A Meta-analysis of the relationship between growth mindset and grit

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ABSTRACT

Growth mindset is one of the popular educational constructs with strong empirical ties to students' motivation and persistence in the academic context, which has been empirically linked to students' grit. Although a growing body of research suggests that growth mindset and grit are related in nuanced ways, a comprehensive and detailed portrait of this connection is needed to better understand how growth mindset is linked to grit. In this study, we systematically reviewed empirical research on growth mindset and grit among student population. Sixty-six eligible studies involving a total of 42,112 participants were examined. Using the robust variance estimation, we found that the correlations of growth mindset with grit/its facets were generally medium to strong ($\rho_{\text{overall grit}} = 0.19$; $\rho_{\text{interest}} = 0.20$; and $\rho_{\text{effort}} = 0.24$, respectively). The *p*-curve analysis results suggested that cumulative studies contained evidential value ($p < .001$). We also investigated 11 potential moderators using meta-regression (covering study, participant, and measurement characteristics), and no significant moderators were observed in the associations between growth mindset and either facet of effort. A stronger growth mindset–overall grit association was observed in a collectivistic context. We concluded with a discussion of heterogeneity, limitations, and implications of meta-analyses.

Growth mindset and grit represent two widely studied and popular psychological factors in explaining student outcomes (Allen, Kannangara, & Carson, 2021; Burnette, O'Boyle, VanEpps, Pollack, & Finkel, 2013). Growth mindset captures the belief that personal intellectual abilities and skills can be developed (Dweck, 2006), whereas grit represents a non-cognitive capacity to sustain passion and effort in pursuit of long-term goals (Duckworth, Peterson, Matthews, & Kelly, 2007). Although both contribute to adaptive cognitive and behavioral outcomes, little is known about how these two attributes influence each other's development (Park, Tsukayama, Yu, & Duckworth, 2020). Recently, empirical studies have shown that individuals with growth mindsets tended to report higher grit levels (i.e., Barbouta, Barbouta, & Kotrotsiou, 2020; Tuckwiller & Dardick, 2018), yet the findings have been inconclusive (e.g., Tang, Wang, Guo, & Salmela-Aro, 2019; Wilson, 2016a, 2016b). A scrutiny of their relationships will elucidate the value of developing a growth mindset when building positive traits such as grit. As there has been no comprehensive quantitative synthesis of results to support this claim, we attempted to systematically review and meta-analyze existing empirical research on the relation between growth mindset and grit with student samples and examine the extent to which growth mindset was correlated with grit. This meta-analytic approach has consistently been used to synthesize a large collection of individual studies with inconsistent findings (Glass, 1976) and integrate the results to bolster empirical coherence and reach a conclusion by addressing potential biases and moderators (Borenstein, Hedges, Higgins, & Rothstein, 2009).

1. Grit

As an important non-cognitive trait in explaining student success (Aparicio, Bacao, & Oliveira, 2017; Lam & Zhou, 2019), grit has been conceptualized as "trait-level perseverance and passion for long-term goals" (Duckworth et al., 2007, p. 1087). A large body of studies has provided empirical evidence for the significant relationships between grit and measures of student mental health and psychological well-being, such as higher levels of happiness (Singh & Jha, 2008) and life satisfaction (Datu et al., 2022), and lower levels of depressive symptoms (Jin & Kim, 2017) and perceived stress (Özhan & Boyacı, 2018). Within educational contexts, grit has been empirically supported as an important factor that promotes students' school engagement (Hodge, Wright,

& Bennett, 2018) and self-regulated learning (Wolters & Hussain, 2015), and is linked to individual performance and achievement in academic study (Lam & Zhou, 2019), workplace (Cho & Kim, 2022), and sports (Ionel, Ion, & Visu-Petra, 2022).

Initially, grit was conceptualized in two facets – consistency of interest (commitment and passion in pursuing the goals) and perseverance of effort (the mental toughness to keep working under pressure) (Duckworth et al., 2007). This two-factor structure has been corroborated with some studies (e.g., Christensen & Knezek, 2014; Datu, Yuen, & Chen, 2018a; Fleckenstein, Schmidt, & Möller, 2014; Li et al., 2018) but not much so in others whereby the dimensionality of grit was best captured when the items of two grit facets loaded on separate factors as opposed to loading on a single grit factor (e.g., Rumbold, Dunn, & Olusoga, 2022). Notably, some researchers have proposed different measurement models when conceptualizing the concept of grit, such as a three-dimensional structure (Datu, Yuen, & Chen, 2017; Kuruveettissery, Gupta, & Rajan, 2023; Postigo et al., 2021), or a unidimensional structure by treating grit at an overall level (e.g., Arco-Tirado, Fernández-Martín, & Hoyle, 2018). However, in this study, we grounded our review on the 2-factor model of grit due to its adoption in the majority of existing studies, which allows for a synthesis of past findings.

In addition to the inconsistent dimensionality of grit, it has also been discussed whether grit is stable over time and across situations (e.g., Tang, Wang, Parada, & Salmela-Aro, 2021) or it is changeable, learnable, malleable, and teachable due to cultivation or deliberate interventions, and therefore has great potential to facilitate youth development (e.g., Duckworth, 2016). For example, in a sample of adolescent students, Won and Lee (2023) reported that grit remained fairly stable over one year, whereas Alan, Boneva, and Ertac (2019) found that grit was malleable in the childhood period (9–10 years old) and increased with age in 3- to 6-year-olds (Sutter et al., 2022). Several studies have provided evidence that students could be educated to grow grit through psychoeducational practices and social contexts (Kaes, Kruse, Maus, Krieweth, & Brettel, 2024; Rhodes, May, Andrade, & Kavanagh, 2018).

1.1. Criticisms against grit

Recently, grit has been criticized by some researchers in terms of its theoretical conceptualization and empirical basis. First, Duckworth's grit conceptualization has been criticized as a case of "old wine in new bottles" (Credé, Tynan, & Harms, 2017). For example, researchers consistently found that grit was highly associated with other trait-like constructs, including conscientiousness, self-control, and resilience (Credé et al., 2017; Ponnock et al., 2020; Schmidt, Nagy, Fleckenstein, Möller, & Retelsdorf, 2018), implying a large conceptual overlap between grit and these constructs. In response to this criticism, Duckworth's research evidence has shown that grit is not a simple combination of perseverance and interest, rather, the element of goal-directedness in grit distinguished itself from perseverance, interest, and a combination of them (Duckworth & Gross, 2014). Indeed, several studies have shown that grit provided incremental predictive validity for academic achievement and school engagement over and above conscientiousness (Datu, Yuen, & Chen, 2018b; Lee & Sohn, 2017; Tang et al., 2021). With regards to self-control, it indicates how individuals regulate their thoughts or behaviors in response to daily distractions, rather than focusing on individual stamina (Duckworth & Gross, 2014). The result of Credé and others' (2017) meta-analytic study also supported that grit was significantly distinct from self-control. Resilience was also similar to grit as the former refers to the ability to mentally recover from adversity (Herrman et al., 2011). A person with a higher level of resilience might not necessarily have a clear goal-directed behavior or a willingness for long-term goal attainment (Hill, Morison, Westphal, Gerwann, & Ricca, 2024; Zhu, Hu, & Zhang, 2024). In sum, someone with a high level of grit is thus expected to be strong in self-control and resilience, but self-control, resilience, and conscientiousness are not the only features for the characterization of grit.

More recently, some researchers have argued that grit is a racist construct that is not relevant to all demographics equally since the current grit literature appears to over-represent white and middle to high socioeconomic status (SES) students (e.g., McGee & Stovall, 2015). For example, most research on grit has focused on White American samples mainly from high SES backgrounds and the samples used for Duckworth's grit scale development have also been questioned for being overreliance on western, white, middle-class people (Ris, 2015). Because of this sampling characteristic, researchers criticized that the extant grit theory only characterized motivational drive towards distal goal-striving for people with high SES and it fails to capture the role of racial/ethnic inequalities in the society that minoritized groups have faced (e.g., black students experienced higher level of racial stereotypes, insults, and assaults), which might hamper these people's motivation and effort to strive for their long-term goals (Herold, 2015; Okeke, Howard, Kurtz-Costes, & Rowley, 2009). However, literature has emerged that offers contradictory findings about the predictive role of grit in non-western and non-high-SES samples (e.g., Huang & Zhu, 2017; Kwon, 2021). Grit has been shown to compensate for the perceived structural disadvantages (e.g., family background disadvantage) for those students with low SES in promoting better mental health and school performance (Gong, Chen, & Tong, 2024).

2. Growth mindset

Mindset theory (or implicit theories) describes core assumptions of people's different beliefs about the malleability of human attributes, such as intelligence, personality, ability, or body weight (Burnette, 2010; Dweck, 2006). This highlights the importance of personal belief when facing obstacles by assigning meaning to events (Dweck & Leggett, 1988). Accordingly, individuals can be placed along the continuum from fixed mindsets to growth mindsets. People with a growth mindset believe that attributes such as intellectual abilities can grow or develop over time (Yeager & Dweck, 2012). They are more likely to sustain efforts to overcome obstacles and challenges, with a higher chance to achieve greater achievement (Blackwell, Trzesniewski, & Dweck, 2007). In contrast, people with a fixed mindset tend to believe such attributes are immutable (Yeager & Dweck, 2012), and thus are more likely to show less willingness in learning and avoid putting effort to overcome obstacles (Dweck, 2007). Prior correlational studies have consistently confirmed the positive impact of growth mindset on various positive outcomes, such as flourishing (Zeng, Hou, & Peng, 2016), resilience (Yeager & Dweck, 2012), subjective well-being (Zhao, Du, Li, Wu, & Chi, 2021), learning motivation (Bedford, 2017), and school performance (Barbouta et al., 2020), as individuals with a growth mindset tended to accept the positive inclusion of failure, and this growth mindset belief could further stimulate them to take on more deliberate learning, persist even when facing obstacles and challenges (Burnette et al., 2013) and thrive in the face of difficulty (Dweck & Yeager, 2019).

In the past decade, scholars have paid great attention to subject-specific growth mindsets in two subfields, namely, second language and math. In the context of second language acquisition, language growth mindsets are domain-specific beliefs about whether the ability to learn any language that a person uses other than a first or native language is malleable or not (Lou & Noels, 2016). Similar to second language growth mindsets, math growth mindsets indicate students' beliefs about developing their math skills through instruction and practice (Daly, Bourgaize, & Vernitski, 2019). Recent studies have consistently shown that students' motivation and performance were associated more strongly with their subject-specific growth mindsets (e.g., second language learning mindsets and math mindsets) than general growth mindsets (e.g., Bui, Pongsakdi, McMullen, Lehtinen, & Hannula-Sormunen, 2023; Lou & Noels, 2017).

3. Relationship between growth mindsets and grit

According to Duckworth (2013), a growth mindset is conducive for individuals to sustain efforts and commit to long-term goals in multiple aspects. This could be understood from at least two theoretical perspectives. From a neuroscientific point of view, both growth mindset and grit share brain activities in the left dorsolateral prefrontal cortex and striatum (Myers, Wang, Black, Bugescu, & Hoeft, 2016; Wang et al., 2018). The prefrontal cortex is often thought of as a neural center for self-regulation, such as planning and monitoring (Kelley, Wagner, & Heatherton, 2015), and the striatum is thought to be the brain region involved in learning, motivation, and performance (Liljeholm & O'Doherty, 2012). Although, as mentioned above, both growth mindset and grit share similar brain activities, the brain imaging studies (Myers et al., 2016; Wang et al., 2018) have indicated that growth mindset was associated with connectivity between brain regions involving error correction and conflict detection, whereas grit was associated with connectivity between brain regions involving motivation, learning, action planning, and tendency of persistence related to reward processing.

Through the lens of educational psychology, Deci and Ryan's (1985) self-determination theory (SDT) articulated that the degree to which individuals perceived the importance of personal choices influenced their autonomous motivation. In a school context, a student with a growth mindset belief tended to have a better sense of self-determination, which was likely to report higher levels of autonomous motivation (Huang, Wei, Lu, & Shi, 2022). Further, this autonomous motivation has been confirmed as a psychological or internal force that drove an individual towards a desired goal (Weissinger & Bandalos, 1995). Therefore, individuals with a growth mindset tended to report more autonomous motivations that enabled them to improve their attributes through effort making (Zhao et al., 2018), which further increased students' likelihood to sustain effort and maintain interest in the engaged activities in order to achieve the goals (Ryan & Deci, 2000).

Despite a theoretical consensus that students' growth mindset was positively associated with grit, existing empirical evidence in this area is mixed. For example, some studies (e.g., Kalesnikava, Ekey, Ko, Shackelford, & Mezuk, 2019; Zhao et al., 2018) have provided evidence for a moderately positive correlation between growth mindset and grit, whereas others (e.g., Holden, 2018; Zhu, Zhuang, & Cheung, 2020) reported a negative correlation. Other studies even failed to detect such a significant association (Dixson et al., 2017; Myers et al., 2016; Tang et al., 2019). One possible reason could be the lack of attention to the domain-specific nature of these two constructs. For example, Fathi, Pawlak, and Hejazi (2024) examined how students' growth L2 writing mindset could substantially influence their L2 writing grit and confirmed the moderate positive relations between them. Altogether, there is a clear need for a rigorous review of the association between growth mindset and grit in academic settings. Further, we attempted to elucidate this relationship by identifying potential factors that influenced this association.

