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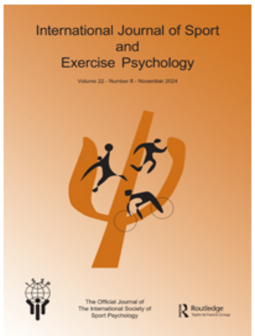

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How small differences grow over time – the snowball effect of grit on practice in sport

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ABSTRACT

Domain-specific practice is crucial for expertise. While much is known about practice, less is understood about what motivates individuals to start and continue with the intensive domain-specific practice needed for expert performance. We demonstrate in a large sample ($N = 388$) of Australian elite youth soccer players that they retrospectively report different amounts of practice at various stages of development and that acquisition is driven by the personality trait of grit. Players reported consistently engaging in domain-specific activities every year from age 8 until 13 years. The estimated logged hours experienced a marked acceleration at the age of 13 years, resulting in an enhanced and curvilinear pattern of practice accumulation. Grittier players, however, start accumulating more practice at the beginning of the talent development process and continue to consistently log more hours throughout the years than less gritty players. Consequently, initially small differences in practice engagement between those with high and low grit scores, snowball into sizable ones at the age of 15 years. The impact of grit on practice accumulation is, however, more subtle, as grit's two components, consistency of interest and perseverance of effort, exert a different pattern of influence. The driving factor of the initial differences and their consistent snowball effect until age 13 years is a consistency of interest, whereas the perseverance of effort aspect impacts the practice acceleration period from age 13 to age 15 years. We elaborate on these findings to explain the complex relationship between grit and practice on the path to performance excellence.

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Introduction

It is well-established that practice is one of the key factors underpinning skill acquisition (Baker & Young, 2014; Ericsson et al., 1993). However, although numerous researchers have highlighted the importance of practice (Campitelli & Gobet, 2011; Ericsson, 2020b; Macnamara & Hambrick, 2020), the effectiveness of different types of practice (Baker & Young, 2014; Ericsson & Harwell, 2019), and the mechanisms underpinning skill learning (Ericsson & Pool, 2016), questions relating to why people practice in the first place, as well as the mechanisms by which motivation impacts practice, remain unresolved. Scientists have reported that numerous biological and psychological factors impact the motivation to practice (Duda, 2007; Fry & Moore, 2019; Roberts & Treasure, 2012; Tušak et al., 2022; Vallerand, 2007; Vallerand & Losier, 1999). Grit, a psychological trait of persistence and determination, seems to be a good candidate for bettering the understanding of the reasons behind highly focused purposeful practice, as demonstrated by studies conducted in academia, military and workplace (Akos & Kretchmar, 2017; Duckworth et al., 2007, 2019; Eskreis-Winkler et al., 2014; Jachimowicz et al., 2018). In this paper, we examine the influence of grit on practice in a large sample of elite Australian youth soccer players. We show that an initially small difference between gritty and less gritty elite young players in the amount of accumulated practice snowballs into larger discriminatory effects as the grittier players consistently log more practice hours over the years. The grit component, consistency of interest (consistency of interest), may be the initial driving factor behind this snowball effect, but other components of grit, perseverance of effort, is the one that influences the acquisition of practice in the later phase when players become serious about their chosen domain and start investing in more practice hours.

The role of practice in expertise development

Expertise, in any field, requires domain-specific knowledge (Broadbent et al., 2015). The acquired knowledge enables experts to recognise the regularities in complex environments and to further utilise those regularities to quickly orient themselves (Bilalić, 2017). To acquire this knowledge, experts immerse themselves in domain-related activities (Sloboda et al., 1996; Williamon & Valentine, 2000; Williams et al., 2012). Leaving aside the current controversy (Ericsson, 2020a, 2020b; Hambrick et al., 2016; Macnamara & Hambrick, 2020) about whether practice (and what kind of practice) is sufficient (Ericsson, 2008; Ericsson et al., 1993) or a necessary component of expertise (Campitelli & Gobet, 2011; Moreau et al., 2019), practice is an essential ingredient as it helps in forming mental structures required for experts' outstanding performance (Bilalić, 2017; Smeeton & Williams, 2012).

Practice also plays an important role in different talent development pathways. Côté's (1999) Developmental Model of Sport Participation (DMSP) offers two primary pathways towards sports expertise that differ primarily with respect to the type of activities future experts engage in during childhood. In the early specialisation pathway, expertise is developed from engaging with high volumes of domain specific deliberate practice in one sport from an early age. In the early diversification/sampling pathway, expertise can be developed through multisport participation and sport-related play activities during childhood (6-12 years). Throughout adolescence, athletes gradually narrow their focus of sport interests during the specialising phase (age 13-15yrs) towards specialisation in a single sport in the investment phase (age 16+) (Côté, 1999; Côté & Vierimaa, 2014).

The model has been pivotal for promoting research into the various outcomes associated with each pathway. Some research groups have claimed distinct benefits from the early diversification approach including skill development (Côté & Jennifer, 2012), decreased drop out from sport (Gould & Maynard, 2009), reduced incidence of injury (e.g., Post et al., 2017) and prolonged intrinsic motivation for sport involvement (Côté et al., 2011; Côté & Jennifer, 2012). Others have highlighted the benefits of an early, but not exclusive engagement in sport-specific practice (e.g., Ford et al., 2009; Hendry & Hodges, 2018; Sieghartsleitner et al., 2018). All these models generally converge with respect to increases in primary sports practice involvement during the specialisation (age 13–15) and investment years (16–18) as the proximity to elite adult sport draws closer. Although sports expertise research has highlighted some of the upturns in developmental activities associated with expertise during adolescence, less is known about the psychological factors that underpin initial and continued engagement in the type of sport practice behaviours necessary for expert performance.

Grit

One factor that has been used to explain the highly focused, almost obsessive, approach to practice and competition is a personality trait known as grit (Hardy et al., 2017; Hodges et al., 2017). Grit is defined as persisting interest and determination in achieving long-term goals in spite of challenges and setbacks (Duckworth et al., 2007, 2019). It is seen as part of conscientiousness (Duckworth et al., 2019), one of the personality traits of Big Five (John, 2021; John et al., 1991), and can be colloquially understood as persevering (at a long-term goal) despite obstacles and challenges (Duckworth et al., 2019; Roberts et al., 2014). Grit, however, differentiates from conscientiousness by its predictive strength and by emphasising long-term stamina instead of short-term intensity that is relevant for conscientiousness (Duckworth et al., 2007; Duckworth & Gross, 2014).

