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A Hierarchy of Psychological Constructs Influencing Inter-Individual Variability in Elite Athlete Development

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Abstract

Repeated engagement with intensive, quality practice, sustained over a long period of time, is a causal mechanism of elite athlete development. The notion that there are psychological variables that result in significant inter-individual variability in how athletes engage in immersive efforts directed towards a sport, in how they engage repeatedly in accumulated practice, and in how they optimize the nature of their practice activities, remains under-examined. Moreover, the literature exploring this topic requires organization from a conceptual perspective. This paper (a) narratively reviews scholarly works relating to variables from personality, motivational, sport and educational psychology, and motor learning, as they pertain to sport expertise development, in order to (b) propose a hierarchical, conceptual model. This model describes three levels of striving for how athletes (1) direct their efforts towards a sport pursuit, (2) augment their practice durations/quantities, and (3) optimize the quality of their practice activities. We identify specific variables from the literature and propose concordant criterion measures that could be considered to test the influence these variables have at each level. While noting that the preponderance of literature addresses cognitively mediated variables in relation to quality practice, we advocate for the integration of eco-physical considerations for how individuals may differentially benefit in skill acquisition at the lowest level of the hierarchy. The model also considers the active and passive interplay of stable personality factors with developmental environments and their effects on practice-related outcomes.

Keywords

talent development, sport expertise, personality, self-regulated sport practice, quality sport practice

Introduction

Sport expertise is the consequence of interactions between stable, heritable factors and unstable, experiential environments that individuals encounter during their development (Baker & Young, 2020; Hambrick et al., 2018; Kaufman & Duckworth, 2017). In particular, the role of developmental experiences has been the subject of considerable research in athlete development, with much work focusing on determining the long-term role of practice and preparatory activities in achieving elite performance levels (e.g., Baker & Horton, 2004; Baker & Young, 2014; Ericsson, 2020; Güllich, 2016). This body of literature shows that developmental experiences through practice activities, in quality preparatory environments, represent an essential mechanism in the pursuit of sport expertise (e.g., Baker et al., 2020).

The role of psychological characteristics in relation to practice and high-quality preparatory environments, however, has not been emphasized in existing work (Macnamara et al.,

2010). Kaufman and Duckworth (2017) claimed that, with respect to people chasing expertise, the "terrain of traits that influence cumulative effort over time" (p. 3) is uncharted, as is our understanding of the factors that allow some individuals to derive more from practice than others. In sport, there has particularly been little scrutiny of variables that may result in heterogeneity (inter-individual variability) in relationships between practice (training-related factors) and acquired performance. For example, there has been little research on psychological variables that explain how developing athletes differentially engage in processes of talent development, such as developmental striving (e.g., differences in athletes' motivation to persist in practice), managing learning conditions (e.g., differences in how athletes establish affordances to optimize their training), and securing supportive assets around training (e.g., differences in how athletes seek help/resources that affect how they benefit from training).

There may indeed be psychological factors that determine inter-individual variability as to who emerges as talented from a long-term developmental trajectory, and who maintains excellence (MacNamara et al., 2010). However, scholars have an incomplete profile of the psychological factors that enable athletes to successfully navigate the "ebb and flow" of training-related demands on the road to excellence (Durand-Bush & Salmela, 2002). The contribution of variables related to personality, temperament, needs, and agentic competencies has been considered with respect to variability in practice and personal preparatory activities in other learning/achievement domains such as musical expertise (e.g., Miksza, 2011) and superior academic achievement (e.g., Ackerman et al., 2011), but there has been considerably less research in sport.

The pursuit of elite performance relies on opportunistic interactions between a developing athlete and their environment, repeatedly, over long periods of development (Baker & Horton, 2004; Baker & Young, 2021). A proper accounting of variables that refer to something psychologically about a person, which influences learning, commitment, motivation, and practice striving, is crucial to understanding this person-environment symbiosis in the course of athlete development. Due to the absence of such an account, the current paper represents our attempt to draft a framework for how scholars might organize and test variables that influence, both qualitatively and quantitatively, different facets in this long developmental process to become a highly elite athlete.

This paper is a narrative review and an invitation for other conceptually driven researchers to confirm, critique, question, and problematize how personality and learning variables intersect with a causal mechanism of expertise, i.e., repeated and long-term engagement with quality practice. It is oriented towards researchers who are trying to better describe, predict and explain developmental behaviors around sport expertise. We contend that there is no existing heuristic that addresses how constructs influencing inter-individual variability might be considered, in a coherent fashion, in relation to pertinent facets of long-term practice and preparation. Specifically, there is no conceptual account for how identifiable variables plausibly exert heterogeneity in how athletes approach, respond to, and enhance their benefits from practice/preparatory activities. Identifying these variables, and conceiving how they may exact variability during the process of development, is important seeing that some scholars have advanced that the highest levels of sport talent are very much a product of inter-individual differences in practice over time (Ericsson et al., 1993; cf., Macnamara et al., 2016).

The Need to Think Conceptually about Psychological Variables Influencing Inter-Individual Variability in Elite Athlete Development

We tender that a conceptualization is needed because constructs that impact learning efforts and motivation to train are likely to vary depending on whether a scholar is trying to

understand behaviors on a micro-analytic scale (e.g., very specific tasks of short duration in a practice trial, or in relation to a workout), or a macro-analytic scale (e.g., voluntary striving aimed at broader goals, such as becoming a national team athlete, sustained by efforts across weeks, months, or longer) (Gould & Chung, 2004; Zimmerman, 2008). Yet, individual difference factors are often mentioned with no concern for their scale of influence. For example, Kaufman and Duckworth (2017) inventoried what they considered to be "effort-related traits" (p. 3) for determining expertise – optimism, passion, inspiration, curiosity, need for achievement, self-efficacy, self-regulation, self-discipline, growth mindset, commitment, self-control, conscientiousness, and grit. However, they portrayed these variables as predictors of various outcomes, with no consideration of whether some factors are more pertinent to macro (e.g., avoiding drop-out from a domain) or micro (e.g., performing during training tasks) outcomes.

