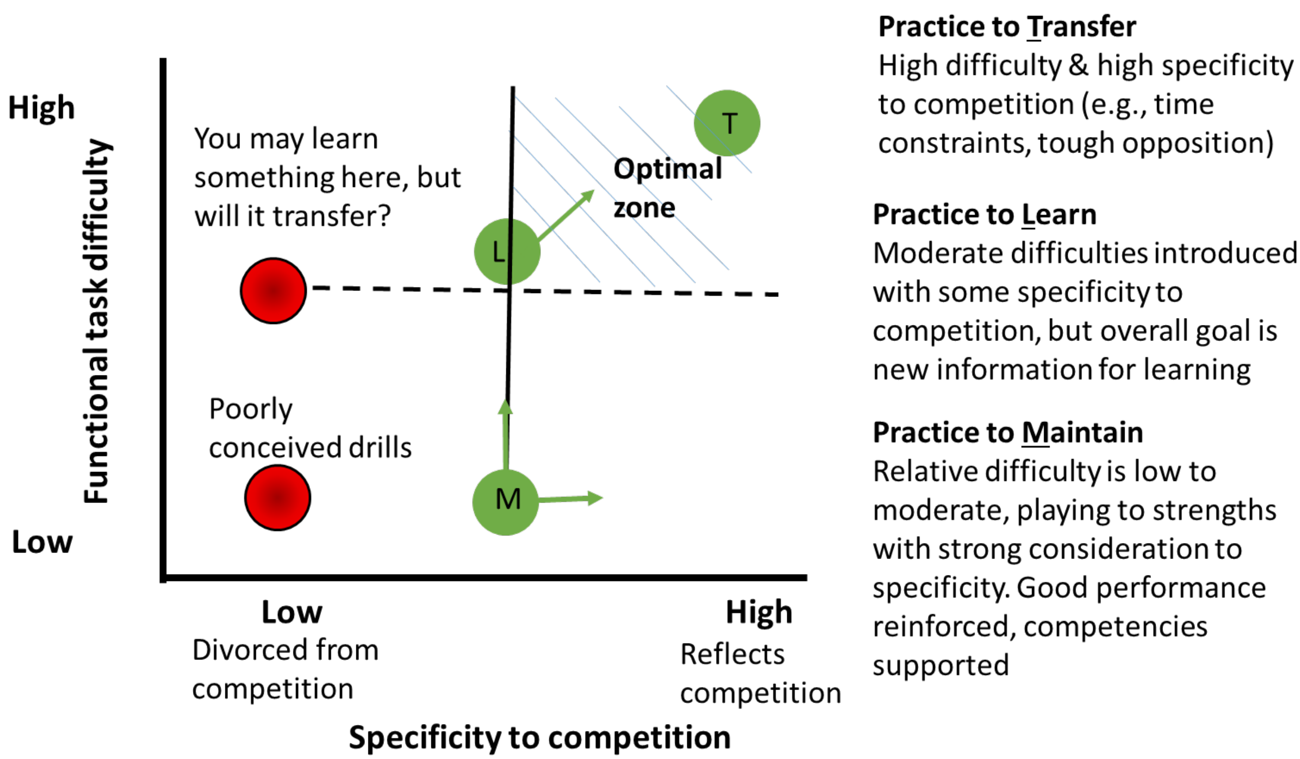

Figure 4. A conceptual model showing different types of practice when the relative difficulty of practice is considered as a function of the specificity of practice. At low levels of specificity, there is little transfer to competition (red dots, black outline). At higher levels of specificity, transfer is expected and coaches can manipulate difficulty dynamically. Practice-to-learn (green, non-outlined dot, "L") takes the individual into the optimal zone for learning and transfer ("T"), where relative difficulty is moderate to high and specificity to the game environment is moderate to high. This zone where specificity is moderate to high, but relative task difficulty is low is also likely to have benefits for maintaining and reinforcing skills (green, non-outlined dot "M").