Grit is composed of two facets, namely, *Perseverance of Effort (PE)* and *Consistency of Interests (CI)*. Perseverance of effort refers to one's ability to maintain effort in the face of difficulties, while consistency of interest refers to continuous interest, throughout time, on a single life goal instead of focusing on different superordinate goals over short periods of time (Duckworth & Quinn, 2009). According to Tedesqui and Young (2017), consistency of interest denotes the direction of one's passion, while perseverance of effort characterises the magnitude of effort put forward in pursuit of that passion. However, the construct validity of grit, as a higher-order structure, has been questioned. A recent meta-analysis of studies conducted in academic domains shows that only perseverance of effort explains variance in performance and has significantly stronger criterion validity than consistency of interest (Credé et al., 2017). Therefore, it has been recommended that researchers, when studying grit, analyse the two facets separately instead of as a composite score (Credé, 2018). Since these conclusions have been drawn from the research in a non-sport domain, and since the participants differed in age and level of expertise compared to our sample, we used both grit as a composite, as well as the two facets separately, in this study (see, also Duckworth et al., 2021).

Grit has been shown to add to the explanation of expert performance, in both academic and non-academic settings (including sports), beyond practice and ability (Akos & Kretchmar, 2017; Cormier et al., 2021; Duckworth et al., 2019; Eskreis-Winkler et al., 2014; Jachimowicz et al., 2018). However, there have been few published reports focusing on the relationships between grit and (deliberate) practice, in both heterogeneous and homogenous samples (see Cormier et al., 2021). Grittier athletes, overall, have been found to log more hours of practice and persist despite setbacks (Fawver et al., 2020; Larkin et al., 2016; Tedesqui & Young, 2017, 2018), a finding that is common in non-sport domains (Duckworth et al., 2011). In a recent study, Cousins and colleagues (2020) found only one facet of grit, consistency of interest, was correlated with the number of years athletes spent practising, which is further corroborated by Tedesqui and Young (2017) who found the consistency of interest to be more strongly and inversely related to switching out of sport activity or quitting. On the other hand, the same study (Tedesqui & Young, 2017) found that perseverance of effort was more strongly related to the amount of practice. However, another replication study by the same authors (Tedesqui et al., 2018) failed to capture this relation.

The effect of grit on practice

Many retrospective studies charted the accumulation of practice in sport and non-sport domains (see Baker et al., 2020; Ericsson et al., 1993; Partington et al., 2014) and demonstrated monotonic relationships between practice and subsequent years of development over time. Studies in sport domain, specifically, established accumulated practice patterns that are linear in nature, with inflection points that appear accelerated or quadric during the adolescent years (e.g., Helsen et al., 1998; Starkes, 2000; Young, 1998). Even though there is a precedent in the retrospective-longitudinal deliberate practice literature in sport for choosing to test linear and quadric models related to practice, studies do not always set to (statistically) identify the best (mathematical) function for describing the developmental practice trajectory, that is, practice (accumulation) curve. Even more seldom do they examine the factors that could modify the shape of the practice curve. This is unfortunate as such findings should have theoretical implications. Theoretically, the shape of the practice curve would develop our current understanding of talent models, which predict changes in the amount of logged practice hours depending on the developmental stage. Moreover, knowing how grit could impact practice acquisition with age would enrich theoretical frameworks of talent development.

The importance of grit for practice engagement is theoretically clear (Ericsson & Pool, 2016) and has been demonstrated empirically (Duckworth et al., 2011). The question, however, remains by which mechanisms grit makes an effect on practice. Grit could lead to a difference only at the very early stage which would then remain constant over the years as illustrated in Figure 1(A) (additive effect). Grit could also consistently impact the practice acquisition at each year as grittier players would consistently invest the same amount or more hours than their less gritty peers (snowball cumulative effect). This results in an initially small difference growing into increasingly larger differences throughout the years (see Figure 1(B)). Grit could, however, only influence the later stages of practice acquisition when the domain-specific activities pick up pace as the players start to specialise (Figure 1(C); accelerated snowball effect). Finally, grit

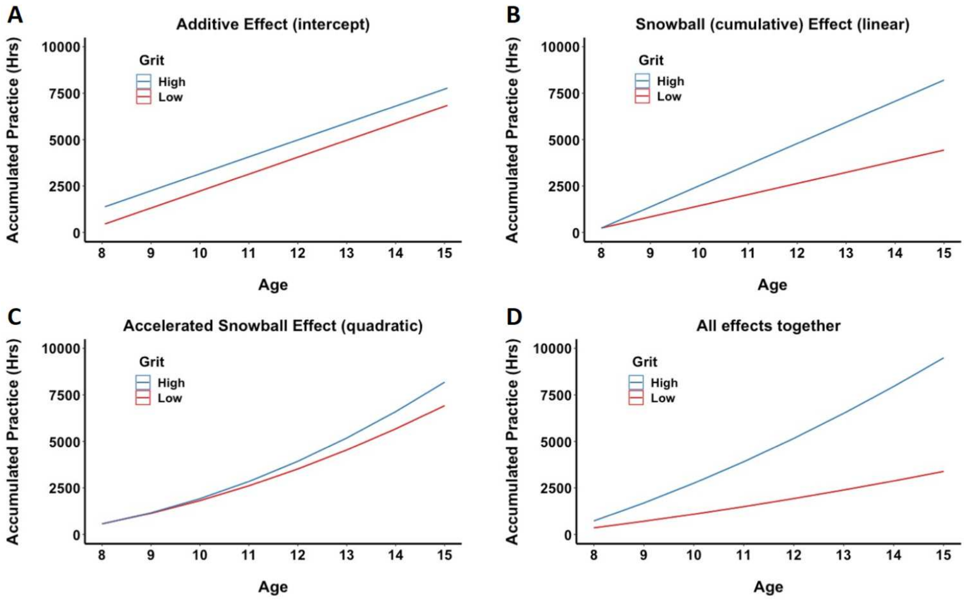

Figure 1. Hypothetical effects. Grit could have only an effect at the beginning (age eight in this study – see method), where the initial differences will be carried over to other years (A). Grit could also have a constant cumulative effect across the years where a small initial difference snowballs into a big difference over the years (B). Finally, grit could play a role in the later phase where small differences exponentially increase over the later years (C). All three effects together could produce a huge difference over the years (D). The terms in the brackets in the title (intercept, linear, and quadratic) indicate the parts of the model (regression) with which grit interacts (see Method for more details).

could have an effect at each stage as depicted in Figure 1(D). Here we set out to statistically distinguish the best mathematical function for describing the accumulation of practice hours during an elite athlete's development, as well as to explore the impact that the personality trait grit, and its components, have on the process of practice accumulation.