In our peer-review of sport expertise research, we have often noticed a concerning lack of concordance between the scale of assessment for psychological constructs and the respective criterion variables to which they are expected to associate. For example, we recently reviewed an article where concordance was lacking because the researchers were assessing grit (discussing it as a macroanalytic measure that plays out across the developmental trajectory of athletes) and attempting to prove its relationships with qualities of deliberate practice (which were assessed microanalytically in specific training sessions). It is unsurprising to us that these relationships, and others in wider research that lacks concordance, have proven non-significant.

Concordant measurement – the extent to which the scale of an independent/predictor variable aligns with the scale of a dependent/criterion variable, has been long emphasized by leading psychology scholars in research on self-concepts. It is the foundation on which the majority of literature on self-perceptions is conceptualized, including in sport (Sabiston et al., 2018). Concordance helps to distinguish whether a variable of interest has effects at a lower or higher stratum of the self-concept. According to the hierarchical structure of self concept (see Sabiston et al., 2018), global, trait-like constructs (e.g., physical self, physical self-worth) at the top of the hierarchy have more explanatory power for striving towards general goals over long periods, but less explanatory power for striving/behaviors at the lower, task, or situationally specific level. Relatedly, Feltz and Chase (1998) argued that effects determined by self-efficacy (a variable at the bottom, or task/state-specific stratum of the self-structure) are contingent on associated criterion variables also being assessed at the level of the task. If associated criterion variables for self-efficacy are broader, for example, if they relate to higher strata of the self in relation to domain interest or adherence, there will not be concordance, and effects should be muted or non-significant. Conversely, singular/cross-sectional measures at the task (micro, e.g., self-efficacy) level have muted associations with meta-constructs of the self (e.g., self-esteem) because meta or higher-level constructs are only moved to change by repeated changes at the task-level, which become integrated to the self, over time. In the elite athlete development field, we know of no conceptualization that encourages scholars to attend to concordant measurement.

The Proposition: A Hierarchical Model for Understanding Inter-Individual Variability in Elite Athlete Development

Our aim is to prompt more consideration of the operationalization and differentiation of a hierarchy of variables so that they may be more coherently treated in studies of athlete development. We have drafted a hierarchical scaffolding to guide the location of variables that exert inter-individual variability in relationships between developmental factors (i.e., investment in sport and practice-related factors) and acquired elite sport performance. The model locates such variables (a) at different conceptual levels, aligned with (b) concordant criterion measures that may help to judge their potency in influencing acquired performance.

We posit that striving towards expert sport development occurs at three levels simultaneously, with each lower level nested in the level above it as follows:

1. At the highest level, individual difference variables act on how athletes direct their developmental efforts towards a sport pursuit.
2. At the middle-level, within a sport pursuit, variables determine inter-individual variability in the duration of athletes' efforts towards practice activities.
3. At the lowest level of the hierarchy, there are variables that come to influence inter-individual variability in the quality of athletes' efforts within particular situations, on certain tasks, or in state-scenarios of practice.

Variables attributed to the highest level are more trait-like, representing global personality dispositions that are slow to change. It is useful to think of individual differences at this level as features that individuals bring with them in directing efforts towards the sport domain. Whereas variables at the lowest level are more state-specific, situationally invoked, and are more amenable to change. Thus, lower order variables represent competencies, skills, and proficiencies that are somewhat more acquirable/refinable. The lowest level is also aligned with specific tasks or trials during practice (see Table 1).

Table 1. Hierarchical model of variables that exert inter-individual variability between developmental factors and acquired elite athlete performance.

Hierarchical Level	Description	Variables:	Examples of Criterion Measures to Assess the Inter-Individual Effects of a Variable:
Highest level: Direction of effort towards a sport pursuit	Describes directed engagement toward a sport activity and the deepening of involvement in one sport	• industriousness, hardiness • commitment to a sport amongst alternatives • constancy of interest • person-discipline fit • motivational orientations and needs • personal identification with a sport	• robustness of sport interest • sport choice • sport load (roster of multiple sports) • survival rates in a sport • years/months of investment without lapsing • burn-out • drop-out
Middle level: Duration of practice efforts within a sport pursuit	Describes sustained engagement towards practice tasks and decisions to accumulate more practice, more often	• perseverance of effort and achievement striving • mental toughness • self-control capacity and ego depletion • reward responsiveness: delayed gratification; approach motivation	• amounts of practice • frequency of practice bouts • frequency of attendance at optional/voluntary workouts • extension of training in free choice paradigms • dual-task paradigm to test for ego depletion
Lowest level: Quality of efforts during practice tasks	Describes: proficiencies for selectively, strategically, or more intensively engaging in practice tasks; processes or decisions to improve the quality of one's practice tasks; processes to manage responses to challenges during practice	• self-regulated learning, self-regulated sport practice • deliberate practice self-efficacy • task-oriented coping • emotional responsiveness • attentional flexibility • need for cognition • eco-physical individual differences	• athlete- and coach-reported quality practice indices • elaborations using a critical incident technique • video-stimulated recall interviews • behavioral observation analyses • time motion analyses • strategic and selective training in free choice paradigms • experimental manipulations of challenge episodes • visual search patterns

Another way to view the scaffolding is seeing the two highest levels as comprising effort-related traits (factors influencing efforts towards the domain of sport at the highest level, and towards recurrent contexts within a sport at the middle level), whereas the lowest level pertains to acquired variables that allow some athletes to optimize their efforts, or derive greater rates of skill acquisition from their efforts, more than others.

The Narrative Review to Illustrate the Model

The genesis of this paper was our aforementioned reflections on the lack of a conceptual model, and lack of guidance on concurrence of scale in research in the development of sport expertise. Over a period of several years, and following our participation in symposia at the International Society of Sport Psychology (ISSP) and the Canadian Society for Psychomotor Learning and Sport Psychology (CSPLSP) on topics related to long-term athlete development, we began in earnest to inventory literature on variables that might narrate our hierarchical model.