All three practice types, regardless of the goal, should have at least a moderate degree of specificity to the upcoming game context. Without this specificity of practice to the game or competition environment, then the learner will be left with poorly conceived drills or acquisition of skills with low relevance to performance demands (as illustrated by the red dots in Figure 4). Of course, the goal of transfer will be highest in specificity of practice to competition. When practising to transfer skills it is likely that the functional difficulty of the practised skills will also be high, although this is not necessarily the case (hence the arrow representing the potential for varying functional difficulty associated with the practice goal of transfer). For example, batting against a live pitcher versus a ball machine will have higher specificity to the game. However, the functional difficulty may be lower against a live pitcher if the ball machine can pitch faster balls, if there is less rest between pitches and because the absence of a real pitcher may make it more difficult to anticipate pitch type.

In Figure 4 we have illustrated the practice-to-learn goal in the centre of the diagram, illustrating functional difficulties just beyond moderate (within the optimal challenge zone). There is the potential for both functional difficulty and specificity to competition to be higher within the zone of optimal challenge, at least to a point where the difficulty does not become "punishing". For example, a height barrier can be included in batting practice to change the ball flight and technique of a batter (e.g., Gray, 2018). By gradually removing the barrier over time, changing the conditions where batting takes place (e.g., different pitchers or pitch types), both goals of learning and transfer to the game environment could be achieved through new information and practice specificity. There may be situations where learning goals are designed to reveal new information, with only minimum consideration of practice specificity for transfer. For example, requiring a player to play in a position not usually experienced, such as a batter practising pitching (or observing actions from a new perspective), introduces new information for learning. The goal is not to have the player take on this new role or position, that is making it specific to the game environment and reflective of competition, but to change behaviour through new information (for similar suggestions about aiding perceptual skills through physical practice of opponent actions see Makris & Urgesi, 2013; Mulligan & Hodges, 2019; Pizzera & Raab, 2012; Tomeo et al., 2013). Although there is an expectation of transfer to the game, coaches should worry less about making the practice conditions identical to competition when practice-to-learn is the goal.

Below this illustration of the learning goal in Figure 4 is a third green dot, illustrating practice-to-maintain. Functional difficulty is expected to be relatively low here (within the comfortable zone), with moderate (to high) specificity to competition. For example, individuals may be engaged in relatively repetitive practice of a well-executed serve in tennis. To increase specificity to the game, these serves could be interspersed with some cross-net play and return of serves. Free-throw shooting in basketball is a skill that is highly specific to the game, but it may be practised under conditions which are more or less game-like, where there are fans or distractions or the athlete is fatigued. We elaborate on these practical examples for the three goals below.

1. Practice-to-learn: Designing challenging practice to elicit improvement

The basic idea about practice-to-learn, is that the athlete or coach needs to be comfortable sacrificing performance or parts of performance in practice in order to maximize learning and improve. For a more competent athlete, performance will shift from a place of stability, good performance, and comfort, to a messier place so that learning can take place. This is achieved through increased challenge and the creation of opportunities for new information. Because there are fewer opportunities to learn and gain new information at higher levels of skill, creativity is needed from coaches (and players) to engineer situations that create the opportunity for learning/ growth. If the goal of practice is to have learning, then the task of the coach or athlete is to create situations that are moderate-to-high in functional task difficulty. This just means that the difficulty is determined in relation to the individual and based on their constraints at that time. Putting someone into a position they do not normally play adds a level of functional task difficulty that is not there for a player who is used to playing that position.

There are of course many ways that challenge can be brought into practice, depending on the sport, the athlete and skills which are being taught or refined. Conditions that serve to increase the cognitive demands on the performer have been shown to lead to better retention/ learning (e.g., Frömer et al., 2016; Lee et al., 1994). The most frequently applied method to achieve this demand aim is to manipulate variability in practice conditions. This can be both variability in the schedule of skills practised, with frequent switching between skills (Wright & Kim, 2019) or variability in the conditions of practice, such as the same skill practised at different distances, or under different pressure or opposition constraints (e.g., Hall & Magill, 1995; Buszard et al., 2017; see also Jones et al., 2020 who showed that variability and random order of practice conditions discriminated elite cricket batsmen from their near elite counterparts during mid-teen development). The aim of increasing challenge through variability is to bring meaningful variation into practice such that the learner is actively involved in determining how and when to act, constantly thinking about what they are doing (Kim et al., 2021; Wright & Kim, 2019).