4. Potential moderators of the growth mindset-grit link

Potential moderators were identified and coded based on their theoretical rationale, empirical evidence in their associations with the target constructs, and their explanatory power of the between-study variance (Arthur Jr., Bennett Jr., & Huffcutt, 2001; Cano, Carrillat, & Jaramillo, 2004). In the current review, we proposed eleven moderators based on theoretical foundations and previous empirical findings: demographics of the sample (i.e., gender, grade level, socioeconomic status, race/ethnicity, sampling location, individualism/collectivism, and long-term orientation) and study characteristics (i.e., grit measures, research design, study quality, and publication types).

4.1. Demographics of sample

4.1.1. Gender ratio of samples

Gender variations in students' tendency to have growth mindset are inconclusive. Female and male students experienced different social costs and benefits in sustaining efforts in schools (Heyder & Kessels, 2017). From the view of gender role socialization theory, female students were socialized to be diligent, i.e., working hard and sustaining more effort at school (Legewie & DiPrete, 2012), as compared to their male counterparts. On the other hand, male students who studied hard were at risk of facing social sanctions because low levels of academic effort symbolized intelligence and masculinity, which in turn increased male students' popularity among their peers (Jackson, 2002, 2003). Given that male students tended to experience negative social costs of sustaining effort and be less socialized to be diligent and higher social benefits of putting less academic effort. Indeed, Sigmundsson, Haga, and Hermundsdottir (2020) only found the significant growth mindset-grit link in female samples. Thus, having a greater proportion of females in the sample tended to result in a stronger association between a growth mindset and grit.

4.1.2. Grade level

From the executive function self-control perspective, older children are more optimal and mature in using self-regulated strategies while younger children have more difficulty in self-regulation since the brain systems that support self-regulation take years to mature (Gagne, 2017; O'Meagher, Kemp, Norris, Anderson, & Skilbeck, 2017). Although growth mindset consistently played a positive role in grit with university samples (Barbouta et al., 2020; Mercado, 2017; Tuckwiller & Dardick, 2018), many non-significant results were found in K-12 populations (Allen, 2018; Cody, 2019; Meindl et al., 2019). Sisk and others' (2018) meta-analysis confirmed that students' grade levels showed a significant buffering effect in the positive effect of growth mindset on students' academic achievement, with a stronger correlation observed in primary school students (weighted $r = 0.19$), compared to secondary school students and postsecondary students (weighted $r = 0.15$ and 0.02, respectively). As such, we propose that cognitive maturity in age would strengthen the association between growth mindset and grit.

4.1.3. Socioeconomic status (SES), race/ethnicity, and country

Sociological perspectives of grit posited that grit could grow through multiple experiences of overcoming struggles (Gorski, 2016; Kundu, 2017). Those with more privileged socioeconomic status were less likely to encounter various structural barriers in their lives (Boehm et al., 2015) and have more resources to bounce back, whereas individuals with less advantaged positions might need to rely more on personal effort and determination (e.g., Danner et al., 2020; Liu, 2019). Empirical studies have shown that individuals' goal-striving-related attributes and behavior depend on social class (Kwon & Erola, 2023). For example, Usher, Li, Butz, and Rojas (2019) found that American 4th to 8th graders with lower SES reported less perseverant grit (mean difference was −0.15) than did those with higher SES. These findings pointed to the impact of economic disparities on students' perseverance and self-beliefs. The opportunity and performance gaps among low and high SES groups could be partly responsible for these observed discrepancies. As such, we propose that students' SES level will moderate the association between growth mindset and grit.

Another important sociodemographic variable that contributes to individual differences in grit level is race and ethnicity (Nothnagle & Knoester, 2022). Higher levels of grit may benefit racial and ethnic minorities because it can boost their intrinsic drive to succeed (Jehanghir, Ishaq, & Akbar, 2024). For example, racial and ethnic minorities often faced more significant sociocultural problems and academic difficulties (Meece & Kurtz-Costes, 2001; Quintana & Mahgoub, 2016) than other ethnicities but these minorities also reported higher levels grit (Bennett, McCarty, & Carter, 2021; Young-Brice & Dreifuerst,

2020) and made more effort to succeed (Bronder, Speight, Witherspoon, & Thomas, 2014). This was in line with the view of high-effort coping with race-related stress in the experience of racial discrimination (Jelsma, Chen, & Varner, 2022). As such, we propose that students' race and ethnicity would moderate the association between growth mindset and grit, while a larger effect size to be expected in racial and ethnic minorities.

Specific contextual features within a country may influence an individual's perception of goal striving and motivation to attain this goal (Urdan, 2001). For example, significant associations were observed in a Korean university student sample (Lee et al., 2017) and a secondary school student sample in South Africa (Kench, 2016), while non-significant results were reported in both Norwegian secondary school (Sigmundsson, 2021) and university student samples (Dybendal, 2022). The inconsistent empirical evidence warrants examinations of participants' nations as a moderator in the association between growth mindset and grit.

4.1.4. Cultural differences

4.1.4.1. Collectivism versus individualism.
According to Grant and Dweck (2001), each culture has its own beliefs, goals, and values related to achievement. Based on Triandis' (1995) widely accepted way of representing cultural differences, Eastern culture is described as collectivistic (such as in China, the Philippines, and Korea). In a collectivist culture, people highly value effortful behavior and individual achievements are seen as resulting more from their effortful behavior than from intelligence and ability. In contrast, Western people (characterized as individualistic; Hofstede, 1980) put more emphasis on individual intelligence and ability as the cause of success more than effort and persistence (Wang, Wiley, & Chiu, 2008). The concept of growth mindset has been consistently confirmed as a very important motivational belief that influences Chinese students' learning achievement (Bai & Guo, 2021; Zhang, Kuusisto, & Tirri, 2019). In this study, we propose students' cultural background (individualism-collectivism difference) as a potential moderator and a higher level of Individualism Index would weaken the association between growth mindset and grit.

4.1.4.2. Long-term orientation.
According to Hofstede (2001), long-term orientation refers to a culture that looks to future benefits and rewards to achieve long-term goals. People in cultures with a high long-term orientation tend to have greater perseverance and thrift, higher preference for future benefits, and better long-term planning for the future even putting aside traditions, while those with a short-term orientation tend to value immediate results, focus on present- or past-oriented virtues such as tradition, personal stability, social obligations, reciprocation of greetings, protecting one's "face", and attribute success and failure to luck (Bearden, Money, & Nevins, 2006; Hofstede, Hofstede, & Minkov, 2005). In an educational context, the approach that students use to frame time (long-term or short-term orientated) will influence whether they invest effort in goal striving that will not yield immediate results (Harackiewicz, Barron, Tauer, Carter, & Elliot, 2000). A study by OECD (2019) also supported that students in long-term oriented countries (e.g., Austria and Germany) tended to have stronger growth mindsets than students in short-term oriented countries (e.g., Peru and Lebanon). Further, long-term orientation provides a macro level of motivation in developing grit which would positively interact with growth mindset. The effect of growth mindset may be more salient among students with stronger desires for goal attainment. To be more specific, the growth mindset might reinforce their desires for long-term goal attainment (i.e., they believe that they are more likely to achieve their goals if they consistently sustain effort), which further strengthens their grit towards long-term goals. As such, we propose that long-term orientation will strengthen the positive relationship between growth mindset and grit.

4.2. Study characteristics

4.2.1. Measures of grit
Given the high popularity of the construct of grit in recent years, several grit measures have been developed, among which only a few have considered theories and grounded in both qualitative and quantitative evidence. Some scales measure grit as a single conceptualization model while other scales consider grit in two or more dimensions. A brief review of existing grit measures is presented in Table 1. Throughout the grit literature in the educational context, the Grit-O and Grit-S were frequently used to measure individual grit levels in eligible studies. In addition to Grit-S and Grit-O, researchers have used several other grit measurements (such as the Academic Grit Scale and the Academic Grit Instrument) or used selected items or a single item in measuring grit. It is worth noting that the definition and measurement of grit poses a fundamental issue, as findings may vary depending on how variables are conceptualized and measured. A number of meta-analytic studies have verified this fact (e.g., Gui, Luo, Zhang, & Deng, 2020; Zalta et al., 2021). Consequently, we propose the type of grit measure to be another potential moderator in the growth mindset-grit link.

4.2.2. Research design
Research design largely depends on the nature of research questions. Typically, cross-sectional designs aim to test the relationship between two or more variables at a single point in time, longitudinal designs aim to satisfy the temporal precedence of correlated phenomena over a period, and experimental designs aim to verify causal relationships between variables (Hua & David, 2008; Hunziker & Blankenagel, 2021). Since cross-sectional and longitudinal designs cannot establish causality, experimental designs are considered stronger methods for testing causality (Ariel, Bland, & Sutherland, 2022). Furthermore, cross-sectional design runs the risk of inflating effect sizes because when participants responded to a set of questionnaires simultaneously, covariances between test variables may inflate the estimated effect size of the relation. Thus, the effect sizes from cross-sectional studies are likely to be stronger than experimental and longitudinal studies. Mixed findings were also shown in the growth mindset-grit relationship. For example, in a longitudinal study, Kalesnikava and others (2019) found that university students' growth mindset level was significantly associated with grit, while in Dees' (2017) cross-sectional study, non-significant results were observed. In this study, we test whether the research design of the study (i.e., cross-sectional or longitudinal) will moderate the strength of the growth mindset-grit relation.

4.2.3. Study quality
Study quality refers to the degree to which researchers conducting research take appropriate steps to maximize the validity of the findings and minimize bias (Khan, Kunz, Kleijnen, & Antes, 2011). Investigation of study quality in meta-analytic research has received considerable attention because such investigations can help generate valid estimates of cumulative effect sizes (Petersen & White, 1989). In a meta-analysis, the quality of primary studies may influence effect sizes in unpredictable directions, such as masking or reversing the direction of effects (Sterne et al., 2002). Additionally, Sterne and others (2002) found that study quality showed confounding effects with other attributes of the study, e. g., differences in estimated effect sizes between published and unpublished studies were observed when controlling for study quality. We, therefore, test whether study quality will moderate the growth mindset-grit link.

4.2.4. Publication type
Publication bias is a type of bias that occurs in research published in peer-reviewed journals (also known as selective publication). The chance of a study being published in a scientific journal is usually related to the statistical significance of its results. For example, important research results are more likely to be submitted and published (Franco,

Table 1
A Review of Existing Measures of Grit (Alphabetical Order According to the First Author).

Measurement	Sample info	Number of items	Factor structure	Reliability	Validation
Clark and Malecki's (2019) Academic Grit Scale	American ($N = 757$ sixth to eighth graders)	10	Unidimensional structure	0.94 for overall scale	• EFA • CFA • Criterion-related validity
Datu et al.'s (2017) Triarchic Model of Grit Scale	Phase 2: Filipinos ($N = 350$ university students) Phase 3: Filipinos ($N = 150$ university students)	10	Three-dimensional first-order structure	In Phase 2: .84 for consistency of interest .84 for perseverance of effort .88 for adaptability to situation In Phase 3: .60 for consistency of interest .78 for perseverance of effort .88 for adaptability to situation	• EFA • CFA • Criterion-related validity
Duckworth et al.'s (2007) Original Grit Scale	Study 1–5: American ($N = 4899$ adults) Study 6: American ($N = 175$ 7 to 15 years old)	12	Two-dimensional first-order structure	Ranged from 0.77 to 0.85 (Study 1 to 6) for overall scale	• EFA • CFA • Concurrent validity • Predictive validity
Duckworth and Quinn's (2009) Short Grit Scale	Study 1: American ($N = 2839$) Study 2: American ($N = 1545$ adults)	8	Two-dimensional second-order structure	Study 1: Ranged from 0.73 to 0.79 for consistency of interest (across four samples) Ranged from 0.60 to 0.78 for perseverance of effort (across four samples) Study 2: .82 for overall scale .70 for consistency of interest .77 for perseverance of effort	• CFA • Predictive validity
Ebadi, Weisi, and Khaksar's (2018) EFL-Grit Scale	Iranian ($N = 306$ EFL learners)	16	Four-dimensional first-order structure	0.83 for overall scale	• EFA • CFA
Kuruveettissery et al.'s (2023) three-dimensional Grit Scale (3-D Grit Scale)	Study 1: Indian ($N = 409$ young adults) Study 2: Indian ($N = 334$ young adults) Study 3: Indian ($N = 514$ young adults) Study 4: Indian ($N = 214$ young adults) Study 5: Indian ($N = 107$ young adults)	17	Three-dimensional first-order structure Three-dimensional second-order structure	Ranged from 0.86 to 0.94 for overall scale (across five studies) Ranged from 0.81 to 0.83 for Perseverance-Commitment (PC) (across five studies) Ranged from 0.69 to 0.73 for Interest-Passion (IP) (across five studies) Ranged from 0.71 to 0.75 for Goal-directed Resilience (GR) (across five studies)	• EFA • CFA • Concurrent validity • Convergent validity
Lim and Cho's (2018) Academic Grit Instrument	Korean ($N = 1454$ junior high and high school students	23	Three-dimensional first-order structure	0.95 for academic passion .92 for academic endurance .86 for maintenance of academic interest	• EFA • Criterion-related validity
Postigo and others' (2021) Oviedo Grit Scale	Spanish ($N = 630$ adults)	10	Unidimensional	0.94 for overall grit	• EFA • CFA • Convergent-related validity
Singh and Chukkali's (2021) Multi-Dimensional Scale of Grit	Study 1: Indian ($N = 297$ university students) Study 2: Indian (N = 120 postgraduate students) Study 3: Indian ($N = 120$ postgraduate students)	12	Four-dimensional second-order structure	Ranged from 0.63 to 0.73 for adaptability to situation Ranged from 0.54 to 0.74 for perseverance of effort Ranged from 0.50 to 0.67 for spirited initiative Ranged from 0.57 to 0.64 for steadfastness in adverse situations Ranged from 0.78 to 0.88 for overall grit	• EFA • CFA • Criterion-related validity • Convergent-related validity • Divergent-related validity
Teimouri, Plonsky, and Tabandeh' (2022) Language-domain-specific Grit Scale (L2-Grit)	Persian ($N = 191$ university students)	12	Two-dimensional first-order structure	0.80 for overall scale .66 for consistency of interest .86 for perseverance of effort	• EFA • Construct validity • Convergent-related validity

Malhotra, & Simmonovits, 2014), and non-significant results of empirical research are even excluded from the quantitative evaluation of research results (Mlinarić, Horvat, & Šupak Smolčić, 2017). Therefore, we propose that the publication type (published versus unpublished) would moderate the strength of the growth mindset-grit relation by considering both published (peer-reviewed journal articles) and unpublished material (conference presentations and unpublished dissertations) to avoid the potential of upward publication bias.