Current study

In this study, a large sample of highly skilled Australian youth soccer players were assessed on the grit measure and its components, as well as on their accumulated practice over the years (from the age of eight to 15 years). At the general level (regardless of levels of grit), we were interested in how players accumulate hours in domain-specific activities from age 8–15 years, corresponding to the sampling and specialising years in the DMSP (Côté, 1999; Côté & Vierimaa, 2014). Based on the DMSP, we would expect to see an accumulation of a consistent amount of practice in the first sampling stage. Only in the second specialisation stage, would we expect players to start logging more practice than previously. In other words, the resulting developmental practice curve should be curvilinear with the later years, starting around the age of 13 years, displaying accelerated patterns of practice acquisition.

Given the scarcity of studies investigating the influence of grit on the accumulation of domain-specific practice over the years, our study can be considered exploratory in nature. We nevertheless expect the personality trait grit to influence the practice acquisition process at all stages. We anticipate that grittier players should be differentiated from their less gritty peers in terms of practice hours at the earliest stage of development (8 years; initial additive effect – see Figure 1). The difference may become increasingly more pronounced over the years as every year grittier players will consistently log more time in practice activities (cumulative snowball effect – see Figure 1). Grit could also be one of the driving forces behind the accelerated accumulation of practice in the later stages (accelerated snowball effect – see Figure 1). The extent of these effects is, however, difficult to gauge without previous studies to build upon.

Finally, it is difficult to predict the impact of the individual components of grit on the developmental trajectory of practice accumulation. Côté's DMSP (Côté, 1999; Côté & Vierimaa, 2014) indicates potentially greater importance of diverse interests during the sampling years (when fun and enjoyment are the primary focus of engagement in sporting activity), as well as the increasing importance of perseverance of effort for the more challenging activities that start from the specialising years onwards (Tedesqui & Young, 2017, 2018). Previous research, however, produced inconsistent results when it comes to the two components of grit (see Cormier et al., 2021).

Methods

Participants

The participants were all youth male soccer players (U16) who were selected by their regional youth soccer development programmes and were competing at the Australian national youth soccer championships at the time of testing in 2013. They can be considered to represent the population of the best Australian youth male soccer players at that time. This is demonstrated by the selection of 20 players to represent the Australian national team at least once by the year 2024. Out of the initial 445 players, 388 (M_{age} = 13.8, SD_{age} = .8) had complete age, grit and practice data necessary for the analyses. The institutional research ethics board of the University of Sidney approved the study, and written parental consent was obtained for all youth players prior to data collection. It should be noted that this study is a part of a comprehensive project and that we previously published data from this sample (Larkin et al., 2016; 2023). The current work, however, addresses a novel question where variables, analysis, and theoretical contribution (e.g., introduction and discussion) substantially differ from the previously published works.

Measures

Grit

We utilised the child-adapted version of the Short Grit Scale (Duckworth & Quinn, 2009). The Grit-S, a general personality inventory, is an eight-item self-report questionnaire where the items were answered on a 5-point rating scale from 1 (not like me at all) to 5 (very much like me). Four of the items measure the consistency of interest (e.g., "New ideas and projects sometimes distract me from previous ones." – reverse scoring), while the other four items measure Perseverance of Effort (e.g., "I finish whatever I begin").

The conducted confirmatory factor analysis (CFA) showed that the model with one factor (only grit) had a poor fit to the data ($\chi^2 = 97$, $df = 20$, $p < .001$; RMSE = .11; CFI = .75; TLI = .65; SRMR = .065), whereas the model with two factors, consistency of interest and perseverance of effort, was fitting somewhat better, but was still suboptimal ($\chi^2 = 59$, $df = 19$, $p < .001$; RMSE = .08; CFI = .87; TLI = .81; SRMR = .056 – see also Section 1 in the online Supplementary Material, SM[1]). The two-factor model was further improved by excluding a question ("Setbacks don't discourage me. I don't give up easily."), which was also found to be a problem in other studies (Dunn et al., 2021; Shields et al., 2018; Tedesqui & Young, 2017, 2018). The modified two-factor model had a good fit ($\chi^2 = 21$, $df = 13$, $p = .08$; RMSE = .04; CFI = .97; TLI = .95; SRMR = .04). It should be noted that this two-factor model can include an overarching Grit factor (comprising the two subordinate factors: consistency of interest and perseverance of effort), which would have the same fit or statistical properties as the two-factor model (see Credé, 2018). Here, we examined the two Grit subcomponents separately because it has been shown that they have distinct effects on psychological constructs (Credé et al., 2017). Consistent with prior research (see Cormier et al., 2021; Larkin et al., 2023), we additionally provided an analysis for the composite grit construct.

Practice

An adapted version of the Participation History Questionnaire, PHQ (Ward et al., 2007), a self-reported measure of practice activities, was used to gather data related to soccer activities that players had undertaken from the current season back to eight years of age. The age (eight years) had been chosen because that is the age when many players start taking part in complex soccer activities such as three-on-three small-side games and training (Australian Football developmental pathway; Australia, 2013 – FFA National curriculum). Participants were asked questions relating to the recollection of the number of hours per week and the number of months per year engaged in five soccer-related activities, including match play (i.e., competitive soccer matches), coach-led practice (i.e., soccer practice with a coach), individual practice (i.e., soccer activity by oneself), peer-led play (i.e., soccer activities with peers, including small-sided games), and indirect involvement (activities of non-physical nature, such as playing soccer computer games and watching soccer games, all counted equally). The players submitted one report annually starting at the current season and going back to age eight. It can be argued that indirect involvement is a different, non-physical, category of relevant soccer activity. In our analysis, we grouped indirect involvement with other physical activities because one could theoretically argue that it still represents an activity reflecting a player's interest and persistence. Most importantly, our primary focus is not on the specific effects different activities have on skill development, but rather on the accumulation of activities as an indicator of interest and perseverance.