Narrative reviews are valuable for synthesizing information from sources using diverse methodologies and theories (Baumeister & Leary, 1997). We felt this approach was appropriate given the breadth of research designs and approaches in the fields of athlete development, talent identification, skill acquisition and sport expertise. We engaged in literature from three axes to develop this narrative review. First, we reviewed literature that we considered essential for understanding personality and expertise in sports; for instance, articles by Allen et al. (2013), Tucker and Collins (2012), and Tedesqui and Young (2018), represented these types of readings. Second, we reviewed broader literature on sport talent development to scrutinize how individual differences were being treated theoretically; key readings included Macnamara et al. (2010), Ericsson et al. (1993), and Baker et al. (2020). We did secondary iterative searches within these literatures to build our scope of review outwards, identifying pertinent themes as we progressed. All along, we kept up to date with a third axis, which included emerging works at preeminent conferences where sport researchers present work on sport expertise and talent development. Specifically, we reviewed abstract/congress programs from 2017-2022 for ISSP, CSPLSP and the North American Society for Psychology of Sport and Physical Activity to integrate any variables we had missed in our reviews. The eventual narrative review, integrated into our model, was a consequence of converging the literatures from these three axes.

Highest Level: What Variables Influence How Athletes Repeatedly and Persistently Direct Effort to a Sport Pursuit?

Description of the level and narrative review. Literature convincingly shows that expert performance levels cannot be reached without concerted efforts directed towards a specific activity over time. No one reaches the highest levels in a recognized sport domain without concerted, intensive efforts dedicated towards a sport activity over a lengthy period of years (Baker & Young, 2014; Young et al., 2021). Thus, the higher-order level considers individual differences that orient a developing athlete towards their sport, and that help to describe the sustenance or reinforcement of that direction of effort over time. This includes dispositions for hard work, industriousness, or hardiness. Wilson and Young's (2024) study of Olympic endurance athletes, for example, shows they have an orientation towards always wanting to do more, to find ways to make themselves better (sometimes to a fault). Similarly, Ericsson et al. (1993) expected that personality factors, especially those predisposing people to higher activity levels, and others associated with emotionality, "may allow these individuals to sustain very high levels of [deliberate practice] for extended periods" (p.393). Variables such as dispositional *optimism* (Gaudreau & Blondin, 2004) and *resiliency* (Kossek & Perrigino, 2016) connotate emotional buoyancy and hardiness, as does *mental toughness* when it is considered as a dispositional trait (Clough et al., 2002) reflecting an athlete's commitment

toward experiences in life during stressful times and feeding a superordinate goal (e.g., unwavering involvement in sport). *Competitiveness* has also been identified as a precocious personality characteristic that initially sets the stage for world-class athletes' developmental trajectories (Macnamara et al., 2010). Such variables could underpin an athlete's sustained effort in a sport over the years of engagement necessary for the development of exceptional skill.

Variables at this higher-order level also relate to how developing athletes gravitate to immersion in one sport over alternative sports or activities. In other words, this level considers variables that describe how developing athletes navigate various life contexts yet ultimately devote greater investitures in sport. Conceptually, this aligns with sport expertise literature that portrays differences in athletes' *sport commitment* through a social exchange lens (Scanlan et al., 2013; Starkes, 2000). Specifically, athletes' decisions to commit and invest themselves in a sport result from weighing the factors that attract them to it, prior investments that make them stay, and appealing alternatives that might pull them away. Thus, we posit that athletes may differ in how they weigh these antecedents of sport commitment. This may explain why some adolescents drop from a sport pursuit (i.e., more attractive alternatives win out) and how others stay committed, accumulating the amount of practice needed to reach elite levels.

Individual differences at this level can also describe the constancy of an athlete's interest in their sport. For example, athletes' self-reported *consistency of interests*, which is a disposition associated with grit that represents the tendency to have a stable, undistracted interest in a project for months at a time (Duckworth et al., 2007), mitigates how frequently they think about switching to another sport, or quitting their primary sport (Tedesqui & Young, 2017). Tedesqui and Young (2018) also reported that *self-discipline*, a facet of conscientiousness that directs one's energies to task completion despite distractions and boredom (McCrae &Löckenhoff, 2010), is inversely associated with thinking about quitting one's primary sport.

Constancy of interest in a sport may also relate to the variability by which individuals experience "fit" between their personality dispositions and contextual nuances in a sport discipline. The Flemish Sport Compass (Pion et al, 2015; 2020), for example, assesses an individual's fit for their prospective sport by considering their personal preferences, current capabilities and the characteristics/requirements of different sports. Forgas (1979) proposed that personality types are drawn to different patterned forms of social interactions (described as commonly recurring social episodes within a subculture). Thus, we contend that certain athlete personality dispositions better match different patterned regimens (e.g., working within the structure of repeated, prescriptive sets and repetitions; or working within collaborative, dynamic game settings; or working in training settings that demand creative tactics) and different recurring episodes of social regulation (e.g., working closely with a coach, working in a large team setting, training in a supervised venue, training in a less supervised setting) in some sports than in others. Thus, the highest-level locates individual differences in athletes' personality preferences that will variably impact their fit within a sport subculture, or their *person-discipline* fit. More simply, it is difficult to imagine a young athlete repeatedly and persistently directing efforts to a sport for which they have a poor personality-discipline fit.

This highest level also implicates variables associated with athletes' satisfaction of motivational needs. According to models of self-determined motivation, we would expect general causality orientations (e.g., individual dispositions for interpreting *autonomy*, or *control* in one's interactions with the environment) to act through basic needs satisfaction in influencing investment in the sport context (Vallerand & Ratelle, 2002). In literature on the Psychological Characteristics of Developing Excellence (Macnamara et al., 2010), constructs such as *drive* (p.64) to be one's best, *commitment to excel* (p.63) (also see *desire to excel*; Scanlan et al., 2013), and *desire*

to prove themselves (p.64) are interchangeable with motivation in explaining initiation and progressive immersion in a sport. Passion types are also pertinent, particularly the balance of *harmonious* with *obsessive passion* (Vallerand, 2012) and how values and contingencies associated with sport become internalized and integrated to the self. The dualistic model of passion (Vallerand, 2012) applies to achievement seekers who are described as having a strong inclination toward a pursuit that they like (or love), they find important, in which they invest themselves – characteristics that epitomize the profile of a majority of competitive athletes. Additionally, whether an athlete is more flexible and adaptive in their passion, or being controlled in an inflexible manner by their sport, has a bearing on the motivation and emotionality required for sustained efforts directed to a sport.