By practicing in ways where the practice environment is different from typical, athletes' (motor system) expectations are violated, so that new information is sought or necessary. When expectations are not met, this suggests that some internal updating of the skill is required. These differences between actual and anticipated consequences are powerful drivers for learning (Sutton & Barto, 1998; Frömer et al., 2016). Uncertain conditions not only serve to keep the performer actively engaged in the learning process, but also provide practice opportunities for events that mimic some of those encountered during competition (where vision may be blurred or obstructed, or playing surfaces are damaged or uneven causing balls or pucks to travel in uncertain ways). This novelty can be achieved through changes to ball size, field size or surface, change in positions, attentional focus or potentially through variations in the perspective shown on video (as exemplified by work on error augmentation; e.g., Abdollahi et al., 2014; Patton et al., 2013 and equipment modification; e.g., Brocken et al., 2020).

During practice designed to bring about long-term improvements to performance, a de-emphasis on outcome attainment may be needed, with the focus instead on behaviours that are desirable if not necessarily successful (e.g., Hodges & Franks, 2004). Because errors will be expected, coaches should consider ways to manage expectations, de-emphasize immediate performance, and reinforce behaviours in the desired learning zone. Because of the potential for errors and poor(er) performance to be considered negatively, a culture can be cultivated so that players know the difference between practice situations for learning and those for performance/maintenance. In the former case, where learning is the goal, certain aspects of performance might suffer in the knowledge that there is no negative recourse. Sustained improvement over time means that the player and coach are comfortable with worse than expected performance in practice, or parts of practice. As game-day or competition approaches, it is conceivable that there will be less emphasis on learning (and permissible errors) as we elaborate below. Learning-based practices can be merged with practice sessions or parts of a practice session, where errors are not allowed and where mistakes have “agreed upon” consequences, better matching game demands and goals of transfer (e.g., Bell et al., 2013). What is key for athletes to appreciate is the distinction between performance and learning, to know what this distinction means with respect to the goals of a practice session (or parts of a session), and to understand when and why mistakes are okay when learning/improvement is the goal. Having these discussions with athletes and creating a culture of learning helps to balance the informational benefits against the motivational costs of increased errors during practice.

2. Practice-to-transfer: Simulating competition demands

The second goal of practice we define with respect to task challenges is to maximize transfer to competition. Here, challenge is matched to expected game demands. Practice should have aspects that mimic difficulties/challenges expected during competition (at both the individual and team-level where appropriate). Considerations for optimal challenge are to find the point at which transfer to the game will be greatest. The focus should be on creating meaningful difficulties which match behaviours and processes required in competition. There are many ways that these “game-day” challenges can be conceptualized, but the most common aspects relate to mimicking psychological and physiological states; such as increased self-evaluation, competition, attention demands and fatigue. Other external/environmental factors could be considered for this type of practice too, such as crowd noise which may make it hard to communicate or weather, playing surface or visibility.

There are likely to be many responses which are made without much thought and weighing of options, as a result of a level of automaticity from playing a particular way regularly (e.g., Raab & Laborde, 2011; Shiffrin & Schneider, 1977). Although there can be some benefits from this automaticity in action responses, there are also potentially some costs. Often players need to be adaptable to different types of opposition, different team-mates, and different playing conditions (e.g., Furley & Memmert, 2012; yet see Furley & Memmert 2015). Therefore, thinking about ways to encourage decision making in practice, where players are faced with options during drills and are potentially rewarded for the most unexpected or creative decisions, could prove useful and best simulate the demands of game play.

One of the ways high cognitive and attentional demands of time-constrained team invasion sports might be simulated in practice, is through a practice designed to challenge players working memory (i.e., memory processes which are current and active and require some translation of information; Baddeley 2007; Memmert & Roca, 2019). Assigning players different coloured pinnies and requiring that every other pass is made to a green shirt or never to the same person as before, could achieve this aim of mimicking attentional demands of the game. Players need to know and remember what the current pass was, what the next pass will be, who received the last pass and select who will get the next pass, placing demands on working memory. The idea with stressing working memory is that the players always have something to hold in memory and use before making their decision.