Data analysis

Longitudinal multilevel modelling

Given we were interested in how grit (or its two components) influences the accumulation of practice over the early career of elite youth soccer players, we employed the multilevel modelling approach which accounts for nested data such as repeated measures within an individual (Singer & Willett, 2003). There are three effects of interest in this study. The first assumes an initial effect of grit which remains constant over the year (intercept, additive effect). The second effect assumes that the effect of grit is constant every year – each year grittier players accumulate more practice hours than their less gritty peers (cumulative snowball effect). Finally, the third effect (accelerated snowball effect) assumes that there is an acceleration of accumulated practice in the later stages. The initial effect can be checked by adding grit to the intercept, the snowball effect by adding grit to the linear term (here of age) to create an interaction (age x grit), while the accelerated snowball is investigated by adding grit to the quadratic term of age (essentially making age^2 x grit interaction). Given that our goal is to examine whether the effects are present (and not to find the best-fitting model), we used the final model (Figure 1(D)) which entails all three effects. In the first version, the grit measure was a composite score (entails both consistency of interest and perseverance of effort items). In the second version, we used consistency of interest and perseverance of effort in the model instead of the composite grit measure. In both versions, we used the total practice as the measure of practice (see SM, Section 2 for the mathematical equations of the two models). In all models, we centred the age on 8 (i.e., the intercept values correspond to age 8 and not 0) and grit, and consistency of interest and perseverance of effort on its mean (3.7, 3.3, and 4.2, respectively).

Bayesian framework

The Bayesian framework has been chosen because it is more robust regarding the issues with non-normality (Kruschke, 2011) and it offers a flexible environment where the individual coefficients can be easily compared to each other (which is necessary for the consistency of interest vs. perseverance of effort comparison). Given the exploratory nature of the study, we used weakly informative priors (for normal distribution) where the direction of the influence is indicated, but the effect's range is set to be very large. For example, the effect of grit (i.e., one unit of difference in grit) was assumed to be equal 150 h per year (M = 150), but its SD is large, (SD = 300 h); thus encompassing a wide range of positive and negative values. Similarly, the effect of grit on the accelerated part was positive (M = 10), but with a large variation (SD = 30). The same priors are used for the models involving both consistency of interest and perseverance of effort (see SM, Sections 5.1 and 6.1 for our reasoning behind the priors). The additional analyses, which use un-informative priors (centred around 0 with the same large SD) and flat default priors, confirmed that the results presented here are rather robust and insensitive to different priors.

We report the estimated coefficients (i.e., central tendencies) and supplement them with the 89% credible intervals (CrI), a range of values on the posterior probability distribution that includes 89% of the distribution. The 89% CrI is taken because they are considered as a more stable alternative to the 95% CrI (Kruschke, 2011; McElreath, 2018) and has been increasingly popular in research using Bayesian statistics (Bilalić et al., 2021; 2023a; 2023b; Makowski et al., 2019; Vaci et al., 2019). The results in our study are robust and their interpretation does not change when 95% CrI is used (see the SM). If 0 is not included in the CrI range, we consider the effect to be consistent in that direction or significant in the traditional sense (Makowski et al., 2019). Besides CrI, we also provide the probability of direction (pd), that is the proportion of the posterior distribution that is of the same sign as the mean estimate (i.e., a Bayesian equal of the p measure in the frequentist statistics; Makowski et al., 2019). We used these measures to interpret the results, as they also correspond well with the frequentist iteration of the same analysis (see, SM, Sections 5.2 and 6.2).

We also present two measures of significance, that is how important the estimates are: Regions Of Practical Equivalence (ROPE) and Bayes Factor (BF) measures. The ROPE assesses the significance of values within the CrI by identifying a "region of practical equivalence" and evaluating the extent to which the posterior distribution lies within this region. On the other hand, the BF quantifies the shift in probability density towards or away from the null hypothesis after data analysis. ROPE and BF extend beyond mere confirmation of an effect's presence; they also determine the possibility of its absence. A high ROPE percentage (e.g., 95%) indicates a substantial region of practical equivalence, while BF is divided into two metrics: BF10, indicating the strength of the effect, and BF01, indicating the strength of the null effect (A BF between 1 and 3, which indicates that one hypothesis is 1–3 times more likely given the data, is considered to provide weak evidence. A BF between 3 and 10 suggests moderate evidence, a BF from 10 to 30 indicates strong evidence, a BF from 30 to 100 is indicative of very strong evidence, and a BF above 100 is considered to provide extreme evidence – van Doorn et al., 2021). It should be highlighted that these measures should be interpreted carefully because (1) it is unclear what regions are not of practical importance in this context (ROPE) and (2) what exactly should be priors, on which BFs are highly dependent, given the lack of similar research.

All analyses were done in R and the multilevel Bayesian analysis was conducted in brms package (Bürkner, 2017). We provide a detailed commented code for the analyses presented in the main and supplemental text (together with the accompanying data) at this address: https://osf.io/zwgta.

Results

Descriptive statistics

Our elite youth players commenced participation in soccer-related activities at approximately age eight, with a few beginning their involvement as early as the age of five.

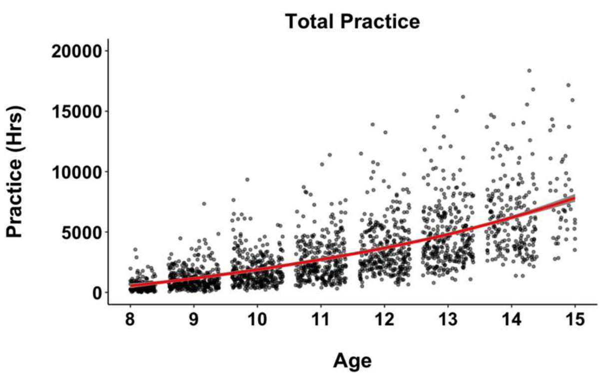

Figure 2. Accumulated practice (total and different types) over the years (8–15). The accumulation of practice is relatively constant until the age of 13 when it suddenly accelerates.