Variables at this level may need to account for the deepening of an athlete's involvement as encapsuled in Ericsson et al.'s (1993) monotonic assumption of deliberate practice (which is where aspiring athletes invest in greater amounts of training in a sport at each successive stage of their developmental journey). It might therefore be important to consider differences in how athletes identify with a sport, including *identity salience* (centrality) and *self-worth contingency* (extent to which one's self-worth is predicated on goings-on in sport) (Brewer et al., 2022). *Identity foreclosure* (Brewer et al., 2021), for example, may be an important variable in analyses that juxtapose multi-sport samplers with sport specializers. Finally, variables associated with how athletes project to a future identity may be important. For example, Canadian adolescent athletes who more strongly identified with a *future possible sport self* on a National team also reported a willingness to continue to work for a greater number of years to reach that status, than teens who less strongly identified with that future self (Young, Tedesqui et al., 2023).

Concordant measures. In sum, the highest level describes more stable dispositions directed towards a sport, including hard work and hardiness of investment, commitment to sport among competing alternatives, constancy of interest, personality-discipline fit, global motivation, and personal identification. These descriptions should ultimately align with criterion measures that are proxies for directing effort toward a pursuit over long periods. From this perspective, the catalogue of dependent measures might include survival rates based on survival analyses of athletes in a sport (Pion et al., 2015); constancy of sport involvement without lapsing; years of perseverance/investment in sport; strength/robustness of interest in a sport; choice of sport among activity alternatives, and indices related to drop-out/burn-out.

Middle Level: What Variables Augment the Duration of Efforts towards Practice Activities?

Description of the level and narrative review. At the middle level, which specifically relates to preparatory (training) activity within a sport context, the variables describe sustained engagement toward practice and athletes' decisions that result in the accumulation of more hours of practice. Variables that predict individual variability in "doing more, more often" are relevant. This includes personality tendencies that promote consistency in perseverance and hardiness across practice situations over time that should result in more accumulated practice. For example, examining the associations of different traits with various practice contexts, Tedesqui and Young (2018) found that *perseverance of effort* (i.e., an athlete's belief in their ability to sustain effort during adversity; Duckworth et al., 2007), most strongly predicted engagement in weekly practice amounts. They also found that *achievement striving* (i.e., the conscientious tendency to set more challenging goals and to work harder to accomplish them; McCrae & Löckenhoff, 2010) explained greater weekly practice amounts, and was the strongest predictor of how much optional practice (i.e., choosing to attend practices that were offered by

a coach, though attendance was not mandatory) athletes undertook.

Certain facets of *mental toughness* might associate with inter-individual variability in accumulated practice. In keeping with the middle-level, we note Gucciardi's (2017) positioning of mental toughness as a resource that could be tapped in a more state-like fashion, embodying transient and flexible characteristics. In this case, how athletes differentially recruit mental toughness could be associated with variability in their hardiness throughout recurring, taxing training tasks, and thus consequent variability in how much practice activity they complete. In this vein, Gucciardi (2020) reported that differences in how individuals perceive physical demands at higher workloads have been associated with varying degrees of mental toughness.

It is plausible that differences for how athletes interpret rewards for their training operate at this level. Côté et al. (2003) suggested that *delayed gratification* might be such a factor. Specifically, athletes who are more capable of linking immediate circumstances of arduous practice to latent, future rewards might accumulate more practice. While conceptually appealing, Young, Tedesqui et al. (2023) failed to find relationships between *consideration of future consequences* (Joireman et al., 2008) and practice amounts, though they noted this could have been due to methodological limitations. Further, *approach motivation* (Carver & White, 1994) may activate behaviors and emotions that facilitate more practice. For example, individuals with tendencies associated with greater *reward responsiveness* (a facet of approach motivation) have more positive responses to the occurrence or anticipation of rewards (Carver & White, 1994), which may be associated with greater training.

Self-control capacity, especially in relation to inhibition, may influence inter-individual variability in accumulated practice. Self-control explains lapses in sport, specifically the failure to resist impulses that are misaligned with sporting goals (Englert, 2016). For instance, during hard practice, an athlete has to resist temptations to forfeit taxing, unattractive (either strenuously effortful, fraught with errors, or mundane) practice in order to complete a full training session (Englert, 2019; Tedesqui & Young, 2015). The key premise is that athletes possess a limited self-control resource, which can suffer *ego depletion* after primary acts of self-control. This leads to a temporary exhaustion of self-control resources, which impairs performance on further self-control tasks (Baumeister et al., 2007). Inzlicht and Smeichel (2012) posited a slightly modified version; instead of assuming self-control to be a limited resource, they contended that people who have already had to exert self-control on primary tasks are less motivated to engage in self-control on subsequent tasks as taxing/unattractive conditions continue. From this perspective, during training, athletes with less self-control would be less capable of downregulating impulses (wanting to quit) associated with the less pleasant, immediate option (having to complete these practice tasks). The resulting negative emotional state and attentional diversion to gratifying the "want-to" impulse would compromise the completion of practice. Self-control capacity is placed at the middle level because the research in this area is task-based (Englert, 2016). Evidence shows self-control on a first task usually compromises the duration of self-control on a second task, implying an impact on amounts invested in successive training tasks. Tedesqui and Young (2015) also argued that ego depletion likely influences athletes' capabilities to even get to a practice session, and that self-control inadequacies may explain less practice amounts indirectly; in this case, athletes with less self-control capacity are more likely to succumb to temptations to forfeit attendance at upcoming, difficult sessions, accruing less practice. Although state self-control is usually observed during the sustenance of tasks in a depleted condition, it is determined by dispositional differences (Tangney et al., 2004) for ego strength and depletion, and conservation of self-control strength (Gröpel et al., 2014). Altogether, self-control capacity is a viable factor that may associate with durations or accumulations of effortful practice, variably impacting athletes' decisions to sustain practice or not.

Concordant measures. In sum, the middle level describes athletes' tendencies in relation to practice quantities, accumulated via the task of practicing, over time. These accumulations are posited to relate to perseverance of effort and achievement striving, mental toughness in relation to workloads at practice, how individuals anticipate and interpret delayed rewards, and differences in self-control strength. These variables determine how some individuals have a propensity to stick-with-it, repeatedly finishing tough practice sessions. We expect these variables would associate with dependent measures such as: amounts of sport-specific practice and/or amounts of deliberate practice (Bartulovic et al., 2018); frequency of practice bouts within a time frame (e.g., practice accumulations in the past season, or frequency of attendance at optional/voluntary workouts in the past season); whether athletes extend durations of training using free choice paradigms; how athletes navigate the dual-task paradigm (see Lee et al., 2016 for methods) to test for ego depletion within a sport practice setting.

