Gritty Measures for Gritty Times: Evaluation of the Grit Scale

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Dedication

This dissertation is dedicated to my mentor, friend, big sister, confidant, proof-reader, and cheerleader, Judy Scearce. Judy got me my first teaching job and was my first boss. She was truly an amazing teacher and person. She always told me I was the smartest person she knew – I would tell her that she needed more friends. Judy, you are greatly missed and will be forever in my heart.

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General Abstract

Background: Grit has been defined as passion and perseverance for long term goals. It is presented as a trait which measures success in certain situations such as retention at West Point, placement in the final round at the National Spelling Bee, and Ivy League GPA. The theory of grit is rooted in personality theory and is closely related to the construct of conscientiousness (Duckworth et al., 2007). Grit theory argues that grit is independent from IQ and essential to high achievement. However, the reliability of the current grit scale has been brought into question in several articles (e.g., Crede, Tynan, & Harms, 2017). These studies have questioned the structure of the grit scale as a hierarchal two-factor model and the degree to which it overlaps with the personality trait of conscientiousness. Many studies reporting on grit's overall relationship to academic success have had mixed results. **Purpose:** In this multiple manuscript dissertation, the first study aims to (1) examine the latent factor structures of the original (Grit-O) 12-item and short (Grit-S) 8-item grit scales, (2) determine whether a new short grit scale based on a different modification of Grit-O and the conceptual definitions of the grit factors creates a better measure than the existing one, (3) analyze the correlations between grit questions and conscientiousness (from BFI), and (4) investigate the relationship between grit and feelings of success in calculus. The second study then examines (1) whether a more generally worded single-factor 4-item scale for grit is reliable, (2) whether this new general grit scale predicts success in a calculus course, and (3) whether the general grit scale is generalizable across gender and ethnicity. **Methods:** The purpose of the first article is to test the validity of the Grit-O and Grit-S scales developed by Duckworth and colleagues (2007, 2009) using confirmatory factor analysis. It also examines the

correlations of the constructs of various grit scales with the personality measure of conscientiousness. This study also presents and validates a new "general grit" scale based on Grit-O and Grit-S, which are conceptually targeted toward the constructs of consistency of interest and perseverance of effort in an academic setting. The second article focuses on the development and validation of general grit items using exploratory and confirmatory factor analysis. Using structural equation modeling, the study tests whether grit predicts student success in calculus. These scales are examined across different genders and races by using Mplus to test for group invariance in the factor structure. **Results:** The results of the first paper show that alternate models for Grit-O and Grit-S fit better than the current ones in the literature (Grit-O: $\chi^2 = 304.882, df = 53, CFI = .828$, Grit-S: $\chi^2 = 65.749, df = 19, CFI = .941$, alternative models: $\chi^2 = 115.556, df = 42, CFI = .950$, $\chi^2 = 34.540, df = 19, CFI = .979$, and $\chi^2 = 2.534, df = 8, CFI = .987$). New questions representing the facets of the Grit-O scale showed good model fit on their own in a two-factor correlated model and had lower correlations with conscientiousness than Grit-O. Different models with grit items and students' perceived feelings of academic success in their calculus class had inconsistent results. Paper 2 created a single factor grit scale, general grit, in order to overcome the inconsistencies in reporting of grit scores. The general grit scale was first tested with EFA and confirmed with CFA. Next, general grit and the new questions from paper 1 were tested with final exam score as an outcome variable. General grit showed good prediction of final exam grade and mediated effects of consistency of interest and perseverance of effort in the model. Last, the structures were tested across gender and ethnicity, and invariance for the structures was confirmed. **Conclusion**: Both papers have

shown that better items can be created to measure grit in an academic setting. Verification of all scales showed good fit and ability to predict academic success. Current calls to abandon grit as a construct may be premature now that measurement issues have been overcome.

Keywords: grit, attitude, personality, persistence, academic success, STEM

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Chapter I.
Overview of Dissertation

This dissertation consists of two manuscripts focused on the construct of grit. The first manuscript analyzes the selection for questions and design of the original 12-item grit scale and the 8-item short grit scale (Duckworth, Peterson, Matthews & Kelly, 2007; Duckworth & Quinn, 2009) while the second manuscript examines the creation of an alternative single-factor 4-item general grit scale and its ability to predict academic performance in a calculus class. Grit is chosen as the focus of these manuscripts because it has been presented in the literature as a personality trait that is highly predictive of undergraduate college student success and performance (Credé, Tynan, and Harms, 2017).