5. Present Study

This study presents a meta-analysis aiming to (a) verify the generalizability of this association while addressing publication biases, and (b) examine potential moderators in explaining this association. Notably, since grit is conceptualized into two distinct facets, growth mindset may influence these facets differently. For instance, Dees (2017) found that college students' growth mindset was significantly associated with consistency of interest but not with perseverance of effort; while some studies showed that growth mindset was significantly associated with perseverance of effort but not with consistency of interest (Dixson et al., 2017; Midkiff et al., 2017; Tang et al., 2019). In order to examine whether the associations between growth mindset and grit differ due to the structure of grit, it is important to understand to what extent the association differs depending on whether grit was measured as an overall grit level or sub-factors. By examining a range of potential moderators, we can reconcile existing discrepancies in the associations between growth mindsets and grit, which can yield helpful insights to advance this field.

This study intends to make the following contributions. From a theoretical point of view, this study contributes to an increased understanding of the nature of the association between growth mindset and grit and brings clarity to previously inconsistent results among the empirical evidence of this association, given that inconsistent findings on this association cast doubts on whether efforts are worthy to be put in attending to students' mindset. From a pedagogical point of view, we would like to shed more light on grit which has been doubted since its popularity among both researchers and schoolteachers. For example, teachers tend to be concerned whether grit is something that can be taught. If such concerns remain, an alternative way to build positive characters in students is to cultivate determinants, or factors that are truly associated with grit. Specifically, this study addressed the following research questions (the corresponding research hypotheses are presented in Table 2):

1. What is the relationships pattern between students' growth mindset and grit?
2. To what extent do students' demographic characteristics (i.e., gender, grade level, race/ethnicity, SES, continent, collectivism/

Table 2
Research Questions and Hypotheses.

Research Question	Hypothesis
RQ1: What is the relationships pattern between students' growth mindset and grit?	H1: There is a significant relationship between growth mindset and grit (overall and its two facets).
RQ2: To what extent do students' demographic characteristics (i.e., gender, grade level, race/ethnicity, SES, continent, collectivism/individualism, long-term orientation), grit measure and study characteristics (i.e., research design, study quality, and publication type) moderate the relationships between growth mindset and grit?	H2: Between-study variance will be explained by 11 proposed moderator variables, including gender, grade level, race/ethnicity, SES, continent, collectivism/individualism, long-term orientation, grit measure, research design, study quality, and publication type.

individualism, long-term orientation), grit measure and study characteristics (i.e., research design, study quality, and publication type) moderate the relationships between growth mindset and grit?

6. Method

We preregistered this study to facilitate transparency. The study protocol can be accessed at [blinded for review]. We followed Page et al.' (2021) recommendations and synthesized the available literature utilizing the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines. A PRISMA flow chart of the selection process is shown in Fig. 1. A completed PRISMA checklist is provided in Table S1 in the online supplemental materials.

6.1. Search strategy

The literature search was performed in November 2022. The search strategy involved systematically reviewing peer-reviewed journal papers and dissertations identified in an initial search of PubMed, PsycINFO, PsycARTICLES, the Education Resources Information Center (ERIC), Education search Complete (EBSCO), dissertation databases, and Google Scholar. We considered Google Scholar as one of the potential online search databases because it has been considered an important source of gray literature (Piasecki et al., 2018). We included the first 300 results from Google Scholar in an initial search for a systematic review (Haddaway et al., 2015). We hand-searched the keywords in the 6 related journals in education field (*Educational Psychologist, Educational Researcher*, and *Journal of Educational Psychology*), and in positive psychology field (*Journal of Happiness Studies, Journal of Positive Psychology, Journal of Positive Psychology and Wellbeing*), and scanned the reference lists of all extracted articles to identify any additional relevant publications. This yielded zero additional studies from scanned journals and 3 additional studies (Calo, Peiris, Chipchase, Blackstock, & Judd, 2019; Mosanya, 2019; Sigmundsson, 2021) from scanned reference lists. Furthermore, to minimize potential publications bias, we attempted to locate and retrieve the gray literature and unpublished studies by searching conference proceedings in relevant listservs and database (e.g., American Educational Research Association, International Positive Psychology Association, IEEE Xplore Digital Library) and contacted researchers publishing in this area to identify in press or unpublished manuscripts and/or datasets. This yielded an additional 4 studies (Barber, van Oostveen, & Childs, 2019; Kinnay, Hignite, Manning, Karkhanis, & Meyer, 2017; Lee & Taylor, 2022; Park, Rosenberg-Kima, Rosenberg, Gordon, & Breazeal, 2017).

A general search with relevant fields (title, subject, abstract, and keywords) included the keywords *mindset* and *grit*, along with the alternative terms *growth mindset, implicit theories, consistency of interest, perseverance of effort, perseverance, and interest*. A Boolean operator (OR) was applied to deal with the various combination of the keywords in the database search and the literature that covered either alternative terms of mindset (e.g., implicit theories) or alternative terms of grit (e.g., perseverance) were initially extracted for further screening. The potential inclusion sources were first screened by examining the abstract and title, then we examined all potential sources in detail to determine whether the articles met the inclusion criteria. To identify more grit studies in different cultural contexts, we also searched Chinese versions of the above English keywords (i.e., "內隱智力理論/内隐智力理论" OR "成長型思維模式/成长型思维模式" OR "成長心態/成长心态" OR "固定型思維/固定型思维" OR "思維/思维" OR "心態/心态" OR "恆毅力/恒毅力" OR "堅毅性/坚毅性") via Google Scholar and robust Chinese databases including Wangfang data, China National Knowledge Infrastructure, and Airiti Library.

6.2. Eligibility criteria

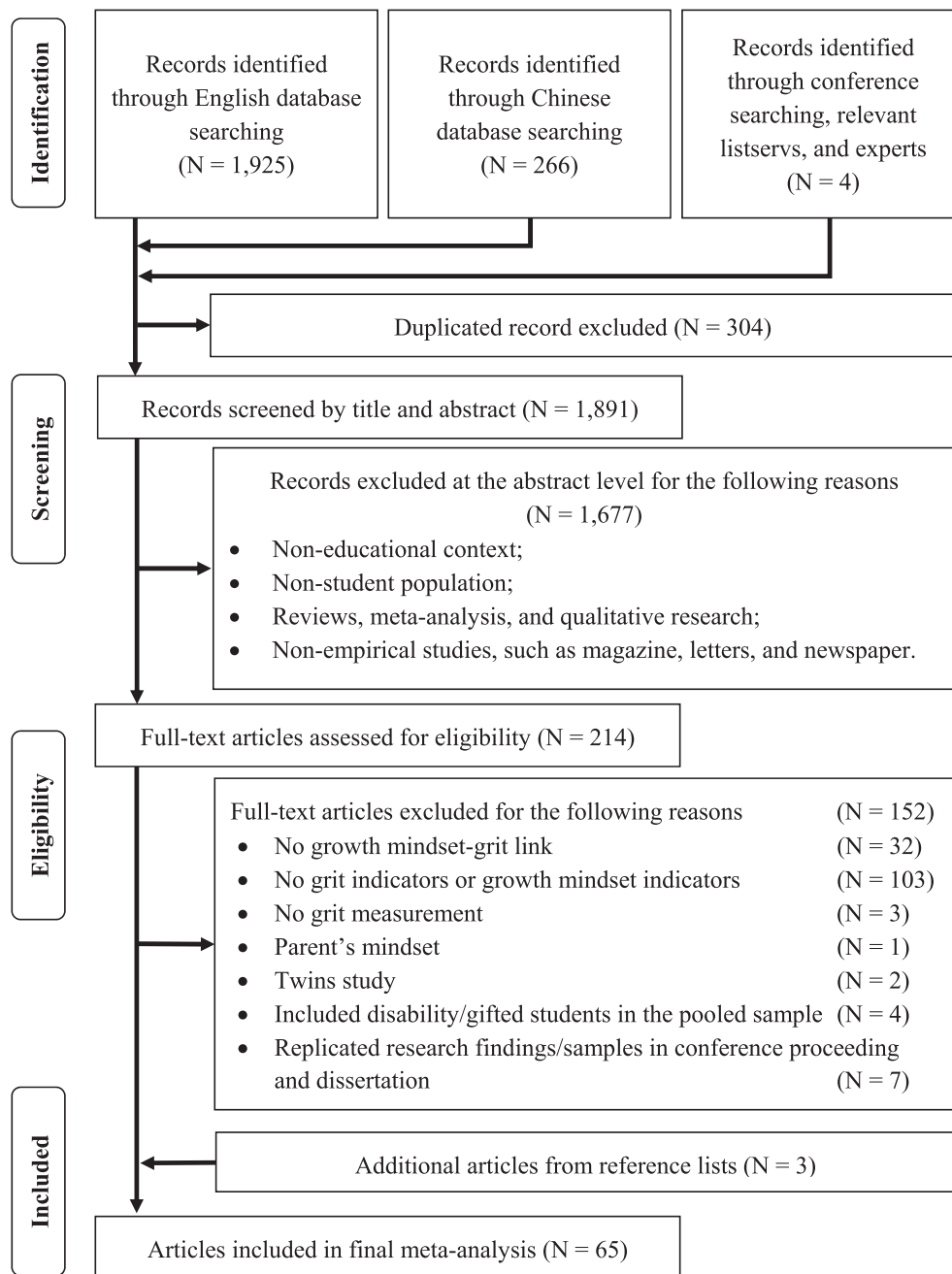Eligible papers comprised peer-reviewed journal papers, book

Fig. 1. The PRISMA Flow diagram for a systematic review of growth mindset on grit.

chapters, conference proceedings and presentations, and dissertations between January 2007 and May 2021. First, we limited our search to this period because the first influential set of studies on perseverance appeared in 2007 by Dr. Angela Duckworth. We handsearched book chapters and papers, Because they have been considered gray literature, they have made important contributions to systematic reviews and meta-analyses (Mahood et al., 2014). The following criteria were used to include articles in the study for analysis.

At the abstract/title screening level:

- Articles were limited to empirical studies.
- Only studies with student samples from K-12 (primary school and secondary school) to higher education (college and university) were included (participants' gender, race, age, and other demographic characteristics were not limited).

- All articles in English or Chinese were preferred due to our language capabilities. However, we do not limit publications to these two languages. We contacted corresponding authors of non-English or non-Chinese articles to request statistical information for our analysis, and we also used online translation tools to help us retrieve statistics from these publications.

At the full-text screening level:

- The studies should provide reliable and valid measures on both growth mindset and grit, and these measures have been validated in both K-12 and higher education student populations, such as using the Implicit Theories of Intelligence Scale (ITIS; Dweck, 1999), Original Grit Scale (Grit-O; Duckworth et al., 2007), and Short Grit Scale (Grit-S; Duckworth & Quinn, 2009). A measurement was

considered to be reliable and valid if (i) it reported at least acceptable internal reliability (Gliem & Gliem, 2003); and (ii) its factorial structure was examined by exploratory factor analysis or confirmatory factor analysis.

- Research sampling and statistical results should be unique, that is, not appear in both journal articles and papers/papers/conference proceedings. Therefore, only studies with (1) original data sources, (2) detailed sample information and (3) sufficient statistical information (Pearson product-moment correlation coefficient (r) or other sufficient statistical information [i.e., a t or F value] that could be transformed into an r value) were included in this meta-analysis.

6.3. Selection process

Studies would be considered eligible for review if they directly examined the relation between growth mindset and grit within K-12 and higher education. Abstracts of identified citations were independently screened by the first author for eligibility. Both authors then checked the full text of potential papers to ensure they were eligible for inclusion. Further, both authors separately and manually coded all eligible studies according to the agreed categorizations. The initial inter-rater agreement reached in coding these categorizations was 96.15 % and the result of intra-class correlation coefficient was high (0.99). Both authors returned to the original paper to resolve the error. If there is disagreement, it is discussed until a consensus is reached.