Figure 2 illustrates that, by fourteen years of age, the players have already accumulated over 5000 h of practice activities on average (see SM, Section 3 for additional descriptive statistics). On grit, they scored high ($M = 3.7$, $SD = .50$) on a 5-point scale. The players scored on Perseverance of Effort 4.2 on average ($SD = .55$), while on consistency of interest, they scored 3.3 on average ($SD = .66$).

The shape of the practice curve over the years (Linear vs. quadratic function)

Figure 2 demonstrates that in the total practice (the sum of all practice types), players logged more practice in later years (specialising) than they did in the early years (sampling). This effect resulted in an accelerated curve at later ages in the total practice, where the amount of practice remained constant over the years. This observation was formally assessed by comparing the model fit where there was only a linear increase, against models where there was also a quadratic increase, with the quadratic term capturing the acceleration of practice logging in later years. The quadratic models fit the data significantly better than the linear model ($\chi^2 = 1134$, $df = 1$, $p < .001$; for more details, see SM, Section 4.1). More importantly, the two-lines analysis which explicitly looks for breaks (Gula et al., 2021; Long et al., 2024; Simonsohn, 2018), indicates that the most likely breaking point is at age 13 (see SM, Section 4.2, Figure SM2).

The effect of grit on the (total) accumulated practice

We first checked the initial additive, cumulative (snowball) and accelerated cumulative (accelerated snowball) effects of grit (measured as a composite) on the total accumulated practice, which includes all activities, over the years. The fixed effect was checked by adding grit to the intercept, the snowball effect by the interaction between age (linear term) and grit, while the accelerated snowball effect was investigated by the interaction of grit with the quadratic age term. In all instances, we used a multilevel regression approach where the repeated measures over the years were nested within participants (see Methods).

Table 1 demonstrates that grit has both an additive (initial intercept) and snowball effect (linear term) on accumulated practice, but that its accelerated snowball effect is not consistent (quadratic term). In other words, the grittier players start with a small

Table 1. The influence of grit on accumulation of total practice.

Effect	Predictor	β	CrI low	CrI high	pd	ROPE	BF_{10}	BF_{01}
Initial (intercept)	Intercept	545	483	606	1	1%	>1000	>1000
Initial (intercept)	Grit	151	27	272	0.98	4%	1.4	0.7
Snowball (linear)	Age	501	459	544	1	0%	>1000	0
Snowball (linear)	Age x Grit	149	62	238	0.99	3%	5.5	0.2
Accelerated Snowball (quadratic)	Age^2	66	63	68	1	0%	>1000	0
Accelerated Snowball (quadratic)	Age^2 x Grit	1.99	−3.58	7.5	0.72	79%	0.1	7.8
Model Fit	Marginal R^2	0.52						
Model Fit	Bayes R^2	0.99						

Note. Age is centred on 8 and Grit is centred on 3.7; β = raw estimates; CrI = 89% Credible Intervals; pd = probability of direction; ROPE = Region of Practical Equivalence (−50/50 for Age and Age^2; −25/25 for Grit and Age x Grit; −5/5 for Age^2; −2.5/2.5 for Age^2 x Grit); BF_{10} = Bayes Factor in favour of H1 over H0; BF_{01} = Bayes Factor in favour of H0 over H1; Marginal R^2 = explained variance for random effects; Bayes (conditional) R^2 = explained variance for random and fixed effects.

but significant edge in the logged practice (one unit of grit equals around 151 more hours at age 8), which constantly increases over the years (around 149 more hours every year). Both the initial and snowball effects were consistent when it comes to the direction (e.g., CrI did not include 0 and pd was 0.99 and 0.98). Similarly, the significance measures were also indicative of grit's initial and snowball effects, although not as strong (e.g., 4% and 3% within the ROPE region, but BF were 1.4 and 5.5 for initial and snowball effects, respectively). The accelerated accumulation of the practice in the last three years is also affected positively by grit (around 2 more hours per year) but the effect was not consistent (0 within CrI and pd = 0.72) nor significant (almost 80% within ROPE and moderate evidence for the absence of effect, $BF_{01} = 7.8$).

To depict the trends, we plot the model results using two hypothetical players with differing grit values. The high-grit player has a value of 4.2, which is about 1SD above the average (3.7 + 0.5), while the low-grit player has a value of 3.2, again about 1SD below the mean (3.7 - 0.5). As depicted in Figure 3, the difference in logged time between the more and less gritty players is small at the beginning. However, the grittier player constantly logs an additional amount of practice compared to his less gritty peer. In the end, the overall logged time is markedly different; at the age of 15, the high-grit player has logged around 8000 h, around 20% more than the low-grit player, who accumulated around 6000 h (model's fit was excellent, see SM, Section 5.3).

The effect of consistency of interest and perseverance of effort on (total) practice

In the next step, we replaced the (composite) grit score in the multilevel regression with its components, consistency of interest and perseverance of effort. Table 2 shows that players with higher consistency of interest accumulated more practice overall at the beginning (additive effect) and then continued to accumulate more practice over the years (snowball effect). Both effects were reliable (CrI and pd), but the snowball effect was particularly significant (the presence of the effect was 15 times more likely than

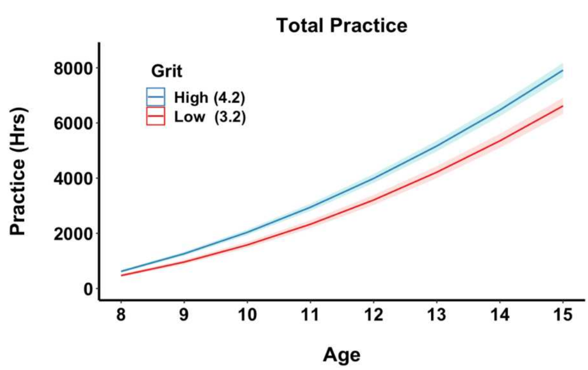

Figure 3. A model illustrating the influence of grit on the total accumulated practice. Presented are accumulated practice times over the years for two hypothetical players, one with high grit score (+1SD) and the other with low grit score (−1SD). The shaded parts around the main lines represent +/- 1 SE of the mean.