Lowest Level: What Variables Enhance the Quality of Efforts during Practice Activities?

The distinction between the middle- and lower-orders of the hierarchy is important for two reasons. First, quantities of practice are not the same as quality of practice. In the framework of deliberate practice, Ericsson et al. (1993) argued that not all preparatory activities are created equally with respect to skill acquisition. Specifically, deliberate practice involves activities in which learners consciously engage in error detection and correction, and engagement in these effortful cognitive processes results in more potent skill development, and higher levels of expertise (Guadagnoli & Lee, 2004). Simply doing more practice that does not include substantial portions characterized by intentional, cognitively effortful optimization of such practice, will be limited in terms of skill development. When studies in sport expertise research fail to discriminate skill group differences (e.g., expert vs. intermediate vs. novice) on practice measures, it is sometimes because the measured practice quantities are poor proxies for cognitively enhanced practice (Baker et al., 2020). A second implication of the distinction between the two lower levels is that the nature of self-regulatory processes involved in "doing more practice, more often" (middle-level) are different from those involved in optimizing the quality of efforts within practice sessions (lower-level).

Description of the level and narrative review. With quality practice front of mind, variables at this level describe various self-regulatory processes, skills, and proficiencies that an athlete can enact in order to more intensively engage in practice tasks, and/or to strategically engage in selective tasks during training. This includes self-control and self-reflective variables pertaining to how athletes manipulate their own practice conditions and practice schedules, and how they differentially respond to diverse practice scenarios.

How an athlete self-regulates their practice using metacognitive processes for planning and self-evaluation, called *self-regulated learning* (Zimmerman, 2006) is integral for quality sport practice efforts (Baker et al., 2017; Elferink-Gemser et al., 2015). Activation of self-regulated learning processes is associated with coach reports and behavioral observation of high-quality practice segments (Kitsantas et al., 2018; Toering et al., 2011). Self-regulated learning processes help athletes manage feedback from coaches by integrating it into their own efforts (Bain et al., 2023). These processes are also important in their own right for making decisions about personal weaknesses and selecting how one spends their time in practice working on relative strengths/deficiencies in their repertoire (Coughlan et al., 2013; Deakin & Cobley, 2003; Macnamara et al., 2010). For example, because more elite athletes are attuned to their weaknesses (via self-reflection and self-evaluation), and because they can link their self-motivation to these metacognitive processes, they are more likely to spend time working on

their deficiencies under taxing practice conditions. In parallel motor learning literature, work on self-controlled feedback schedules suggests individuals may have different preferences for when and how much feedback they select to receive after trials during practice (Carter et al., 2016).

Self-regulated sport practice competencies, how self-regulated learning pertains to sport practice scenarios (Young, Wilson et al., 2023), are essential for optimizing cognitively-mediated, deliberate practice conditions. Research shows that more elite individuals know when to activate key metacognitive (i.e., planning, checking, evaluating-reflecting) and motivational (self-efficacy for challenges during training, effort) proficiencies, depending on the scenarios they find themselves in during practice (Wilson et al., 2021; Young, Bain et al., 2023). For example, being frustrated by a learning plateau, or performing below expectancies during intensive practice, are scenarios that are expected to prompt self-regulated sport proficiencies. By activating these proficiencies, athletes can contend with obstacles to skill acquisition, while sustaining effort. In this way, self-regulated sport competencies can be both intentional, but also reactive by allowing athletes to resourcefully "figure things out" during adverse tasks.

This level considers variables for how athletes differentially recruit personal motivation, sustain their efficacy, and respond emotionally, to trying practice conditions. For example, Hodges and Lohse (2022) expect that there would be inter-personal variability in how athletes respond to the same absolute difficulty of a practice task, which implies that athletes may have different ranges of emotional temperament around the same challenge. In this instance, *deliberate practice efficacy* may explain how individuals differentially navigate the motivational and effortful constraints associated with tasks of deliberate practice (LaForge-MacKenzie et al., 2016). A pertinent, but unexplored notion, is that *task-oriented coping* (which is associated with strategies such as thought control, imagery, logical analysis, support seeking, reinvestment of effort, and relaxation; Gaudreau & Blondin, 2004) may be invoked by athletes to varying degrees as they confront challenge episodes during training. Finally, emotional tolerance to challenging practice remains unstudied. However, the dual mode theory of dose-response affect during exercise (Ekkekakis et al., 2020) suggests there is critical inter-person variability in responses during heavy training loads. During heavy loads, some individuals have *emotional responsiveness* involving debilitating negative affect, whereas others at the same load experience less negative affect and are able to maintain cognitive regulation of their efforts. Altogether, we believe that there are task-focused coping and self-regulation variables that implicate inter-individual variability in how people negotiate extremely frustrating/taxing learning scenarios.

Motor learning research shows that where athletes focus their concentration is important and selecting internal/external foci has a bearing on skill acquisition (Wulf & Lethwaite, 2020). Specifically, an athlete's capability to regulate attention is a function of the practice task, context, and skill level, and is a proficiency associated with quality learning efforts. Nideffer (1993) proposed that there are stable interpersonal differences for attentional style. Ensuing research has shown that *attentional flexibility*, and the ability to shift types of focus, is subject to inter-individual variability. Recent narratives also implicate variability in whether athletes succumb to deficient attentional styles when training in pressured situations, when they are experiencing anxiety (Gray, 2020). Altogether, we locate attentional flexibility in the lowest level because it is implicated with respect to specific tasks embedded in a learning scenario, specifically directing one's attention to be compatible or not with the optimal foci on these tasks. In this fashion, inter-individual variability in attentional processes serves to enhance/diminish the quality of practice, which impacts acquired performance.

Knowledge is a common substrate of the lower-level variables we have outlined to this point. From an information processing perspective, for example, advanced perceptual-

cognitive performance and speeded working memory processing are underpinned by knowledge of "what to look for" (Eccles, 2020), which tends to be more declarative knowledge with novices and early developing athletes. Such knowledge becomes increasingly proceduralized in elite athletes. Furthermore, domain knowledge, task knowledge, and knowledge of learning strategies are cognitive resources that enable highly proficient self-regulated learning (Winne, 2011).