6.4. Coding procedure

We performed data coding in Microsoft Excel. Both authors were involved in the data extraction and encoding phases. For missing data (particularly where non-significant effect sizes were not available), the corresponding author of the paper was contacted by email. The r values were set to 0 if the authors did not respond (Borenstein et al., 2009). We operationally coded elementary school, middle school, and high school as the K-12 setting, and college/university and graduate school as the higher education. The eligible studies were also coded by grit indicators: overall grit, consistency of interest, and perseverance of effort. Since these structures were explicitly manipulated in each study, minimal divergence occurred during the coding phase. However, the two authors cross-checked the accuracy of the data analysis to ensure that no errors were involved. A brief coding scheme for this study is provided in Supplemental Table S2. Further, we used "m" to indicate the number of eligible studies with independent samples and "k" to indicate the number of dependent effect sizes in the meta-analysis.

6.4.1. Effect size
Pearson's correlation (r value) was used as the metric of effect size. When the r value was not reported in the eligible studies, the available statistical information (i.e., a t or F value) was transformed into r using effect size calculators (Lenhard & Lenhard, 2016).

6.4.2. Female ratio of sampling
The moderating effect of gender was coded as a continuous variable using the percentage (%) of female participants in each study, ranging from 0 % to 100 %. This coding approach has been widely used in analyzing the moderating effect of gender in previous meta-analytic studies (e.g., MacCann et al., 2020; Zhang & Dong, 2022).

6.4.3. Grade level
Within education settings, the categorizations of grade level are widely acknowledged as primary, secondary, and tertiary education, which have been consistently adopted in analyzing the effect of grade level in meta-analysis reviews (Lam & Zhou, 2019; Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014; Zhou & Lam, 2019). Therefore, in this study, grade level was operationally coded as a categorical moderator in three levels: primary ($m = 7$, $k = 31$), secondary (m

= 17, $k = 44$), and tertiary ($m = 39$, $k = 72$). Four studies used mixed samples (Ingebrigtsen, 2018; Khan, 2018; Logan, 2019; Zhao et al., 2018); therefore, these studies were coded as "other" and excluded from the analysis of the moderating effect of grade level.

6.4.4. Race/ethnicity
Regarding the race/ethnicity data, 28 studies involved American samples and only 17 of them have collected participants' race/ethnicity data. In order to avoid confounding ethnicity and country of origin, the moderating effect of race/ethnicity was explored only in American samples. Race/ethnicity was coded as a continuous variable using the percentage (%) of Asian Americans, Black or African American, and White participants in each study, ranging from 0 % to 100 %. Any effect sizes without reporting the race/ethnicity information were removed in this moderator analysis.

6.4.5. Socioeconomic status
It is worth noting that only five studies have collected the SES data from the participants and this data was measured differently across studies. Only the annual household income was obtained as the indicator of SES in one study (Ohtani et al., 2020), one study only reported that the participants were mainly from families of low to medium SES (Kaya & Karakoc, 2022), one study only reported that 49.0 % of the participants were from low-income households (Meindl et al., 2019), one study created a composite SES score by averaging parents' educational years and household income variables (Zhang et al., 2022, b), and one study just asked participants to rate their family's financial situation (1 = bad to 5 = good; Tang et al., 2019). Nevertheless, SES can be measured at individual-, peer-, school-, system-, or country-based level (e.g., Hua & Wang, 2021; Ralston et al., 2017). We used country-based level indicators of SES (participants' geographic location) in our analyses, given that other levels of SES indicators were unavailable in most eligible studies.

In this review, we coded country-level SES according to the most recent and up-to-date report of the United Nations Development Programme with the Human Development Index (HDI; United Nations, 2022). The HDI is a measure of nation-level social and economic development that combines three dimensions: (a) higher life expectancy rates showing long and healthy lives, (b) accessibility in education specifying knowledge level, and (c) the possibility of having a decent standard of income level. The HDI has been used as an objective indicator of country-level SES and is frequently employed in recent meta-analytic studies (i.e., Kumar & Nayak, 2023; Neves, Oliveira, & Santini, 2022). According to Morren and Grinstein (2016), countries with higher scores indicate developed countries (e.g., a score of 0.921 for the United States), whereas countries with low to high scores indicate emerging or less developed (e.g., a score of 0.385 for South Sudan). We coded country-level SES into three categories based on the benchmarks for interpreting the HDI: medium ($m = 2$, $k = 2$), high ($m = 14$, $k = 42$), and very high SES ($m = 50$, $k = 102$), for further inspection of the effect sizes in the different categorization of SES. Therefore, in this study, socioeconomic status was coded as a continuous moderator with higher scores representing higher country-level SES, ranging from 0 to 100. Notably, no eligible studies were categories in low SES group. Studies with mixed samples from different countries were removed from this moderator analysis.

6.4.6. Continent
Continent information was entered according to the reported region by the paper for the sample for each effect size and coded into five categories: Africa ($m = 2$, $k = 4$), Asia ($m = 22$, $k = 52$), Europe ($m = 11$, $k = 14$), North America ($m = 31$, $k = 72$), and Oceania ($m = 3$, $k = 4$). No eligible studies were from South America. Studies with mixed samples from different countries were removed in this analysis.

6.4.7. Collectivism versus individualism

We employed Hofstede's (1980, 2001) country-level cultural dimensions as the indicator of the individualism-collectivism difference. Hofstede's framework of cultural dimensions has been shown to be an effective and powerful tool and is frequently employed in cross-cultural meta-analytic studies (i.e., Choi, Oh, & Colbert, 2015; Lam & Zhou, 2022). In this review, we coded countries' individualism levels according to Hofstede's Individualism Index (see www.hofstede-insights.com). The individualistic index ranged from 0 (most collectivistic) to 100 (most individualistic). A higher score indicates a culture of individualism in the country/society (e.g., a score of 91 for the United States), whereas a lower score indicates a highly collectivist culture (e.g., a score of 20 for China). Two studies (Barbouta et al., 2020; Mosanya, 2019), which recruited students from different cultural contexts in one sample (e.g., Caucasian and Asian), were removed in this moderator analysis. We also coded this moderator into two categories: collectivistic ($m = 23$, $k = 55$) and individualistic ($m = 41$, $k = 91$), for further inspection of the effect sizes in the collectivistic and individualistic contexts.

6.4.8. Long-term orientation

Long-term orientation was coded as a continuous moderator with higher scores representing a culture's level of focus on the future (Hofstede, 1980). The long-term orientation index ranged from 0 (short-term orientation) to 100 (long-term orientation). Two studies (Barbouta et al., 2020; Mosanya, 2019), which recruited students from different cultural contexts in one sample, were also removed in this moderator analysis.

6.4.9. Grit measure

Grit measure was coded into two categories: Grit-O ($m = 25$, $k = 69$) and Grit-S ($m = 38$, $k = 77$). Because only two studies (Clark, 2017; Kaya & Karakoc, 2022) used the Academic Grit Scale, one study (Kalesnikava et al., 2019) used Social Emotional Learning scales (Panorama Education, n.d.), one study (Kim, 2020) used Academic Grit Instrument (Lim & Cho, 2018) in measuring students' grit level, one study (Lee & Taylor, 2022) used self-developed items in measuring grit in English learning context, these five studies were added to a category named "other" ($m = 5$, $k = 8$) due to an insufficient number for the moderator analysis.

6.4.10. Research design

Research design was coded as a categorized moderator in two categories whether the extracted effect sizes was cross-sectional or longitudinal: cross-sectional ($m = 59$, $k = 114$) and longitudinal ($m = 7$, $k = 40$). Although there were 5 eligible studies using experimental design, we decided to combine the effect sizes from these five studies with cross-sectional manner in the moderating analysis due to the eligible effect sizes from these experimental designs being cross-sectional in nature. It is noteworthy that five reviewed studies used mixed methods (Fillmore, 2015; Kench, 2016; Mercado, 2017; Ryan & Beamish, 2018; Slone, 2020). Therefore, we categorized these five studies into the appropriate cross-sectional or longitudinal category with the quantitative portion, given the limited number of mixed methods studies.

6.4.11. Study quality

We followed the journal article reporting standards for quantitative research (JARS; Appelbaum et al., 2018) and coded study quality as a dichotomous moderator: inadequate ($m = 58$, $k = 123$) and adequate ($m = 9$, $k = 31$). A study was thus considered to be of high quality if it reported all the information specified in the quantitative research in psychology (see Supplemental Table S4). A score of 0 was assigned if the studies reported inadequate, unclear, or incomplete information, and a score of 1 was assigned if the studies clearly and adequately met the reporting standards of JARS.

6.4.12. Publication type

Publication type was coded as a categorized moderator in two

categories: published ($m = 40$, $k = 91$) and unpublished ($m = 27$, $k = 63$).

6.5. Analytic strategies

All statistical analyses were performed using RStudio (version 4.0.3) to perform effect aggression and meta-regression ("*metafor*", "*psychmeta*", and "*robumeta*" packages were performed). For the data extraction, we used Pearson's r (the bivariate correlation between growth mindset and grit) for the effect size metric in this meta-analysis. Effect sizes and sample sizes were extracted from each article and listed in Microsoft Excel. To detect outliers in the extracted correlations, we calculated Fisher's z-scores and checked for any z-scores greater than or equal to 3. None of the correlations met this criterion. To present easily interpretable metrics with good statistical properties, all effect sizes were converted to r values (Rosenthal & DiMatteo, 2001). We followed Kraft's (2020) recommendation for new empirical benchmarks for interpreting effect sizes in educational research: <0.05 for a small effect, 0.05 to 0.20 for a medium effect, and >0.20 for a large effect. We also calculated weighted correlation coefficients (weighted r) with 95 % confidence intervals to explain the results. Following Schmidt and Hunter's (2015) suggestion of the meta-analytic approach, we used a random-effects model which allowed for corrections of sampling error and measurement error. We also computed the corrected effect size (ρ), the 95 % confidence interval (CI), and the 80 % credibility interval (CV).

Many of the eligible studies in this meta-analysis provided more than one effect size (e.g., Ingebrigtsen, 2018; Zheng, 2020) because of (a) the examination of multiple correlations for overall grit and its two facets, and (b) multiple independent sample subgroups within a single study (i.e., high school sample and university sample). In the case of (a), where non-independent and multiple effect sizes from a single study threaten the validity of the interpretation of the results due to bias (Cheung, 2019), we used the random-effects robust variance estimation (RVE; Hedges, Tipton, & Johnson, 2010) to account for statistical dependencies of multiple effect sizes via the *robumeta* package in RStudio (Fisher, Tipton, & Zhipeng, 2018). The RVE approach allows meta-analysis studies to include multiple effect sizes from a single study, and this approach is often recommended by other researchers (Tanner-Smith, Tipton, & Polanin, 2016). The RVE method corrects for study standard errors to account for correlations between effect sizes from the same sample and provides accurate estimates of effect sizes, even if the precise nature of the correlation between effect sizes is unknown, without the need for combined or average effect sizes from the same sample (Moeyaert et al., 2017). To test whether our results are sensitive to within-study correlations (in this meta-analysis, the correlation rho with a reasonable range of values between 0 and 1) and to choose rho values for our meta-analysis, we performed a sensitivity analysis that resulted in suggesting our findings could be interpreted as robust across different rho values. Therefore, we used the default value of the correlation rho (0.8) in the current meta-analysis, and this value has been supported as the typical value when the correlation between effect sizes is unknown (MacCann et al., 2020).

In the case of (b), where multiple effect sizes in a single study were generated from independent samples, we considered these to be independent effect sizes because of the uniqueness of each sample (Borenstein et al., 2009). For example, in a meta-analysis examining how computer-based scaffolding affected students' STEM learning (Kim et al., 2020), researchers treated multiple effect sizes and student samples in independent experiments as independent in a single study case. Since individual studies often report multiple correlations, we followed Cooper (2010)'s suggestion of using moving units of analysis for moderated analyses. To calculate the overall effect sizes between growth mindset and grit, all of the correlations from a single study were averaged into a single effect size; while investigating the moderating effects, each correlation representing each type of category (e.g., type of grit measure, grade level) were counted separately, even when they were

extracted from the same study.

Further, we computed Cochrane's Q to assess heterogeneity in effect sizes for examining whether true differences existed in effect sizes across samples (Borenstein et al., 2009). In addition to Cochrane's Q, we also computed I^2 to indicate the proportion of total variation across study estimates due to heterogeneity rather than chance. Higgins and Thompson's (2002) recommendation was followed concerning the interpretation of I^2 by 0 (no heterogeneity), 25 (small heterogeneity), 50 (medium heterogeneity), 75 (large heterogeneity), and 100 (complete heterogeneity). In addition to I^2, we also provided the between-study sampling variance (τ^2) for assigning study weights in the random-effects model (Borenstein, Higgins, Hedges, & Rothstein, 2017).