There are potentially many other methods and tools which could help achieve the goal of creating scenarios in practice that match to game /competition demands. One potential method is to include consequential practice sessions or part of sessions, whereby errors and undesirable plays have negative consequential outcomes, like in a real game. This idea is based off work from Hardy and colleagues and related to ideas of developing mental toughness (see Beattie et al., 2020). Such an intervention was used in elite youth cricketers in the UK to make practice conditions more similar psychologically to those encountered during competitive play (Bell et al., 2013). The players and coaches created consequences for bad decisions, such as staying later after practice or performing shuttle runs. In “punishment” or consequential training, these outcomes were enacted and designed to simulate the game pressures that would be faced by athletes in sports where mistakes can cost the game. Other methods for creating situations that match game demands might be to have practice conditions at the end of practice which require good decisions, such that players are practising good decision making when fatigued.

3. Practice-to-maintain: Maximizing rewards and successes through attainable goals

When dealing with accomplished athletes or in preparing for an upcoming competition, there may be a number of reasons for a "reinforcement" type practice, where accomplished skills and techniques are honed and practiced. In such sessions, the focus is on maintaining difficulties at an individual appropriate level that serves to reinforce current "good" performance. Maintenance practice and reinforcement of desirable behaviours are critical for player engagement, motivation and of course performance. In such practice situations, practice is designed to encourage strong, desired behaviors. As with the other goal considerations, this goal might serve to guide design of part of a practice session, rather than the whole session. Athletes could progress within a practice session from conditions with potentially high challenges or functional difficulties (where the goal has been to learn new skills, improve upon old skills or to practice under conditions which simulate high levels of competition), to practice that has fewer challenges or specifically designed uncertainties, where the focus is instead upon opportunities to excel in the athlete's comfort zone. This does not mean that practice is made easy or loses it specificity, but that practice is designed so that an athlete, groups of athletes or a whole team are afforded opportunities to succeed and demonstrate their strong(er) skills. This may be necessary for certain players, if dealing with a team sport, rather than practically possible for all players.

The relationship between difficulty and performance is illustrated in Figure 2. For maintenance practice, the point where performance is optimal is before the point (in terms of functional difficulty) where learning is optimal. There is typically no new information to be gained by the performer (or at least this is not the goal of practice), rather expectations and actuality are well matched. The athlete can focus on managing and maintaining their strengths. As shown in Figure 4, however, we also need to consider the level of specificity in addition to functional difficulty. When training to maintain, the skills and actions demanded of the athlete in practice should be increasingly specific to those skills required in the competitive environment (assuming individual capacity allows).

There are three main subcomponent goals of maintenance practice; to reinforce key skills and strengths; to motivate and instill encouragement; and to develop a degree of automaticity of certain skills. Reinforcing key skills is a valuable part of practice related to experimental work on the concept of "overlearning" and hyperstabilization of memories (e.g., Rohrer et al., 2005; Shabata et al., 2017). Similarly, doing maintenance practice to increase automaticity is desirable because it allows performance to be achieved with low attentional demands (e.g., Beilock et al., 2002; Gray, 2004; Leavitt, 1979). Resources can then be allocated to dynamic and unpredictable environmental cues, which demand attentional resources (e.g., monitoring the play, opponents, the softness of the snow etc; all aspects important for transfer). In order to help maintain and reinforce such behaviours, the coach and athlete would be working on creating scenarios where there is more opportunity to practice fundamental, developed skills. This maintenance and reinforcement could be also encouraged through feedback and video, where successful plays/ attempts/ routines are shown.

There are myriad ways that coaches could approach practice to maintain skills that have already been acquired. Blocked practice conditions can help to reinforce competence and repeated success where actions that perhaps are rare in a game setting are honed and reinforced. Success in practice can also be achieved by keeping the strongest line of attackers together so that they are scoring and building off each other in something like basketball or hockey. Athletes may even be allowed to lead the practice and demonstrate strengths to others. Ultimately, because the goal of practicing to maintain is to exploit existing skills (not make errors while exploring new skills), the focus is on keeping athletes' motivation high and elicit a high level of performance on that day. Athletes are provided opportunities to excel in the “comfortable” zone, where they should be expecting high success/low errors and low variability/ strong play(s). Here the functional difficulty is well matched to the athlete or team’s current competencies.