Table 2. The influence of components of grit, consistency of interest (CI) and perseverance of effort (PE), on the accumulated total practice.

Effect	Predictor	β	CrI low	CrI high	pd	ROPE	BF_{10}	BF_{01}
Initial (intercept)	Intercept	585	517	653	1	100%	>1000	0
Initial (intercept)	Consistency of Interest (CI)	129	33	226	0.98	3%	3.5	0.6
Initial (intercept)	Perseverance of Effort (PE)	15	−102	134	0.58	26%	0.2	4.6
Snowball (linear)	Age	542	493	591	1	100%	>1000	0
Snowball (linear)	Age x CI	139	68	208	0.99	2%	15.1	0.1
Snowball (linear)	Age x PE	8	−76	94	0.52	52%	0.2	6.2
Accelerated snowball (quadratic)	Age^2	65	62	68	1	100%	>1000	0
Accelerated snowball (quadratic)	Age^2 x CI	−2.6	−7.1	1.8	0.83	81%	7.6	0.1
Accelerated snowball (quadratic)	Age^2 x PE	7.1	1.9	12.4	0.98	6%	1.1	0.9
Model fit	Marginal R^2	0.52						
Model fit	Bayes R^2	0.99						

Note. Age is centred on 8 CI is centred on 3.7 and PE is centred on 4.2; β= raw estimates; CrI = 89% Credible Intervals; pd = probability of direction; ROPE = Region of Practical Equivalence (−50/50 for Age and Age^2; −25/25 for CI/PE and Age x CI/PE; −5/5 for Age^2; −2.5/2.5 for Age^2 x CI/PE); BF_{10} = Bayes Factor in favour of H1 over H0; BF_{01} = Bayes Factor in favour of H0 over H1; Marginal R^2 = explained variance for random effects; Bayes (conditional) R^2 = explained variance for random and fixed effects.

absence, $BF_{10} = 15.1$) unlike the initial effect (BF_{10} only 1.7, but only 3% in ROPE). Perseverance of effort, in contrast, was not a significant predictor of the total amount of practice either at the beginning or in the follow-up years. In both cases, there is evidence that the effect was truly absent ($BF_{01} > 3$).

However, the situation was different in the last phase where the accelerated snowball effect was visible, that is, the players accumulated more practice per year in the last three years than in the previous years. The players with higher perseverance of effort accumulated more practice in the last three years than the players with lower perseverance of effort scores. Consistency of interest, in contrast, was not a significant predictor of the accelerated acquisition of practice in the later stage (again, the model's fit was excellent, see SM, Section 6.3). It should be noted that while the absence of the consistency of interest's impact on the accelerated snowball effect was reliable and significant (e.g., $BF_{01} > 7$), the perseverance of effort's influence was reliable but not particularly strong (e.g., BF_{10} only 1.1, although only 6% of the effect was within ROPE).

The different impact of the consistency of interest and perseverance of effort on the total practice accumulated over the years is presented in Figures 4 and 5, where the regression results (Table 2) are graphically presented. The difference between more and less "consistently interested" players is already large at the early stages of development. For example, at the age of 12 years more consistently interested players have logged approximately 4,120, 650 h more than their less consistently interested peer (they logged around 3,470 h – both players are assumed to have the average level of perseverance of effort). At the same age, the players who score high on perseverance of effort have not had necessarily logged more practice than players who scored lower – around 230 h more (the more "persevering" players logging around 3910 h of total practice, while the less "persevering" players log around 3680 h).

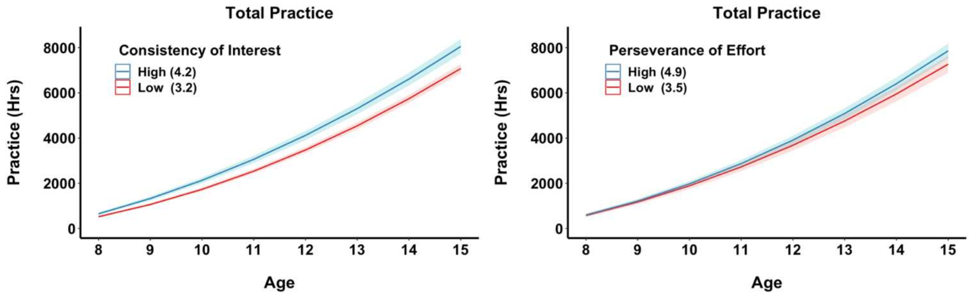

Figure 4. A model illustrating the influence of components of grit, consistency of interest (CI) and perseverance of effort (PE) on the accumulated total practice. Presented are accumulated practice times over the years for two hypothetical players, one with high score (+1 SD) and the other with low score (−1 SD) for CI (left panel). The right panel presents the same high and low players for PE. The shaded parts around the main lines represent +/- 1 SE of the mean.

However, the trend changes in the later accelerated phase where suddenly perseverance of effort has more impact on the separation (in a number of logged practice hours) between those players with higher and lower perseverance of effort scores (see Figure 4 – both players are assumed to have the average level of consistency of interest). The more "consistently interested" player, has expanded the advantage over his less "consistently interested" peer from 650 h at age 12–970 h at the age of 15 years (8050 h vs 7080 h), an increase of about 50%. However, the more "persevering" has almost tripled the advantage over less "persevering" player from 230 h at age 12 to 590 h at age 15 (7860 vs. 7270 h; an increase of 156%). In other words, consistency of interest seems to impact the initial and subsequent linear increase, whereas perseverance of effort exerts more influence in the later, quadratic stage.