Last, we used meta-regression analyses using RVE to examine the moderating effects of publication type, research design, grade level, grit measurement, female ratio of sampling, individualistic index, and study quality. For categorical moderators, we directly input dichotomous moderators (e.g., publication type) into the meta-regression model. For those categorical moderators with more than two categories (i.e., grade level and research design), Cohen, Cohen, West, and Aiken' (2013) approach was followed to create several sets of dummy-coded variables to examine comparisons among categories. We also performed subgroup analyses to show the relative magnitude of the difference within each categorical moderator. Further, as several moderators shared substantial overlap and potentially acted as covariates (e.g., Hox, 2010), it is suggested to add all significant moderators simultaneously in a single model to estimate the unique and true effect of each moderator. Therefore, we conducted a meta-regression with multiple significant moderators to examine which moderator had a unique and true effect on the association between growth mindset and grit, while controlling for confounding effects among moderators. Significant results of this model indicated significant regression coefficients for continuous moderators and significant differences between subgroups for categorical moderators.

6.6. Publication bias

To assess potential publication bias in extracted studies, we first performed Egger's regression test (Egger, Smith, Schneider, & Minder, 1997) for its accurate test of publication bias. Insignificant results indicated a lack of publication bias. Second, we performed a trim and fill analysis and examined the funnel plot. According to Duval and Tweedie (2000), the trim and fill method used a random effects model to assess the presence and impact of imputed studies shown in the funnel plot and then provided adjusted effect sizes for detected imputed studies. Specifically, symmetrical funnel plots and a small number of imputation studies indicated a low risk of publication bias, which provided strong support for the findings of a meta-analysis.

Third, we tested the robustness of the estimated overall effect size by using the precision-effect test–precision-effect estimate with a standard error method (PET-PEESE; Stanley & Doucouliagos, 2014). This test adjusts for the linear (PET) and quadratic (PEESE) relationship between the obtained effect size and the standard errors. If these two parameters are independent, it indicates no publication bias (Stanley & Doucouliagos, 2014).

Fourth, since meta-analytic results can be biased by Type-1 error, *p*-curve analysis was conducted. This *p*-curve analysis has been suggested as an ideal test of publication bias to the meta-analytic approach (Boggero, Hostinar, Haak, Murphy, & Segerstrom, 2017). By following Simonsohn, Nelson, and Simmons's (2014) procedure, we examined whether significant studies contained evidential values, using the *p*-curve App (Version 4.05, www.p-curve.com/app4). A right-skewed distribution suggested that the true effect had more *p*-values at the lower end (0.01) than at the upper end (0.04 or 0.05), to indicate inflation bias (Simonsohn et al., 2014). Finally, we performed moderation analyses by directly comparing the effect sizes of published and unpublished studies (such as dissertation and conference papers) to assess whether significant research findings were more likely to be published.

6.7. Sensitivity analyses

We performed sensitivity analyses to assess how robust the results were concerning study assumptions and the presence of possible outliers during synthesis (Borenstein et al., 2009). First, according to the literature, extremely large sample sizes can strongly influence meta-analysis results, because studies with large samples received large weights in the estimation of within-study variance (Huang, 2016). Therefore, we considered this to be a potential bias in this meta-analysis.

Second, some studies measured growth mindset and grit using selected items or unvalidated measures (e.g., Albert, Petrie, & Moore, 2021; Holden, 2018). If the scale used in a study was not psychometrically validated for the targeted population, we cannot ensure that it accurately and efficiently captured the theoretical conceptualization of the construct (e.g., Boateng, Neilands, Frongillo, Melgar-Quiñonez, & Young, 2018). We, therefore, considered this to be another potential bias in the meta-analysis.

Third, we considered the report type of mindset and grit measures as a potential bias. Self-report is the most reliable assessment strategy in accessing individual levels of psychological factors (i.e., personality traits) (Olino & Klein, 2015); however, the accuracy of self-reported measures can be potentially influenced by social desirability and the better-than-average effect (Jago, Baranowski, Baranowski, Cullen, & Thompson, 2007). For example, people tend to be intentionally or unintentionally influenced by social acceptability or preferences when reporting their experiences (Van de Mortel, 2008), and they might overestimate their desirable personality or psychological traits (Ones, Dilchert, Viswesvaran, & Judge, 2007). Funder (1995) suggested that informant reports were more likely to provide accurate assessments of traits and behaviors because raters tended to have a higher quantity and quality of trait-related observations. We, therefore, considered report type (self-report vs. informed report) of growth mindset and grit as a potential bias.

Last, we performed the leave-one-out method by sequentially excluding each study and calculating the weighted effect size of the rest of the studies. This method allows us to assess the stability of the results of a meta-analysis and shows how each study affects the estimated overall effect size (Higgins et al., 2019).

7. Results

7.1. Description of studies reviewed

The initial database search strategy resulted in 2195 findings. Two hundred and fourteen full-text articles were assessed for eligibility and ultimately 65 papers with 66 studies were considered relevant for this systematic review. Among 66 eligible studies, sixty-two studied domain-general growth mindset, two studies investigated language mindset (Balan & Sjöwall, 2022; Khajavy, MacIntyre, & Hariri, 2020), one study investigated students' domain-general growth mindset in English as a Foreign Language context (Nouara, 2020), and one study investigated students' math growth mindset (Kaya & Karakoc, 2022). A descriptive list of included studies is provided in Supplemental Table S3. To the best of our knowledge, there were no book chapters with empirical studies demonstrating the associations between growth mindset and grit/its facets. The current eligible studies, therefore, covered only peer-reviewed journal articles, conference papers and posters, and dissertations.

We categorized the extracted effect sizes into three groups: overall grit (75.32 %, $k = 116$), consistency of interest (11.69 %, $k = 18$), and perseverance of effort (12.99 %, $k = 20$). We provided forest plots in Figs. S1–S3 and funnel plots in Figs. S4–S6 in online supplemental materials. As shown in Table 3, growth mindset was significantly associated with overall grit ($\rho = 0.19$; 95 % CIρ [0.252, 0.295]). Significant

Table 3
Direct Effects Between Growth Mindset and Grit/Its Facets.

	m	k	r / B^a	95 % CI	ρ	95 % CIρ	80 % CRρ	τ^2	I^2
Overall Grit	61	116	0.279	[0.237, 0.320]	0.189	[0.252, 0.295]	[0.134, 0.413]	0.02	91.39
Consistency of Interest	15	18	0.215	[0.133, 0.298]	0.195	[0.195, 0.290]	[0.126, 0.360]	0.01	90.28
Perseverance of Effort	16	20	0.254	[0.174, 0.334]	0.242	[0.246, 0.365]	[0.146, 0.465]	0.01	90.77

Note. m = the number of eligible studies with independent samples; k = number of correlations including in the analyses; 95 % CI = 95 % confidence interval for the pooled effect size; ρ = correlation coefficient corrected for measurement error; CIρ = confidence intervals for corrected correlation coefficients; CRρ = credibility interval for corrected correlation coefficients. All the analyses were run separately with using robust variance estimation approach via *robumeta* package in RStudio. ^{a} r is used for categorical moderators, while B is used for continuous moderators. All the continuous variables were first centered before being entered into the model. * $p < .05$, ** $p < .01$, *** $p < .001$.

associations were also found for consistency of interest ($\rho = 0.20$; 95 % CIρ [0.195, 0.290]) and perseverance of effort ($\rho = 0.24$; 95 % CIρ [0.246, 0.365]). Regarding the probability of heterogeneity, the significant heterogeneity Q statistics [overall grit: $Q(115) = 1496.08$, $p < .001$; consistency of interest: $Q(17) = 147.57$, $p < .001$; perseverance of effort: $Q(19) = 227.36$, $p < .001$] and large I^2 value [overall grit: 96 %; consistency of interest: 94 %; perseverance of effort: 96 %] suggested systematic between-sample variability, supporting further moderation testing (Viechtbauer, 2008).

7.2. Moderation analyses

In the meta-regression model (see Table 5), all the continuous variables were first centered by subtracting the mean to 0 to avoid multicollinearity which may affect the model convergence and/or inflate the standard errors (Dalal & Zickar, 2012).

7.2.1. Female ratio of sampling

The mean ratio of females was 57.71 %, and the reviewed studies tended to have slightly more female than male participants. Only 13 studies recruited more male students than females. As shown in Tables 4 and 5, gender did not play a significant moderating role in the associations between growth mindset and grit/two facets, suggesting that these associations did not vary across gender.

7.2.2. Grade level

As shown in Tables 4 and 5, the meta-regression results indicated that grade level did not significantly moderate the relationship between growth mindset and grit/its facets, suggesting that these relationships did not vary much across grade levels.

Race/ethnicity. Among the eligible studies that have recruited American samples, the mean ratio of White participants was 44.72 %, the mean ratio of Asian American participants was 12.87 %, and the mean ratio of Black or African American participants was 34.50 %. As shown in Table 4, the percentage of Asian Americans, Black or African Americans, and Whites did not significantly moderate the relationship between growth mindset and grit/its facets, suggesting that these relationships did not vary much across categories of race/ethnicity.

7.2.3. Continent

As revealed in Table 4, growth mindset was significantly correlated with overall grit for all continents except Oceania, while growth mindset was significantly correlated with consistency of interest for both Asia and North America and also correlated with perseverance of effort for Asia, Europe, and North America. Regarding the subgroup analyses, there were no statistically significant differences in the relations between growth mindset and grit/two facets between samples from each of the continents (overall grit: $Q(4) = 1.80$, $p = .772$; consistency of interest: $Q(3) = 2.02$, $p = .567$; and perseverance of effort: $Q(3) = 2.222$, $p = .527$). As shown in Table 5, continent did not significantly moderate the relationship between growth mindset and grit/its facets, suggesting that these relationships did not vary much across continents.

7.2.4. Socioeconomic status

The range of the HDI was between 0.591 and 0.961, indicating that all of the studies recruited student samples in the regions with medium to very high human development. As shown in Table 4, socioeconomic status did not significantly moderate the relationship between growth mindset and grit/its facets, suggesting that these relationships did not vary much across SES levels.

7.2.5. Collectivism versus individualism

Notably, the individualistic index was not distributed evenly across the studies. The mean score of the individualistic index was 63.38 and most studies were conducted in an individualistic cultural context. Only 23 studies were conducted in a collectivistic context (including Algeria, China, India, Iran, Japan, Korea, Portugal, and Turkey). As shown in Tables 4 and 5, the individualistic index did play a significant moderating role in the relationship between growth mindset and overall grit with an effect size of $B = -0.08$, $SE = 0.03$, $p < .05$, suggesting that this relationship did vary substantially across different sociocultural contexts: a significantly stronger effect was observed in samples with collectivistic cultural backgrounds (weighted $r_{\text{collectivistic}} = 0.35$ and weighted $r_{\text{Individualistic}} = 0.24$, respectively). No significant moderating effect of the individualistic index was observed in consistency of interest and perseverance of effort.

7.2.6. Long-term orientation

The long-term orientation index was not distributed evenly across the studies. The mean score of this index was 45.79 and most studies were conducted in the short-term oriented countries. As shown in Table 4, the long-term orientation index did not play a significant moderating role in the relationships between growth mindset and grit/its facets.

7.2.7. Grit measure

As shown in Tables 4 and 5, meta-regression results indicated that the grit measure did not play a significant moderating role in the relationship between growth mindset and overall grit, suggesting that this relationship did not vary substantially across grit measures. We did not conduct moderator tests for the two facets of grit because the eligible studies in these two categories all used the Grit-S to measure students' level of consistency of interest and perseverance of effort.

7.2.8. Research design

As shown in Tables 4 and 5, the meta-regression results indicated that the research design did not significantly moderate the association between growth mindset and overall grit, suggesting that the relationship between growth mindset and overall grit did not vary much across the research design. We did not run this moderator test for the two facets of grit because the eligible studies in these two categories all used cross-sectional designs.

7.2.9. Study quality

As shown in Tables 4 and 5, study quality did not significantly moderate the associations between growth mindset and grit/its facets,

Table 4

Univariate Moderation Tests of Categorical and Continuous Variables for the Association between Growth Mindset and Grit/Its Facets.