Summary and Conclusions

Here we have presented the challenge-point framework, originally proposed by Gauadgnoli and Lee (2004), as a viable framework for coaches to use in their consideration and design of practice sessions. We recognize that this framework has the potential to resonate with practitioners who are in charge of organizing practice sessions across the short and long term and across various individuals and skill sets. We think the unifying concept of challenge in bringing about improvement to current levels of performance is a critical concept which despite its robust empirical support has not been widely recognized in sport related literature. In the fields of clinical rehabilitation for example, the challenge point framework has received considerably more attention (e.g., Onla-or, & Winstein, 2008; Pesce et al., 2013). Moreover, in education, a related framework for learning of cognitive skills, that of desirable difficulties, is a widely recognized and highly cited method for optimizing learning (e.g., Bye, 2015; Bjork & Linn, 1999).

Our aim in this paper has been to both present and expand upon the main tenets of the challenge-point framework and in particular, to give some practical recommendations for considering how the notion of task challenges or difficulties can be applied to practice design and instruction. In addition to taking an informational perspective, we also consider motivational needs and literature which might impact engagement as well as learning directly.

Although we are expanding on a theoretically grounded framework of motor learning, in this paper we have taken liberties in expanding the concept of challenge, beyond its initial meaning. We do keep the important idea of challenge as new information in relation to learning, but we consider other types of challenges. These challenges are not necessarily related to cognitive effort, but are nevertheless important considerations for effective coaching practice. We should also acknowledge that our biases are as academics interested in motor skill acquisition broadly and the ability to apply principles generated from rigorous behavioural and neuroscientific research to an applied setting. Although we are both sports' enthusiasts and have been engaged in various sport roles, we would not define ourselves as coaches, nor have we been trained through coaching pedagogies. Therefore, we apologize if this paper sounds in anyway preachy or directive. It is meant as a way of assisting coaches to organize their thinking about practice and why or how particular aspects of practice may or may not work. This is a work in progress which we hope will spur research and discussion.

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Figure captions

Figure 1. Abstract figure showing the typical reversal effect from a contextual interference study. Randomly scheduled practice is more difficult than blocked scheduled practice, so performance is worse during practice. However, randomly scheduled practice leads to better long-term learning, so there is a reversal in performance on the delayed post-tests (also called retention/transfer tests). Notably, the learning benefit of randomly scheduled practice is seen across both blocked and random formats. However, there is also often a specificity of practice effect such that each group does better in the testing format that matches their practice condition.

Figure 2. A conceptual illustration of the challenge point framework (Guadagnoli & Lee, 2004), at three different levels of difficulty and performance (a, b and c). As functional difficulty increases (panels from a-c), performance decreases monotonically as denoted by the grey dot, but the relationship to learning is nonlinear. There is a theoretical "optimal" point or zone of difficulty at which learning is maximized. Note that the terms, "comfortable", "optimal", and "punishing" (a-c, respectively) are our own terms for qualitatively describing levels of difficulty.

Figure 3: Illustration of the hypothetical relationship between information availability, or what we refer to as task uncertainty, and task difficulty, as a function of skill level. For novices, even low levels of nominal task difficulty create rich learning situations where information and uncertainty are both high under these relatively low difficulty conditions. For intermediates, less information or uncertainty is available when difficulty is low, but as difficulty increases the amount of potential information from the situation to learn should rapidly increase. For a more skilled individual, low and medium difficulty practice conditions do not create situations of uncertainty where information is available for learning. High levels of difficulty are needed to garner such situations, where there is novelty and a degree of uncertainty.

Figure 4: A conceptual model showing different types of practice when the relative difficulty of practice is considered as a function of the specificity of practice. At low levels of specificity, there is little transfer to competition (red dots, black outline). At higher levels of specificity, transfer is expected and coaches can manipulate difficulty dynamically. Practice-to-learn (green, non-outlined dot, “L”) takes the individual into the optimal zone for learning and transfer (“T”), where relative difficulty is moderate to high and specificity to the game environment is moderate to high. This zone where specificity is moderate to high, but relative task difficulty is low is also likely to have benefits for maintaining and reinforcing skills (green, non-outlined dot “M”).