We advanced our analysis by formally evaluating whether the differences between consistency of interest and perseverance of effort at various stages are statistically significant. When we compared the estimates for consistency of interest and perseverance of effort in the initial additive (intercept) effect ($M_{CI} = 129$ and $M_{PE} = 15$), the difference is not significant ($\Delta_{CI\text{-}PE} = 114$, with it 89% CrI well including 0 [282 to −56]). This is visible when we plot the posterior distributions of the estimates for consistency of interest and perseverance of effort in the initial additive (intercept) effect (Figure 5, left panel), as the two distributions overlap extensively. However, both snowball and accelerated

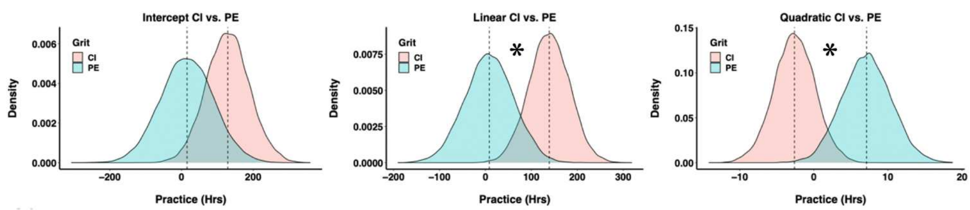

Figure 5. Posterior distributions of the estimates for consistency of interest (CI) and Perseverance of effort (PE). The dashed lines correspond to the means presented in Table 2. The shaded area represents the overlap between the two distributions. (* indicates that 89% CrI intervals do not encompass 0.)

effects are influenced significantly differently by the consistency of interest and perseverance of effort. The cumulative effect of practice is driven more by consistency of interest than perseverance of effort ($\Delta_{CI\text{-}PE} = 130$, 89% CrI [253, 6]), as can be seen by hardly overlapping posterior distributions of the consistency of interest and perseverance of effort (Figure 5, middle panel). The later burst of logged activity is more influenced by the perseverance of effort than the consistency of interest (Figure 5, right panel; $\Delta_{CI\text{-}PE} = -5.7$, 89% CrI [−0.9, −10.5]). The pattern of result is not influenced by slightly different scale characteristics of consistency of interest and perseverance of effort (e.g., higher mean of perseverance of effort and higher SD of consistency of interest). When all values in the regression are standardised, the different patterns persist (see SM, Section 6.4).

Discussion

We demonstrated that elite youth soccer players accumulate a constant amount of domain-related practice every year for the first few years of their careers. However, after the age of 12 years, there is a sudden increase in engagement in soccer-related activities which produces an accelerated accumulation of practice over the remaining two to three years measured in our study (e.g., curvilinear trajectory, see Figure 2). The personality trait of grit, and its components consistency of interest and perseverance of effort, affect this practice acquisition process at all stages. Grittier elite athletes accrue slightly more hours in accumulated practice at the beginning (initial additive effect). However, these athletes consistently invest more time in practice (than their less gritty peers) which, over the years, leads to a situation where an initial minor difference in the amount of time spent in soccer-related activity snowballs into a much larger difference (Figure 3). Grit as a composite measure does not quite influence the later increased engagement, but its two components, consistency of interest and perseverance of effort, affect the accelerated accumulation. Their effect is, however, markedly different. The players who are consistently more interested accumulate more practice during initial soccer participation and throughout development (Figure 4). The consistency of interest is, however, not a driving force behind the accelerated accumulation of soccer practice during early adolescence (~13 years). In contrast, persistent effort does not impact the early stages of the practice accumulation, but it does influence the upturn in logged practice hours after the age of 12 (Figure 5).

The role of grit in the accumulation of practice in elite youth soccer players

The growth in a number of hours our sample of elite players logged, during the early stages of development, as well as the type of growth that we registered (constant first and then accelerated during adolescence) are in line with the expected outcomes in the first two stages of DMSP (Côté, 1999; Côté & Vierimaa, 2014). Similar trends have been empirically supported in elite soccer players across several prominent soccer nations in both the men's (Ford & Williams, 2012) and women's game (Ford et al., 2020). Thus, it appears that age 13 years demarcates an important cut-off between the first two phases of sports expert development, namely, the sampling years (between ages 6-12) and the specialising years (between ages 13 and 15).

One pragmatic explanation for these results is forwarded by several prominent authors (e.g., Baker, 2003; Côté, 1999; Ericsson et al., 1993) who underline the importance of leadership roles within families of elite youth athletes when it comes to engagement in sport related activities, as well as how that role changes over the years of early development. According to these authors, the leading role switches from elite athletes' parents, in the very first stage of development, to the elite athletes themselves around the age of 13 years. At this age, elite athletes start committing to one or two sports (compared to many in the prior phase) and are becoming more focused on sport-specific skill development (through practice) instead of centring their sports engagement on fun and enjoyment, like they did in the earlier phase. In other words, after the age of 12 years, players themselves assume responsibility for their engagement in sport-related activities under their own control and deciding what to focus their efforts on, and how to spend their time, by themselves. This change in leadership role may be expressed psychologically via grit, which seems to exert a significant influence on the talent development process as its constant influence on practice accumulation over the years produces a sizable practice difference in one of the main predictors of expertise.

The role of components of grit, consistency of interest and perseverance of effort, in the process of practice accumulation

By using both components of grit within the same multilevel model, we were able to establish their differing patterns of influence on the process of practice acquisition. Consistency of interest was more strongly related to accumulated soccer practice than perseverance of effort, especially at the beginning and the earlier stages of development – when linear increases in hours are happening (or, in other words, cumulative snowball effect). However, for the accelerated snowball effect, at approximately 12 years, the trend was reversed – only perseverance of effort had a significant effect on the sudden increase in soccer activities.

How do these trends relate to diversified and early-engagement pathways? As mentioned, the sampling years between the ages of eight and 13 are the period of early development when elite youth athletes are focused on enjoyment, having fun, exploring numerous sport play activities, and developing an overall interest in sport (and sport engagement). The difference between the diversified engagement and early-engagement pathway being how specialised the majority of engagement activities are (Hendry & Hodges, 2018). While diversified engagement pathway (such as DMSP, Côté, 1999; Côté & Vierimaa, 2014) advocates for sampling multiple sports in this period (to develop interest in engaging in any sport activities), the early-engagement pathway is primarily defined by majority engagement in high volumes of (main) sport-specific practice and play.

In line with our findings, both pathways seemingly propose that more interested players would accumulate more practice hours than their less interested peers because the more interested the players are (i.e., the higher scores on consistency of interest), the more they would be inclined to engage with sporting activities. However, the very nature of diversified engagement can be interpreted as somewhat in a clash with the consistency of interest, as it promotes exploring and having multiple interests as opposed to being focused on one consistent interest throughout time (regardless of distractions).