Moderator	m	k	r / B[a]	95 % CI	ρ	95 % CIρ	80 % CRρ	τ^2	I^2
Overall Grit									
Categorical variables									
Publication type									
Published	35	73	0.277*	[0.224, 0.330]	0.171*	[0.229, 0.278]	[0.126, 0.381]	0.03	93.38
Unpublished	26	43	0.283*	[0.216, 0.351]	0.271*	[0.303, 0.381]	[0.192, 0.491]	0.01	86.26
Research design									
Cross-sectional	57	78	0.279*	[0.236, 0.322]	0.237*	[0.301, 0.364]	[0.166, 0.499]	0.01	90.97
Longitudinal	6	38	0.253*	[0.103, 0.403]	0.152*	[0.205, 0.245]	[0.157, 0.292]	0.01	89.38
Study quality									
Inadequate	53	89	0.283*	[0.236, 0.329]	0.178*	[0.241, 0.291]	[0.124, 0.408]	0.01	89.07
Adequate	8	27	0.257*	[0.145, 0.369]	0.219*	[0.248, 0.335]	[0.154, 0.429]	0.03	96.13
Grade level									
Primary	7	27	0.332*	[0.135, 0.528]	–	–	–	0.06	96.07
Secondary	15	35	0.246*	[0.168, 0.323]	–	–	–	0.01	83.91
Tertiary	35	49	0.269*	[0.219, 0.320]	–	–	–	0.01	83.01
Grit measure									
Grit-O	5	8	0.182	[−0.234, 0.598]	0.168*	[0.228, 0.270]	[0.152, 0.345]	0.06	95.89
Grit-S	52	70	0.284*	[0.243, 0.325]	0.273*	[0.307, 0.395]	[0.158, 0.544]	0.02	90.21
Other	5	8	0.442*	[0.225, 0.660]	0.411*	[0.124, 0.811]	[0.057, 0.879]	0.03	92.62
Cultural background									
Collectivistic	19	37	0.352*	[0.281, 0.423]	–	–	–	0.03	95.22
Individualistic	39	75	0.238*	[0.186, 0.291]	–	–	–	0.01	86.38
Socioeconomic status									
Medium	2	2	0.491*	[0.050, 0.933]	–	–	–	0.00	0.00
High	10	25	0.327*	[0.240, 0.414]	–	–	–	0.03	96.83
Very high	46	85	0.259*	[0.208, 0.309]	–	–	–	0.01	88.17
Continent									
Africa	2	2	0.345*	[0.113, 0.577]	–	–	–	0.00	0.00
Asia	18	35	0.293*	[0.217, 0.369]	–	–	–	0.03	95.68
Europe	10	11	0.213*	[0.101, 0.325]	–	–	–	0.03	89.14
North America	28	60	0.277*	[0.212, 0.343]	–	–	–	0.01	86.74
Oceania	3	4	0.290	[−0.148, 0.728]	–	–	–	0.03	89.64
Continuous variables									
Race/ethnicity (American context)									
Asian%	15	42	0.036	[−0.507, 0.578]	–	–	–	0.01	87.80
Black%	14	37	0.018	[−0.113, 0.150]	–	–	–	0.01	92.56
White%	17	44	0.016	[−0.081, 0.112]	–	–	–	0.01	90.79
Socioeconomic status	58	112	−0.016	[−0.055, 0.022]	–	–	–	0.02	91.92
Individualistic index	58	112	−0.047*	[−0.088, −0.006]	–	–	–	0.02	91.59
Long-term orientation	58	112	0.024	[−0.012, 0.060]				0.02	91.79
Female percentage	53	101	−0.007	[−0.059, 0.045]	–	–	–	0.02	91.76
Consistency of Interest									
Categorical variables									
Publication type									
Published	6	8	0.223*	[0.120, 0.327]	0.194*	[0.161, 0.349]	[0.109, 0.401]	0.01	90.27
Unpublished	9	10	0.210*	[0.061, 0.360]	0.195*	[0.176, 0.302]	[0.128, 0.351]	0.01	91.35
Research design									
Cross-sectional	14	17	0.227*	[0.140, 0.313]	0.208*	[0.212, 0.304]	[0.151, 0.365]	0.01	88.79
Longitudinal	–	–	–	–	–	–	–	–	–
Study quality									
Inadequate	13	16	0.225*	[0.128, 0.321]	0.203*	[0.203, 0.298]	[0.143, 0.358]	0.01	89.41
Adequate	2	2	0.170	[−0.847, 1.19]	0.161	[−1.160, 1.600]	[−0.243, 0.682]	0.01	95.94
Grade level									
Primary	–	–	–	–	–	–	–	–	–
Secondary	4	4	0.236	[−0.000, 0.473]	–	–	–	0.02	93.80
Tertiary	9	11	0.167*	[0.101, 0.232]	–	–	–	0.00	77.12
Grit measure									
Grit-O	–	–	–	–	–	–	–	–	–
Grit-S	14	17	0.227*	[0.140, 0.313]	0.196*	[0.192, 0.300]	[0.140, 0.352]	0.01	88.79
Other	–	–	–	–	–	–	–	–	–
Cultural background									
Collectivistic	6	8	0.227*	[0.140, 0.314]	–	–	–	0.00	77.37
Individualistic	8	8	0.198*	[0.024, 0.372]	–	–	–	0.01	93.78
Socioeconomic status									
Medium	–	–	–	–	–	–	–	–	–
High	6	8	0.202*	[0.131, 0.274]	–	–	–	0.00	35.54
Very high	8	8	0.216*	[0.052, 0.380]	–	–	–	0.01	94.74
Continent									
Africa	–	–	–	–	–	–	–	–	–
Asia	6	8	0.227*	[0.140, 0.314]	–	–	–	0.00	77.37
Europe	–	–	–	–	–	–	–	–	–
North America	6	6	0.220*	[0.008, 0.433]	–	–	–	0.01	95.25
Oceania	–	–	–	–	–	–	–	–	–
Continuous variables									

Table 4 (*continued*)

Moderator	m	k	r / Bᵃ	95 % CI	ρ	95 % CIρ	80 % CRρ	τ²	I²
Race/ethnicity (American context)									
Asian%	3	3	0.245	[−0.033, 0.522]	–	–	–	0.00	0.00
Black%	4	4	−0.038	[−1.372, 1.297]	–	–	–	0.01	96.46
White%	4	4	−0.170	[−1.198, 0.859]	–	–	–	0.02	96.73
Socioeconomic status	14	16	−0.001	[−0.087, 0.085]	–	–	–	0.01	91.46
Individualistic index	14	16	−0.002	[−0.105, 0.101]	–	–	–	0.01	91.42
Long-term orientation	14	16	0.019	[−0.067, 0.104]	–	–	–	0.01	91.01
Female percentage	15	18	−0.066*	[−0.131, −0.001]	–	–	–	0.01	89.73
Study quality	15	18	−0.020	[−0.211, 0.176]	–	–	–	0.01	90.58
Perseverance of Effort									
Categorical variables									
Publication type									
Published	7	10	0.211*	[0.051, 0.372]	0.200*	[0.138, 0.392]	[0.028, 0.502]	0.02	94.08
Unpublished	9	10	0.290*	[0.197, 0.383]	0.269*	[0.271, 0.385]	[0.228, 0.428]	0.00	83.11
Research design									
Cross-sectional	15	19	0.262*	[0.177, 0.347]	0.253*	[0.251, 0.374]	[0.151, 0.475]	0.01	89.80
Longitudinal	–	–	–	–	–	–	–	–	–
Study quality									
Inadequate	14	18	0.268*	[0.175, 0.361]	0.258*	[0.250, 0.382]	[0.148, 0.485]	0.01	89.93
Adequate	2	2	0.174	[−0.143, 0.491]	0.172	[−0.132, 0.615]	[0.160, 0.323]	0.00	57.94
Grade level									
Primary	–	–	–	–	–	–	–	–	–
Secondary	4	5	0.229*	[0.060, 0.399]	–	–	–	0.00	81.83
Tertiary	10	12	0.230*	[0.115, 0.344]	–	–	–	0.01	91.69
Grit measure									
Grit-O	–	–	–	–	–	–	–	–	–
Grit-S	15	19	0.262*	[0.177, 0.347]	0.232*	[0.217, 0.372]	[0.128, 0.462]	0.01	89.80
Other	–	–	–	–	–	–	–	–	–
Cultural background									
Collectivistic	7	10	0.264*	[0.092, 0.437]	–	–	–	0.02	94.12
Individualistic	8	8	0.246*	[0.141, 0.351]	–	–	–	0.01	87.67
Socioeconomic status									
Medium	–	–	–	–	–	–	–		
High	7	9	0.272*	[0.081, 0.463]	–	–	–	0.02	94.10
Very high	8	9	0.248*	[0.156, 0.340]	–	–	–	0.01	88.01
Continent									
Africa	–	–	–	–	–	–	–	–	–
Asia	6	9	0.243*	[0.037, 0.448]	–	–	–	0.02	94.42
Europe	2	2	0.146*	[0.002, 0.291]	–	–	–	0.00	0.00
North America	6	6	0.299*	[0.182, 0.415]	–	–	–	0.00	86.96
Oceania	–	–	–	–	–	–	–	–	–
Continuous variables									
Race/ethnicity									
Asian%	3	3	0.149	[−0.412, 0.711]	–	–	–	0.00	80.40
Black%	4	4	0.052	[−0.604, 0.708]	–	–	–	0.00	89.57
White%	4	4	−0.094	[−0.593, 0.406]	–	–	–	0.00	86.23
Socioeconomic status	15	18	0.000	[−0.112, 112]	–	–	–	0.01	91.95
Individualistic index	15	18	0.003	[−0.095, 0.101]	–	–	–	0.01	91.94
Long-term orientation	15	18	−0.000	[−0.102, 0.093]	–	–	–	0.01	91.92
Female percentage	16	20	−0.041	[−0.153, 0.070]	–	–	–	0.01	91.27
Study quality	16	20	−0.029	[−0.131, 0.074]	–	–	–	0.01	89.35

Note. m = the number of eligible studies with independent samples; *k* = number of correlations including in the analyses; 95 % CI = 95 % confidence interval for the pooled effect size; ρ = correlation coefficient corrected for measurement error; CIρ = confidence intervals for corrected correlation coefficients; CRρ = credibility interval for corrected correlation coefficients. All the analyses were run separately with using robust variance estimation approach via *robumeta* package in RStudio. The ρ is only provided if the group included sufficient valid correlations and sample sizes. ᵃ *r* is used for categorical moderators, while *B* is used for continuous moderators. All the continuous variables were first centered before being entered into the model. * *p* < .05, ** *p* < .01, *** *p* < .001.

suggesting that the magnitude or direction of the weighted average relationship between growth and grit/its facets did not vary much across the varying degrees of study quality.

7.3. Publication bias

According to the trim-and-fill test, the current meta-analysis should be interpreted cautiously, and the existing publication bias was likely to affect the results of this meta-analysis.

7.3.1. Egger's regression test

Based on Egger's regression test, no suspected publication biases were found in overall grit ($z = −0.16$, $p = .872$), consistency of interest ($z = 0.56$, $p = .579$), and perseverance of effort ($z = 0.25$, $p = .804$).

7.3.2. Trim-and-fill test

No imputed missing studies were trimmed for consistency of interest. However, this test resulted in 20 trimmed and filled effect sizes for overall grit, with an adjusted estimated weighted *r* of 0.27 [0.240, 0.299], and 3 trimmed and filled effect sizes for perseverance of effort, with an adjusted estimated average weighted *r* = 0.21 [0.129, 0.282]. The contour-enhanced funnel plot with trim-and-fill results was provided in Figs. 2–4. Because of the potentially missing studies, the asymmetrical funnel plots indicated publication bias.

7.3.3. PET-PEESE test

As shown in Table 6, the results indicated a significant relation between the standard error on transfer effect size for overall grit and its two facets (CIs included 0), indicating clear evidence for publication bias. The PET-PEESE results indicated a true effect in overall grit might

Table 5

Multilevel Regression Model on the Association between Growth Mindset and Grit/Its Facets (All Moderators in the Same Equation).

Moderator	B	SE	95 % CI	t
Overall Grit ($m = 52$, $k = 105$, $\tau^2 = 0.01$, $I^2 = 83.19$ %)				
Intercept	0.318	0.086	[0.126, 0.510]	3.696
Publication type (Unpublished as the reference level)				
Published	−0.039	0.045	[−0.134, 0.056]	−0.860
Research design (Cross-sectional as the reference level)				
Longitudinal	−0.014	0.057	[−0.148, 0.120]	−0.242
Study Quality (inadequate as the reference level)				
Adequate	−0.039	0.068	[−0.192, 0.115]	−0.565
Grit measure (Grit-O as the reference level)				
Grit-S	−0.017	0.046	[−0.111, 0.077]	−0.376
Other	0.245	0.137		
Grade level (Primary as the reference level)				
Secondary	0.053	0.081	[−0.132, 0.238]	0.656
Tertiary	0.056	0.060	[−0.096, 0.208]	0.928
Continent (Africa as the reference level)				
Asia	−0.149	0.074	[−0.331, 0.034]	−2.003
Europe	−0.142	0.072	[−0.312, 0.028]	−1.972
North America	−0.039	0.065	[−0.195, 0.117]	−0.602
Individualistic index	−0.084*	0.033	[−0.158, −0.010]	−2.575
Consistency of Interest ($m = 13$, $k = 15$, $\tau^2 = 0.00$, $I^2 = 80.20$ %)				
Intercept	0.246*	0.055	[0.031, 0.460]	4.507
Publication type (Unpublished as the reference level)				
Published	0.058	0.057	[−0.101, 0.218]	1.014
Study Quality (inadequate as the reference level)				
Adequate	−0.126	0.120	[−0.590, 0.339]	−1.047
Grade level (Secondary as the reference level)				
Tertiary	−0.067	0.080	[−0.331, 0.197]	−0.830
Continent (Asia as the reference level)				
North America	−0.025	0.079	[−0.249, 0.200]	−0.311
Female percentage	−0.060	0.039	[−0.170, 0.050]	−1.559
Perseverance of Effort ($m = 14$, $k = 17$, $\tau^2 = 0.01$, $I^2 = 92.34$ %)				
Intercept	0.353*	0.042	[0.123, 0.584]	8.386
Publication type (Unpublished as the reference level)				
Published	−0.022	0.075	[−0.411, 0.366]	−0.297
Study Quality (inadequate as the reference level)				
Adequate	−0.111	0.068	[−0.971, 0.748]	−1.647
Grade level (Secondary as the reference level)				
Tertiary	−0.127	0.129	[−0.824, 0.570]	−0.992

Table 5 (*continued*)