There are two implications of noting the link between knowledge and perceptual-cognitive elements at this level. First, although knowledge is accrued through experience, there may be differences in how individuals seek and process knowledge when they engage with practice tasks/trials. For example, Hill (2003) found that athletes varied in their *need for cognition* (Cacioppo et al., 1996), manifested in their motivation for seeking information and propensity to engage in cognitively effortful sport practice. Findings also showed that more skilled players were more likely to report a greater need for engaging in cognitively effortful practice environments. Such *information seeking propensities* may aid an athlete directly in their practice activities, and they may also embody the "coachable" qualities that coaches like from their athletes during training. Second, this link may reflect a bias towards knowledge-based, or cognitively mediated variables in the literature, a possibility we address further below.

Concordant measures. The lowest level describes individuals' proficiencies as they relate to optimizing specific practice sessions. We would expect these variables to align with criterion indices assessed in practice tasks or trials, particularly with proxy measures of quality practice. Quality practice is plausibly associated with, for example, metacognitive and motivational facets of self-regulated learning or self-regulated sport practice, task-oriented coping, deliberate practice efficacy, emotional responsiveness, attentional flexibility, and need for cognition, among other potential variables.

These variables may explain why some athletes have advantages in managing their own practice activity, in learning through self-reflection, in learning how to navigate training obstacles, and in staying on-task despite off-putting emotions. We expect that these variables would relate to dependent measures, such as athlete-reported indices of quality practice. These indices could be derived using a critical incident technique (Butterfield et al., 2005), taking an athlete's initial journal entry indicating a critically good practice, then following up with video-stimulated recall interviews or behavioral analyses of recorded practices to elaborate on the athlete's optimal approaches in specific situations. Coach-reports of quality practices could be instrumental, as well as coach-assessed or independently assessed behavioral correlates of self-regulated sport practice. There is precedent for conducting time motion analyses to infer whether athletes are using practice to strategically work on weaknesses/strengths in their repertoire (Deakin & Cobley, 2003). Notably, Coughlan et al. (2013) employed a free choice paradigm within an ecologically valid training session, then used behavioral observation to determine athletes' selection of more effortful patterns/schedules of practice. Researchers might also consider manipulations of anxiety or other off-putting emotions in simulated challenge episodes during training, then recording consequent decisions and behaviors (e.g., on-task pursuit versus disengagement, information- or help-seeking, reinvestment of effort). Measures of attentional focus and flexibility could be derived from eye-tracking protocol to determine inter-individual compatibility between visual search patterns and the task at hand.

Do athletes always need to be aware of cognitive processes during engagement in high-quality practice? Our discussion of this lowest level has in large part emphasized metacognitively mediated variables, which assumes that practicing athletes need to bring to consciousness (at least at key junctures on certain tasks) information that they work with to improve their efforts. More broadly, reflecting

on the many variables we used to exemplify the three levels of the hierarchy, we note a bias in methods towards what has been self-reported by athletes, again relying on an individual's awareness of self. This bias in sport expertise research has been noted by Baker and Young (2021), who recommended that researchers better consider how learners are inseparable from the environments in which they act, by using methods focused on athletes' behaviors in externally valid (practice) contexts rather than athlete self-report.

Carvalho and Araújo (2022) advocated for consideration of "eco-physical variables" (p.5) to capture skill learning differences between athletes. Here, between-athlete differences relate to how athletes experience the dynamic interaction of three facets: their individual resources; the environmental constraints at hand during practice; and the specific demands of the practice task. Differences in how athletes experience this triadic interaction are measured through behavior (Araújo et al., 2021). This approach is rooted in ecological dynamics, wherein the assessment of action and cognition is more metacognitively tempered as there is less concern over the athlete's awareness of their thoughts during practice. Instead, the emphasis is on the way that athletes will constantly attune to the information from the environment to coordinate and integrate multiple subprocesses (cognitive, emotional, physical) to achieve a task goal (Button et al., 2020).

Through this lens, cognition is better understood as "the on-going, active maintenance of a robust performer-environment system, achieved closely by coordinated perception and action" (Araújo et al., 2019, p.5). This meaning of cognition is very different than how it was positioned in the sections above, in that it is embodied (i.e., influenced by one's body) and embedded (i.e., constrained by the environment) (Araújo et al., 2019). Therefore, measures to assess inter-individual variability need to be behavioral in nature, with these behaviors ideally performed in practice environments that mimic demands in competition (Pinder et al., 2011). It is likely that individual difference variables (perceptual skills, physical skills and abilities, and intentions) influence how practicing athletes attune to and act upon environmental affordances (Button et al., 2020), thereby having an effect on the quality of skill acquisition.

Unlike the prior descriptions located in the lowest level of our hierarchy, this ecological perspective on quality practice does not concern itself with cognition as something that is explicitly "turned-on" by an athlete in response to challenges in practice. Instead, cognition is inextricably intertwined in the coupling of an athlete's perceptions and actions which guides their navigation and use of environmental affordances (Button et al., 2020). This perspective challenges researchers and research-practitioners to re-consider how individuals optimize situations during practice. This is important because expert athletes are often characterized by their ability to better attune their actions and decisions to information during practice (Button et al., 2020), and thus some inter-individual variability related to expertise may uniquely be captured by their behaviors in representative practice settings (Seifert & Davids, 2012).

We present this ecological perspective to emphasize that inter-individual variability around quality practice is not fully caught by metacognitive variables. This said, we are not convinced that the eco-physical perspective can be completely devoid of metacognitive features. Scholars from the ecological perspective provide roles for coaches in creating learning environments that appropriately challenge athletes (Button et al., 2020) and in priming an athlete's intentions for task goals ahead of immersion into the learning environment (Renshaw et al., 2019). The priming of an athlete's intentions would appear to catalyze processes akin to planning. It is also possible that athletes "turn on" self-monitoring and reflective processes when immersed in an ecologically contrived setting; they may do so reactively as part of human nature. We also suspect that coach debriefing of an athlete after ecological practice, or having the athlete watch a videorecording of how they had navigated the

environment, might bring awareness and reflexivity to the completed practice, engendering metacognition. By integrating eco-physical variables at the lowest level, we are setting a placeholder for future considerations around quality sport practice, and specifically the dynamics related to how different athletes use metacognitively-mediated proficiencies and more indirect/embodied conceptions of cognitions.