Therefore, Ford and colleagues' (Ford et al., 2009, 2015; Ford & Williams, 2012) early engagement hypothesis might be more in line with our findings – players that have more consistent interest overtime tend to engage more with (main) sport-specific activities (both practice and play) therefore accumulating more engagement hours.

The specialising years (age: 13–15), on the other hand, are the period when the elite youth athletes are focusing more on a specific sport, developing their skills instead of enjoyment and interest and are starting to engage with more complex and demanding forms of practice (compared to the previous developmental stage). During this period, the increasingly complex nature of practice requires athletes to, among other things, be able to withstand and address new challenges, regulate themselves (e.g., not quit workouts), and delay gratification through practice (see Chambliss, 1989; Côté et al., 2003; Tedesqui & Young, 2015). In other words, to be able to deal with the demands of practice at this stage, athletes need to be resilient and be able to stick-with-it regardless of obstacles they come across. At this juncture, perseverance of effort becomes pivotal and it aligns well with the findings of our study – the athletes who can persevere more and hold out against the odds will, therefore, be able to practice more and log more hours of engagement in sport activities.

Therefore, it would not be unreasonable to assume a relation between consistency of interest and primary sport engagement at earlier stages of development when the players are still developing their interests and motivation to continuously participate. This is in line with Tedesqui and Young's (2018) thesis that consistency of interest directs one's passion towards goals. Later on, when the nature of practice changes from fun/interest to skill and strategy development, perseverance of effort becomes the importance point (and driving factor) as it helps young athletes withstand the increasing complexity of demands both in and out of practice and competition (Hendry et al., 2018; Partington et al., 2014). This would, consequently, also be in accordance with the interpretation of perseverance of effort as characterised by the magnitude of effort put forth in maintaining the pursuit of goals (Tedesqui & Young, 2018). If so, the investment period (after the age of 15), which is often when the complexity of practice and competition further increase to a much higher level, although not captured by our sample, would be expected to be even more impacted by factors related to persevering efforts despite an increase in struggles and setbacks (Collins & MacNamara, 2012; Cook et al., 2014). This seems to be the case in other sport-related studies (Cormier et al., 2021; Tedesqui & Young, 2018), as well as in a large meta-analysis in academic settings (Credé, 2018; Credé et al., 2017), where the perseverance of effort is a far better predictor of success.

Shortcomings and future directions

It is important to mention that in our study both grit and practice were self-reported measures taken at age 13–15. Personality traits often remain consistent throughout life (Hampson et al., 2007; Harris et al., 2016), yet there appears to be a gradual enhancement in grit as children mature (Duckworth, 2016). The increase in grit among all children should not affect its relationship to practice in this study, because it is presumed that the grit scores of all players, not just some, increase consistently over time. One could, however, imagine a scenario where more skilled athletes have developed a stronger sense of grit compared to their less proficient counterparts, potentially because of the affirmative feedback received from their successes (Jiang et al., 2019). Likewise, the questions within the grit survey were general and did not explicitly pertain to domain-specific activities. Although participants might have implicitly linked the grit questions to the domain, considering the research context and the closely administered PHQ questionnaire about soccer activities, future research should explicitly conceptualise and measure grit as a domain-specific construct (see Cormier et al., 2021). Retrospective recollections of activities, especially those going back to early age as in our study, are also prone to memory errors and biases (Wang & Gülgöz, 2019). Ideally, these should be corroborated by parents for the early stages and by coaches for the later stages, when formal training has started.

Our sample was relatively homogeneous, featuring only elite soccer players around the age of 14, who were also of the same gender and country, and from a single sport domain. Presumably, there are many young players who did not reach the elite level, about whom we know little. It is safe to assume that their absence leads to range restrictions in the elite sample, which generally results in smaller effects (Pearson, 1902; Vaci et al., 2014). Even when investigating a single domain, as in our study, it is beneficial to employ more diverse samples. These should include participants with larger age ranges and greater differences in expertise levels.

Throughout our work, we presuppose a causal link from grit to practice. There are compelling theoretical and empirical grounds for this assumption. It is understood that personality traits are largely stable and exert an influence on other, more variable measures such as practice over the course of a career (Duckworth et al., 2011; Larkin et al., 2023; Lee & Sohn, 2017). However, we recognise that the measure of grit could also be an outcome of consistent practice. In elite youth players who have previously succeeded, a positive feedback loop may have developed. Grit might initially influence practice, but over time, better players could report more consistency in their interest due to positive reinforcement from their success, leading them to engage in more practice time, which, in turn, contributes to their proficiency.

A longitudinal research design would be more adequate as it would allow us to accrue annual measurements of grit to see how it changes depending on success and logged practice hours. In other words, we should check whether grit is stable throughout the whole skill acquisition process, instead of capturing it at one-time point, to be able to better our understanding of the positioning of grit along trait-state continuum (for similar recent approaches, see Criticos et al., 2020; Santos et al., 2022). This approach could also incorporate corroborative estimates of practice from additional individuals involved in the skill acquisition process, such as parents and coaches, as well as other potential factors that could influence the acquisition of practice.

Conclusions

We demonstrated how the personality construct of grit could be used as an explanatory mechanism behind the process of acquisition of practice, arguably one of the main factors in expertise development. Athletes who report high scores on the grit scale consistently log more practice time than their less gritty peers so that initially small differences snowball and become more visible with time; to the point that by the time they reach early teenage years accumulated practice hours, under the influence of grit, differentiate even among the very best Australian athletes. We should be careful when interpreting these results as our measures of grit and its subscales were not longitudinal in nature. Nevertheless, our findings hint at the potential of personality factors for explaining the development of expertise, especially within elite samples where other factors may play a smaller role given that, at this level, athletes are similar in terms of talent and physical abilities. Future studies should try to measure grit and its influence on practice acquisition longitudinally to establish how stable or malleable it is over time.

Notes

1. The oSM can be accessed using this OSF link: https://osf.io/zwgta/

Disclosure statement

No potential conflict of interest was reported by the authors.

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Data availability statement

The data and the code used for the analyses can be retrieved from https://osf.io/zwgta (DOI 10.17605/OSF.IO/ZWGTA).

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