Moderator	B	SE	95 % CI	t
Continent (Asia as the reference level)				
Europe	−0.089	0.076	[−0.720, 0.542]	−1.166
North America	0.036	0.115	[−0.399, 0.471]	0.313

Note. B = unstandardized regression coefficient; 95 % CI = 95 % confidence interval for the pooled effect size; $t = t$ statistic for each moderator. All the moderators were entered in one model for overall grit and its two facets with using robust variance estimation approach via *robumeta* package in RStudio. All the continuous variables were first centered before being entered into the model.
* $p < .05$.
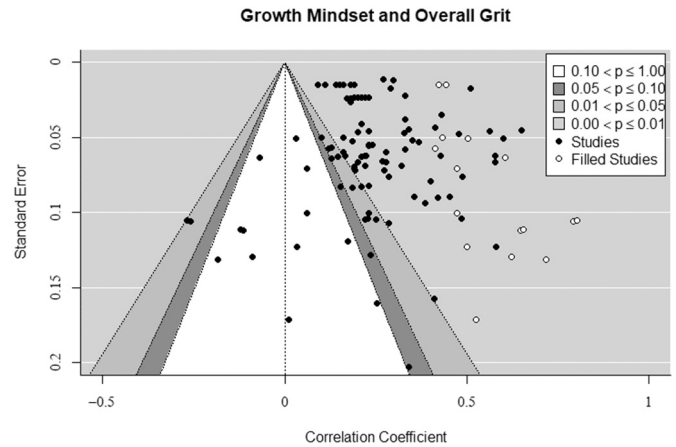
Fig. 2. Contour-enhanced funnel plots with trim-and-fill results for correlations between growth mindset and overall grit.
Note. Each black dot (hollow) represents an individual effect size and is positioned according to its Pearson's correlation r effect size (x-axis) and standard error (y-axis). Confidence intervals represent non-significance of study effects within the area (*p*-value: white = 0.10, dark gray = 0.05, gray = 0.01, and light gray = 0.001) while the dashed line represents the estimated effect size. Trim-and-fill analysis yielded 20 trimmed or filled effect sizes, and the Egger's regression test suggested ($z = -0.16$, $p = .872$) no small study effects.

be slightly larger (Unadjusted $r = 0.23$ vs. Adjusted $r = 0.29$), while the true effect in consistency of interest (Unadjusted $r = 0.22$ vs. Adjusted $r = 0.16$) and perseverance of effort (Unadjusted $r = 0.24$ vs. Adjusted $r = 0.20$) could be slightly smaller.

7.3.4. p-curve analysis

Fig. 5 presented the *p*-curve plots of overall grit and its two facets. The *p*-curve analysis indicated that for all eligible effect sizes, the *p*-values (defined as $ps < 0.001$) and half-*p* values (defined as $ps < 0.001$) were all right-skewed ($ps < 0.001$), and their flat tests were all non-significant ($ps > 0.999$). For overall grit and its two facets, *p*-curve estimated that the statistical power of the tests included was 99 %, indicating that the evidence-based values were all present and inflation bias was unlikely to occur.

7.3.5. Publication type

As shown in Tables 4 and 5, the publication type did not significantly moderate the associations between growth mindset and grit/its two facets, indicating that these associations did not differ significantly between published and unpublished data.

7.4. Sensitivity analyses

The sensitivity analyses showed that the findings were robust across

Growth Mindset and Consistency of Interest
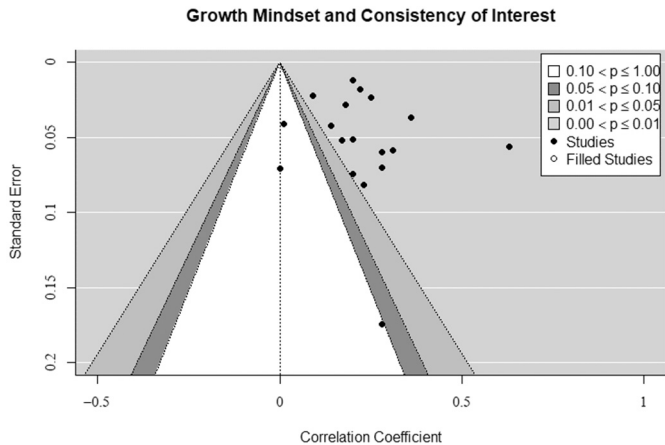
Fig. 3. Contour-enhanced funnel plots with trim-and-fill results for correlations between growth mindset and consistency of interest.
Note. Each black dot (hollow) represents an individual effect size and is positioned according to its Pearson's correlation r effect size (x-axis) and standard error (y-axis). Confidence intervals represent non-significance of study effects within the area (*p*-value: white = 0.10, dark gray = 0.05, gray = 0.01, and light gray = 0.001) while the dashed line represents the estimated effect size. Trim-and-fill analysis yielded no trimmed or filled effect sizes, and the Egger's regression test suggested ($z = 0.56$, $p = .579$) no small study effects.

Growth Mindset and Perseverance of Effort
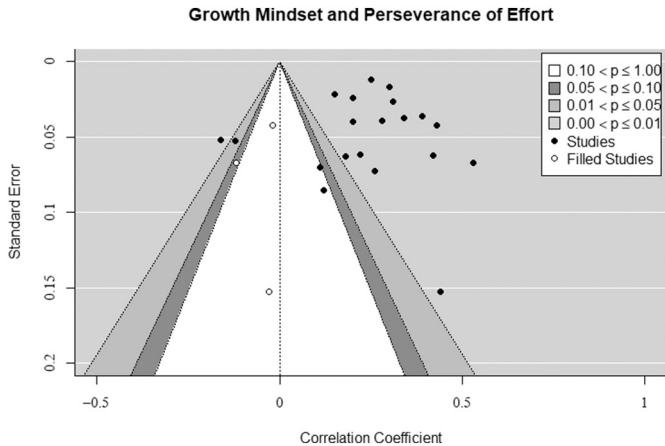
Fig. 4. Contour-enhanced funnel plots with trim-and-fill results for correlations between growth mindset and perseverance of effort.
Note. Each black dot (hollow) represents an individual effect size and is positioned according to its Pearson's correlation r effect size (x-axis) and standard error (y-axis). Confidence intervals represent non-significance of study effects within the area (*p*-value: white = 0.10, dark gray = 0.05, gray = 0.01, and light gray = 0.001). Trim-and-fill analysis yielded 3 trimmed or filled effect sizes, and the Egger's regression test suggested ($z = 0.25$, $p = .804$) no small study effects.

different reasonable estimates of ρ. Further, the range of the sample sizes (20 to 5952) of the eligible studies was acceptable (Lin, 2018) and it would not be considered biased in this meta-analysis.

7.4.1. Report type

All the eligible studies were identified as using a self-reported mindset. One study (Park et al., 2020) was identified as using teacher-reported grit. After removing this identified study, no substantial changes in the estimated effect size or confidence interval were found ($z = 0.01$, $p = .496$). Consequently, the report type of grit would not be considered biased in this meta-analysis.

7.4.2. Selected items or non-validated scales in measuring growth mindset

The most popular measure used to assess growth mindset was the 8-item Growth Mindset Scale (Dweck, 2006) with 22 studies, followed by the 6-item Implicit Theories Scale (TIS; Dweck, 1999) with 18 studies, and the 16-item Dweck Mindset Instrument (DMI) with 7 studies. After removing the seven identified studies using selected items or non-validated scale (Albert et al., 2021; Allen, 2018; Holden, 2018, Experiment 2 and 3; Kench, 2016; Lee & Taylor, 2022; Zhu et al., 2020, Study 3), no substantial changes in estimated effect size or confidence interval were found ($z = -0.01$, $p = .496$). Therefore, studies that used selected items or non-validated scales in measuring growth mindset were not considered to bias this meta-analysis.

7.4.3. Selected items or non-validated scales in measuring grit

After removing the five mentioned studies that did not use Grit-O and Grit-S in measuring students' grit levels, no substantial changes in estimated effect sizes or confidence intervals were found ($z = -0.15$, $p = .442$). Therefore, studies that used selected items or non-validated scales in measuring grit were not considered to bias this meta-analysis.

7.4.4. Leave-one-out method

The estimated effect sizes ranged from 0.22 to 0.23 for overall grit, ranged from 0.20 to 0.23 for consistency of interest, and ranged from 0.23 to 0.26 for perseverance of effort when leaving out one study. Compared with the original estimated effect size, no substantial changes in estimated effect sizes or confidence intervals ($ps = $ ns.) were observed. That is, the removal of any one study did not significantly affect the estimated effect size in overall grit/its facets.

8. Discussion

The purpose of this meta-analysis was to examine the association between growth mindset and grit among K-12 and university students and to identify potential moderators and underlying mechanisms of such association.

8.1. Overall average effect size

Regarding the first research question about the association pattern between students' growth mindset and grit, the results revealed a statistically significant positive relationship between growth mindset and grit (overall grit, consistency of interest, perseverance of effort). First, we found that overall, there was a medium, positive association between growth mindset and overall grit ($\rho = 0.19$), based on the standards put forth by Kraft's (2020). This is in line with previous assumptions that students with a high growth mindset tended to have higher grit levels (Calo et al., 2019; Tang et al., 2019). For example, according to Dweck's (1986) mindset theory, students with growth mindset tended to have mastery goal orientation and these students were more likely to

Table 6
Results of PET and PEESE in Estimating the Association between Growth Mindset and Grit/Its Facets.

	Unadjusted r	Adjusted r (PET)	Adjusted r (PEESE)
Overall Grit	0.23 [0.202, 0.256]	0.32 [0.275, 0.361]	0.29 [0.258, 0.318]
Consistency of Interest	0.22 [0.156, 0.286]	0.14 [0.096, 0.192]	0.16 [0.127, 0.195]
Perseverance of Effort	0.24 [0.165, 0.314]	0.20 [0.106, 0.296]	0.20 [0.106, 0.296]

Note: 95 % confidence intervals depicted within brackets. Confidence intervals that do not include 0 are statistically significant.
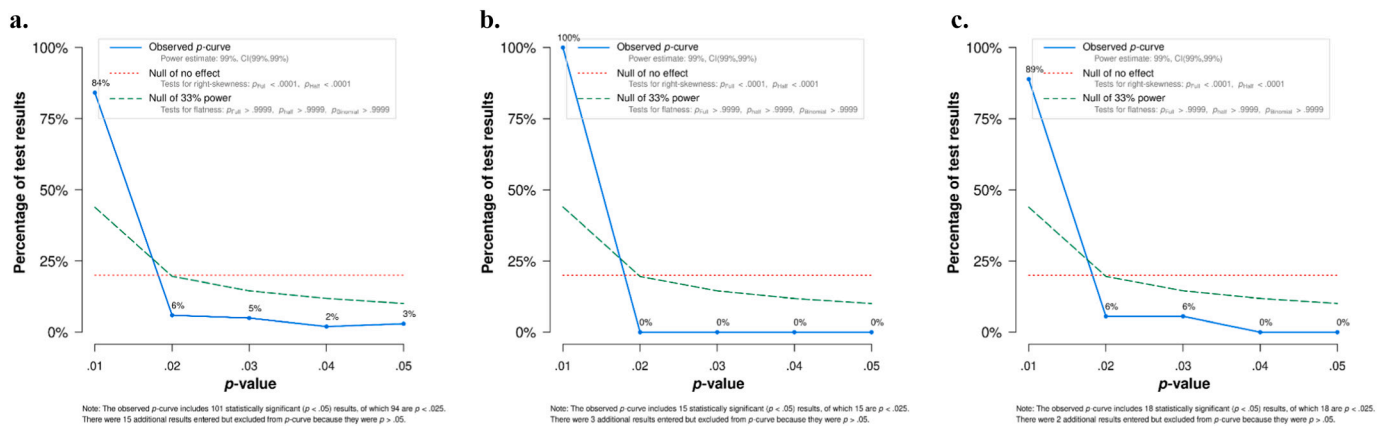
Fig. 5. The p-curve plots of the correlation of growth mindset with a) overall grit, b) consistency of interest, and c) perseverance of effort.

persevere in learning, view challenges as learning opportunities, and display high consistency in pursuing their goals. Further, from a view of the self-determination theory (Deci & Ryan, 1985), students with growth mindsets tended to exhibit lower extrinsic motivation and higher intrinsic motivation in learning, which further significantly contributed to their grit levels (Zhao et al., 2018).

Although growth mindset beliefs can play a distinct role in helping students work with passion and interpret perseverance as the key to success (Dweck, 2009), we found that growth mindset was less related to students' consistency of interest and slightly higher related to perseverance of effort. This result was in line with previous findings which indicated growth mindset was more consistently related to perseverance of effort and overall grit, but less consistent to consistency of interest (Midkiff et al., 2017; Tang et al., 2019). Notably, the current results can be due to the relatively small number of studies that examined this relation by separating consistency of interest from perseverance of effort. Our findings call for more research on each of the grit facets to obtain more representative results in the relationships between growth mindset and grit.

8.2. Moderators

Our second research question about the extent to which students' demographic characteristics, and measure and study characteristics affect the association between growth mindset and grit was addressed through moderator analyses. We found that after grouping effect sizes by subgroups within our moderators, significant positive associations between growth mindset and grit/its facets remained for most of our subgroups. Only cultural backgrounds (collectivistic vs. individualistic) significantly moderated the association between growth mindset and overall grit level.