Integrating the Model with Multifactorial Perspectives on Expertise Development

Hambrick et al. (2018) noted, "Both psychological traits and training—*nature* [emphasis added] and nurture—contribute to individual differences in expertise" (p. 289). To offset the risk of portraying our model in strict nurturistic terms, it is important to note that individual differences in personality can be genetic in origin and relatively stable. A meta-analysis of 134 studies in the field of personality heritability showed that 39% of individual differences are due to genetic factors and 61% are due to environmental influences (Vukasovic & Bratko, 2015). Personality traits implicate "relatively enduring patterns of thoughts, feelings, and behaviors that distinguish individuals from one another" (Roberts et al., 2007, p.375) and the magnitude of personality change is only around one standard deviation across an individual's life span (Roberts et al., 2008). With individual differences in personality having substantive genetic origin, it is necessary to locate our hierarchy within narratives that see sport expertise as a product of interactions between stable factors and environments.

For instance, according to the Multi-factorial Gene-environmental Interaction Model (MGIM; Ullén et al., 2016; 2018), people experience different developmental environments in a systematic fashion because of heritable differences. They may also experience the same developmental environment differently because stable traits reflected in personality, interests, motivation, and abilities are associated with which domain a person elects to invest time in, variability in the domain and intensity of practice, as well as in the quantity and quality of practice (Ullén et al., 2016; 2018)[1].

In the MGIM, stable factor-environment interplay occurs in different ways (Hambrick et al., 2018; Tucker-Drob, 2018). *Passive rGE* occurs when a person inherits from their biological parents both a heritable stable factor and an environment linked to that stable factor (Hambrick et al., 2018). Thus, a developing athlete might share a high degree of heritability for the "need for competence" with their parents and the sport domain as the environment for fulfilling that need. Additionally, the developing athlete might share a high degree of heritability around "person-discipline fit" for sport and endurance sports as the environments for reinforcing that fit. Passive *rGE* relies on the direct influence of heritable individual differences and indirectly via parents' stable factors which influence how environments are passed along, introduced or reinforced to developing athletes. In this case, a developing athlete benefits passively, or indirectly, as they inherit rearing/developmental environments that suit their heritable stable factors. For instance, a parent who has a need for competence and personality fit for endurance sports, and who was skilful at endurance Nordic skiing, may both raise their child in an environment that is conducive to acting on these proclivities and pass on to that child their stable dispositions for need for competence, which together help to foster elite ski development.

Active rGE (Hambrick et al., 2018) occurs when a heritable stable factor influences the experiences a person seeks/creates for themselves, as when a person with high industriousness is predisposed to choose sport as the domain to act out their work ethic. Active interplay is also illustrated by a person with high "constancy of interest" who makes decisions to increasingly take on immersive opportunities in sport to consolidate that stable trait. These examples reflect "attraction" effects or "active niche-picking" (Roberts et al., 2007, p. 333) whereby people choose experiences whose qualities align with their inherited personality. Tucker-Drob (2018) described differences in "experience producing drives" (p.248) for how people select environmental experiences (e.g., training, practice) based on proclivities, motivations, goals and aptitudes for the skills (e.g., high level performance in a sport) being acquired.

We have illustrated our hierarchy in Figure 1 with stable factor-environment interplay added in the left column. Passive and active interplay are noted in larger font at higher hierarchical levels than at lower ones. This does not dismiss the influence of stable individual difference factors for motivation and learning at lower levels; however, it recognizes their possibly diminished relative influence in keeping with traditional conceptualizations of self-concepts in the psychological sciences.