8.2.1. Demographic characteristics as moderators

8.2.1.1. Gender. Gender did not emerge as a significant moderating factor, indicating that the relationships between growth mindset and grit were similar across gender groups. This finding differs from prior empirical studies, where females tended to report better growth mindset and grit than males (Christensen & Knezek, 2014; Degol, Wang, Zhang, & Allerton, 2018). Our findings showed that the relation pattern was similar for male and female students when linking these two constructs. Possibly, gender role socialization may further affect the association between growth mindset and grit.

8.2.1.2. Grade level. Subsequent moderator analyses showed that this association was not significantly moderated by students' grade levels. This stands in contrast with previous assumptions that K-12 students

seemed to benefit more from their growth mindset (Sisk, Burgoyne, Sun, Butler, & Macnamara, 2018). We found that both K-12 and university students benefited from growth mindset in an undifferentiated way. However, the underlying mechanism in explaining this association might vary across grade levels. For example, in a group of 3rd to 9th graders, the researchers found that students' learning motivation significantly mediated the association between growth mindset and grit (Zhao et al., 2018). However, the effect of learning motivations might not be that effective in explaining the association between growth mindset and grit among university samples since this population was less emphasized in terms of learning motivation (e.g., self-efficacy and task value; Mazumder & Kilaru, 2016). Notably, due to the limited research findings in this area and insufficient data in revealing potential mechanisms, more research in this line is recommended.

8.2.1.3. Race and ethnicity. Race and ethnicity failed to moderate the growth mindset-grit association, indicating that growth mindset appeared to be manifested in similar ways for White, Asian American, and Black or African American participants in the American context, and all students with diverse race/ethnicity groups could develop grit by shaping growth mindset belief. However, this result should be interpreted with caution since it was only drawn from the samples within the United States. Given the complexities of categorizing race/ethnicity in every country (Vertovec, 2007), the true effect of race/ethnicity in the growth mindset-grit link should be examined across a variety of race/ethnicity groups from different countries rather than a single country. These would provide cross-cultural insight into specific cultural practices for a specific type of race or ethnicity in a growth mindset intervention setting to ensure a more optimal cultural fit.

8.2.1.4. Continent. Our results suggested that there are no statistically significant differences in the relationships between growth mindset and grit/two facets at the continental level. This finding implied that regardless of continent, growth mindset was significantly associated with grit and its two facets, except for the Oceania continent. However, note that most of the studies were conducted in Asia and North America continents and only a few studies were in other continents. The small number of eligible studies in Africa, Europe, and Oceania might have reduced the statistical power to detect true differences between the continents, which could lead to biased estimates (Rubio-Aparicio et al., 2020). Therefore, the results of this analysis should be treated with caution.

8.2.1.5. SES. We did not detect a significant moderating effect of SES in the association between growth mindset and grit. One plausible reason was that all studies under review recruited student samples with medium to very high social status, and potential variations in the

relationship patterns between growth mindsets and grit were not fully captured. This indicates the need to recruit participants with more diversified socioeconomic backgrounds.

8.2.2. Cultural differences as moderators

Our results supported a significant cross-cultural difference in the strength of the association between growth mindset and overall grit. We observed that the significant association between growth mindset and overall grit was equivalent across samples from both individualistic and collectivistic cultural backgrounds, but a significantly stronger effect was observed in collectivistic samples. These findings were consistent with previous empirical findings, which supported the common assumption that Eastern cultures tended to value more effort, i.e., Chinese students emphasized more about diligence whereas American students emphasized more about ability in schools (Li, 2004; Zhang et al., 2019). However, our results should not be interpreted as an endorsement that "one size fits all" when considering the natural association between growth mindset and grit. It is critical that educators and researchers use a cultural-specific conceptualization of grit to indicate grit.

With regards to long-term orientation difference, we found that the long-term orientation index did not moderate the associations between growth mindset and grit/its facets. This implied that growth mindset could be activated in both long-term-oriented and short-term-oriented cultures and showed a positive association with grit even though individuals from these cultures might have different approaches in time investment (investing and preparing for the future or present) or goal selection (present or future goals, short-term or long-term goals). Although the moderating effect of the long-term orientation index was non-significant, we still observed the positive effect for overall grit and consistency of interest, which was in line with our previous assumptions that students' long-term orientation could strengthen the positive relationship between growth mindset and grit by providing a macro level of motivation in developing grit. More contextual research in analyzing how external motivation (at the social and cultural level) shapes grit is highly recommended.

8.2.3. Measure and study characteristics as moderators

8.2.3.1. Existing grit measures.
With regards to the scales used to measure grit, we found that the association between growth mindset and overall grit did not significantly differ when using the two widely used grit scales (Grit-O and Grit-S) or other scales (such as scales measuring the multidimensional construct of grit), indicating that a similar relation could be expected with growth mindset no matter which grit scale was used. However, after correcting for sampling errors and measurement errors, we observed smaller relations of growth mindset with the studies using Grit-O ($\rho = 0.17$) and Grit-S ($\rho = 0.27$) than did the studies adopting other grit scales ($\rho = 0.41$). Further, we did not yet have evidence to specify how other types of grit measures (different conceptualizations of grit) performed in the association between growth mindset and grit due to insufficient data for subgroup analysis. More work is needed to evaluate the cross-cultural reliability and validity of these newly developed grit measures across students' development.

8.2.3.2. Research design.
With respect to study design, we did not observe a significant moderating effect, although studies examining the association between growth mindset and overall grit reported slightly smaller effects for longitudinal (weighted $r = 0.25$) than cross-sectional (weighted $r = 0.28$) studies. Additionally, the significant weighted effect in the longitudinal domain in this study indicated that early growth mindset influenced later overall grit levels among student samples. This finding appeared to suggest that growth mindset was generally a significant and necessarily potent longitudinal predictor of students' overall grit. However, more longitudinal research is needed to specify whether

the longitudinal effect of the growth mindset plays a similar role in shaping different facets of grit. We also call for more research that assesses longitudinally mediating chains (e.g., growth mindset to mindfulness inductions to persistence; Nagy et al., 2023).

8.2.3.3. Study quality.
Although we did not detect a significant moderating effect of study quality in explaining the variation of the associations between growth mindset and grit/two facets, the weighted effect sizes in the inadequate domain were slightly higher than those in the adequate domain. This implied that inadequate study quality might lead to overestimates of the effect size of the growth mindset-grit link. We observed that several studies used selected items or non-validated scales in measuring growth mindset and grit (see sensitivity analyses section), nearly 61.54 % of eligible studies employed inadequate sample sizes (⟨200) or did not perform a power analysis, and only 9 studies met the reporting criteria recommended by Appelbaum et al. (2018). Future empirical studies on this topic should consider following Appelbaum et al.'s (2018) reporting standards for quantitative research practice to increase the reproducibility of research findings and methodological integrity of research. Good research practice can also prevent the inflation of false-positive rates of research findings and draw valid and reliable scientific conclusions about the growth mindset-grit link (Murayama, Pekrun, & Fiedler, 2014).

9. Implications

From a theoretical perspective, our findings confirmed the theoretical consensus that students' growth mindsets were positively linked to their grit levels. The detected heterogeneity of effect sizes was not observed in all our proposed moderators (some of them showed null results), indicating that there was still a significant amount of variance left unexplained. We thus call for more work on the mechanisms underlying the effect of growth mindset on grit, such as investigating the role of positive character traits and cognitions of students (like mindfulness, zest for life, or gratitude; Lam, 2023; Samuel & Warner, 2021; Wilson, 2016a, 2016b) which has been fostered in some positive education programs and testifying how this role interacts with growth mindset in contributing grit.

From a methodological standpoint, this study revealed some concerns about the operationalization and measurement of growth mindset and grit in education research. First, we detected several studies that used selected items or non-validated scales in measuring students' growth mindsets and grit levels. Although the results of sensitivity analyses supported that this concern was not considered to bias this meta-analysis, such articles did not factually measure growth mindset or grit with a good, psychometrically sound measurement. Further, because most studies adopted the bidimensional operationalization of grit, the paucity of eligible studies using multidimensional grit measurements did not allow us to testify whether the association between growth mindset and grit varied regarding the dimensionality of grit. Since grit research is still developing, more studies are needed to answer the fundamental question of how many facets exist for grit. We believe this work can be fruitful in knowing how individuals strive for their long-term goals and what can cultivate their grit in education.

Practically, our results have important implications for educational practices on how to design related interventions to promote students' grit. The significant association between growth mindset and grit is observed across gender, race/ethnicity, SES, and grade level, and students from both collectivistic and individualistic cultural backgrounds can benefit from growth mindset. Indeed, several growth mindset interventions have been developed to facilitate students' growth mindset (Bedford, 2017; Debacker et al., 2018; Miu & Yeager, 2015), such as the "saying-is-believing" exercise (Aronson, Fried, & Good, 2002), and computer-based learning intervention (Yeager et al., 2019), trained students to adopt and/or develop growth mindset belief and implement

this belief in life, which can further promote student academic achievement. Additionally, our findings point to the need to attend to certain aspects of such interventions by considering what part of grit is intended to develop and the audience's sociocultural backgrounds. We propose that, in order to optimize the effectiveness of interventions on grit, future growth mindset interventions should pay more attention to the collectivist context when promoting growth mindset interventions to increase students' grit levels. Importantly, the present work indicates that the association between growth mindset and overall grit is detectable in primary school students. This suggests that growth mindset can be a good target to enhance students' grit and can start at an early age. For example, in the growth mindset intervention, educators can provide a script for teachers emphasizing the focus on the growth mindset element, such as process praise and Acknowledge mistakes and failures as a chance to learn and grow, together with the embracing of challenge (Donohoe, Topping, & Hannah, 2012; Savvides & Bond, 2021). In addition, the roles of educational psychologists and educational-psychological service counselors are important in supporting teacher training and helping in the design of age-tailored interventions since they can provide professional guidance on developmental theory at school age. Through this collaboration, we can maximize the effectiveness of the implementation of growth mindset interventions for the children population.

10. Limitations and future directions

The current findings should be interpreted with caution. First, nearly 61.54 % of correlations contained small sample sizes (smaller than 300), which might compromise the data quality. Second, 40 eligible studies were conducted in Western countries, wherein 28 studies involved American samples. Given that cultural impact and social norms often differ across countries, future research is recommended to be conducted in other underrepresented countries. Third, only 5 studies used experimental designs and two of them showed non-significant results. The causal effect of growth mindset on grit remains unclear. More controlled studies (e.g., randomized controlled trials) are thus recommended to identify the potential causal relationship between growth mindset and grit. Further, our results only supported several moderators in explaining the variation of the association between growth mindset and grit. More studies in identifying other potential moderators, such as mental health (Lam & Zhou, 2020) and commitment (Tang et al., 2019), in revealing the underlying variables that modified the strength of the association between growth mindset and grit are warranted. Fifth, our findings were subject to some publication bias which may limit some of the validity of our meta-analytic findings. The consideration of using pre-registration and Registered Reports (RR) for future studies, publishing all high-quality studies regardless of their significant or non-significant findings, and making the research data open are highly recommended (Chambers, Feredoes, Muthukumaraswamy, & Etchells, 2014; Song, Hooper, & Loke, 2013). Sixth, in this meta-analysis, SES was determined by HDI at a country level. We recognize the potential limitation of this operationalization of SES in that the HDI only represents some aspects of SES. Future studies that examine growth mindset and grit may purport to include other subjective or objective levels of SES (such as individual-level, peer-level, or neighborhood-level), or other aspects of SES that the HDI has not captured. Seventh, due to the insufficient eligible studies investigating the link between subject-specific growth mindset and grit, this study failed to answer whether the link between growth mindset and grit/its facets can vary between more subject-specific domains of growth mindset. Future research may consider investigating the effects of both domain-general and subject-specific growth mindsets on students' grit to enrich our understanding of the growth mindset-grit relations from different perspectives.

11. Conclusion

Despite the above limitations, to our knowledge, this study is the first meta-analysis to synthesize the evidence to date about the association between growth mindset and grit among K-12 and higher education students. A recent study has documented that nearly 65 % of the world's school-age children will live in low- or lower-middle-income countries by 2030, while young people may have more difficulty facing obstacles and challenges to upward economic and social mobility (Dweck & Yeager, 2021). To date, there is still a debate about whether fostering growth mindset can be a desirable approach to close the achievement gap or even improve education systems. However, one of the most remarkable patterns that emerged from this study is the broad association between growth mindset and grit. Our findings suggest that growth mindset plays a positive role in developing students' grit across gender, race/ethnicity, SES, and grade level. That is, at least, growth mindset can be a tool to develop grit among student samples and help them pursue what they truly want in life. As researchers continue to study and emphasize grit in education in the 21st century, more experimental studies and longitudinal studies are expected. This also opens the door for further meta-analyses with a specific focus on the effectiveness of growth mindset intervention on students' grit development. By doing so, we could be better prepared to help students be grittier, thereby greatly promoting their future success.

CRediT authorship contribution statement

Kelly Ka Lai Lam: Writing – original draft, Visualization, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Mingming Zhou:** Writing – review & editing, Supervision, Formal analysis, Conceptualization.

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Declaration of competing interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi. org/10.1016/j.actpsy.2025.104872.

Data availability

The data that support the findings of this study are available from the corresponding author upon request.

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