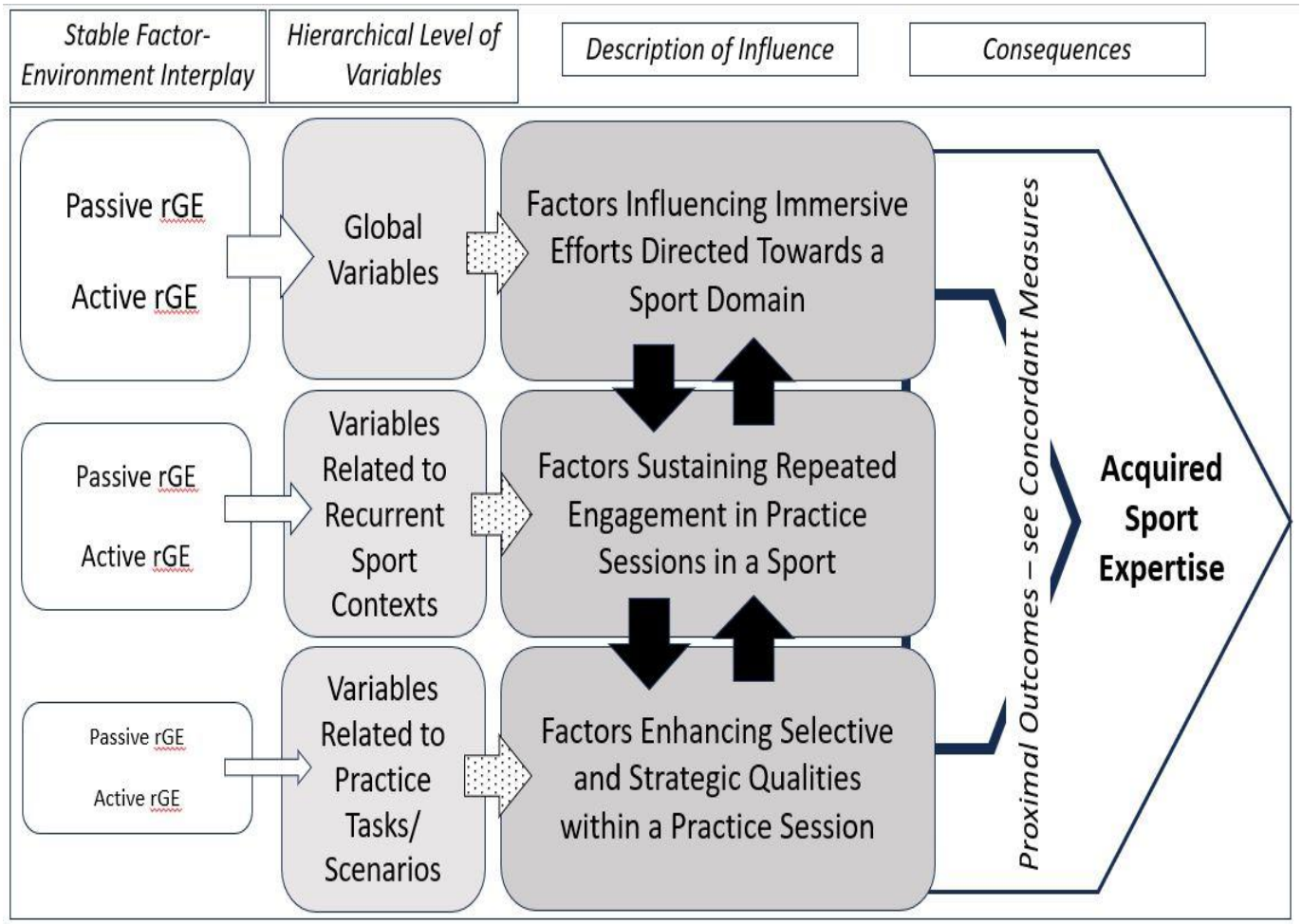

Figure 1. Graphical representation of our hierarchical model showing interplay with passive and active stable factors

Closing Remarks

The study of elite athlete development is highly complex, with so many variables that there is the risk of disjointed analytics and unfocused empirical approaches. Thus, we aimed to present a model for considering how to locate variables that have potential influence on inter-individual variability in elite athlete development, especially psychological variables that are likely to influence efforts towards practice, and how athletes may vary in their proficiencies for optimizing practice. It is our hope that conceptually minded scholars might consider variables at three levels and how these variables predict effects associated with i) long-term striving and ever immersive engagement in a sport (i.e., highest level), ii) accrual of practice amounts (middle level), and iii) facets of quality sport practice (lowest level). By no means is our effort exhaustive – indeed, we hope we have introduced the skeleton of our model sufficiently that others might populate it with their variables of interest. The impact of this manuscript depends on how scholars interrogate

their work on elite athlete development according to conceptual levels (and associated psychological mechanisms/descriptions) and the concordant outcome variables they associate with these levels. We posit that better alignment between conceptual levels and concordant measurement should result in greater or more reliable effects in talent development research, which serves to advance the field.

As with any initial effort, there are notable caveats. First, the boundaries between the levels are not "hard and fast." They are meant to be abstractly intuitive, similar to the conversation around hierarchical constructs differentiating levels of self-system constructs in sport psychology (see Sabiston et al., 2018) and micro-macro perspectives on athlete self-regulation (Gould & Chung, 2004). Second, we have focused on variables that are attributed to "something about the person psychologically" in relation to motivation, personality psychology or learning psychology. Third, scholars who subscribe to a social interactionist perspective will query where social affordances, social influences, social constraints, social inequities, and the process of socialization in sport have been ascribed to this model. We have not attempted to treat this, but suggest that social influences act at all levels, act as antecedents to variables throughout the model, and generally impact all relationships between the variables and concordant measures.

In this vein, a third type of gene-environmental interplay is *evocative rGE* (Hambrick et al., 2018), which occurs when a developing athlete's stable heritable factors elicit certain reactions in other people. We believe that evocative *rGE* works at all hierarchical levels, as when a sport organization recognizes a young athlete's "person-discipline fit" and creates early precocious sporting opportunities for them, or when a coach gives preferential training opportunities to a young athlete in an esteemed training program because they manifest achievement striving and perseverant qualities.

The finding that coaches prefer athletes with conscientious qualities and see them as more coachable (Tedesqui & Young, 2020) suggests evocative *rGE* acts at the lowest hierarchical level around affordances to quality practice. This said, we acknowledge that we have not developed the evocative *rGE* aspect of our model beyond these cursory comments, leaving room for future elaboration. Such elaboration should locate variables within a broader social-cultural context to include social inequities that create relative (dis)advantages.

We have not treated our model in a longitudinal sense, beyond advancing the idea that lower levels represent nested repeated occurrences within a higher-level "current" of sport interest, investment, and motivation over time. This is an area ripe for development. Tucker-Drob (2018), for instance describes the co-occurrence of two longitudinal processes. First, stable factors (genotypes) cause inter-individual variability in effort-related aspects, such as motivation, drive and constancy of interest to seek out practice/preparatory opportunities, which accrue and increasingly distinguish people over time. Second, stable factors cause inter-individual variability in rates of responsiveness to learning (assuming the same amounts of practice/preparatory activity), which also increasingly differentiate people longitudinally. These co-occurring factors seem to align with the stable factor-environment interplay we have positioned at the higher level and lower-levels of our model, respectively. However, work is needed to model this longitudinally and to consider recursive trends associated with increasing effects of heritability over time (Tucker-Drob, 2018), including Matthew Effects (Hancock et al., 2013).

In conclusion, there have been inconsistent, if not disjointed, associations between psychological variables identified as exerting inter-individual effects in elite athlete development, and the associated criterion measures of striving and practice they are meant to effect. To remedy this, we articulated a model that could provide greater coherency to the empirical landscape. In this model, we suggested that a fulsome understanding of athlete development requires consideration of metacognitively-mediated proficiencies as well as metacognitively-tempered facets, including

eco-physical variables. Respectfully, it is our hope that the model carries sufficient rigor that it encourages our colleagues to consider the level at which their study purports to work, and the expected associations between their key psychological constructs and any concordant criterion measures for athlete development.

Endnote

1. The MGIM model considers that expert performance can be influenced directly by a number of other variables than practice or preparatory activities. It considers a range of individual difference variables for expertise, including genes dictating physical properties, sensorimotor and neural mechanisms, which have their own effects on expertise beyond effects mediated through practice. However, seeing that our purpose is to align individual difference variables with ontogenetic expression in relation to developmental experiences, we have not addressed these broader considerations. Readers are referred to Ullén et al. (2016; 2018) for more fulsome treatment of this topic.

Authors' Declarations

The authors declare that there are no personal or financial conflicts of interest regarding the research in this article.

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