Grit is defined as "perseverance and passion for long term goals" (Duckworth, Peterson, Matthews & Kelly, 2007). Talk of grit and how it can help children be better students is on television, YouTube, podcasts, and in TED talks. Some schools and online educational programs even now teach grit to students (Bashant, 2014; KIPP, 2020). A problem with teaching grit would arise if grit is considered a personality trait as opposed to an attitude because personality traits are assumed to be mostly stable over time and are not learned (Costa, Yang, & McCrae, 1998).

Despite all of the media coverage on grit, the measurement instrument for this trait has produced mixed results when it is used to determine if grit predicts or even correlates with academic success among undergraduate college students. The current grit measurements (Grit-O and Grit-S) are conceptualized as two-factor hierarchal structures but the authors of these scales recommend reporting a single overall score (Duckworth et al., 2007; Duckworth & Quinn, 2009).

In order to investigate this trait and its measurements further, a survey was sent out to all undergraduate students in calculus II and III at the University of Houston. This survey consisted of questions from the Big-5 Inventory conscientiousness scale, the original grit scale, new questions written by the first author of the present study which are theorized to tap into the separate facets of grit (consistency of interest and perseverance of effort) as well as overall general grit, questions on how the student feels about their performance in their class, and demographic questions (which included self-reported GPA). Also gathered were instructor reported grades from the class they were enrolled in and attendance. The survey had 826 responses.

Paper 1 discusses the concept of grit, how it is measured, why it should be studied, and what the criticisms of grit are in the literature. Using the results of the survey from undergraduate students in calculus II, confirmatory factor analysis was used to examine the structure of the grit scales and to test new models and new items. Correlations between answers to items on grit and conscientiousness were examined. Lastly, the grit scales were analyzed with the latent variable representing how students felt about their performance in their calculus class.

Results of paper 1 revealed that the posited hierarchal structure of both Grit-O and Grit-S is invalid. For the Grit-O, the bifactor model had the best fit and for Grit-S, the two-factor correlated model was best. Two alternate versions of Grit-S were shown to have even better model fit. It was also shown that many of the correlations of Grit-O items and conscientiousness items were higher than the correlations of the Grit-O items within their own common factors. Lastly, it was shown that the relationship between grit items and feelings of academic success are not consistent across different models.

The second paper examines how grit "scores" are reported across the literature. It was found that there is not a consistent way to use the measurement scale in research. Although Duckworth and colleagues (2007, 2009) state that grit is a higher order construct with two facets, their own research uses an average of all responses. Other papers use an average of all responses for the score while some use averages from each of the two facets of grit or structural equation modeling. This inconsistency of how grit is calculated and used in predicting outcomes has led to mixed results in the research. Paper 2 discusses creation of a general grit scale to measure overall grit and how it can be used in the prediction of academic success. The new general grit scale is examined with exploratory factor analysis using half of the respondents and then confirmed with confirmatory factor analysis using the other half. The general grit score is also used in structural models to determine if grit is a predictor of final exam grade in calculus.

The results of paper 2 showed that the new general grit items have a good fit alone as a single-factor model or in other models which included the new consistency of interest and perseverance of effort items from paper 1. Also shown was that general grit alone was a good predictor for final exam grade and that general grit acted as a full mediator in a model which included consistency of interest and perseverance of effort facets on final exam grade.

Both papers focus on grit – as a personality trait as well as how it is measured and reported. It will be determined if grit can be used in prediction of academic success, and if so, what is the best measurement model for grit. Examining non-cognitive traits such as grit can help educators determine what makes some students successful while others not when holding cognitive factors such as IQ constant.

Chapter II.

Research Questions and Methodology

This two-manuscript dissertation addresses the factorial structure of the 12-item original (Grit-O) and 8-item short (Grit-S) grit scales published by Duckworth and colleagues (2007, 2009). These manuscripts focus on the structure of the current models and what improvements can be made to better measure the construct of grit. Current and new measures are tested with confirmatory factor analysis and structural equations. Relationships with outcome variables related to academic success are also examined in both papers using structural equation modeling. Both studies use responses from a survey given to calculus II and calculus III undergraduate students in the fall semester of 2020.

The first manuscript aims to (1) examine the latent factor structures of the Grit-O and the Grit-S scales, (2) determine if a new short grit scale based on a different modification of Grit-O or the conceptual definitions of the grit factors creates a better model than the existing one, (3) analyze the correlations between the grit questions and the conscientiousness scale (from BFI), and (4) investigate the relationship between grit and feelings of success in calculus.

Using the responses from the calculus II undergraduate students in the study, paper 1 uses confirmatory factor analysis (CFA) to evaluate different models for Grit-O and Grit-S. New questions created by definitions of the two factors of grit, consistency of interest and perseverance of effort are also tested with CFA. Results are given for single-factor, two-factor correlated, and bifactor models. Grit-O items and new grit questions are also compared with items from the BFI conscientiousness scale using correlations.

Lastly, models with the grit questions and a latent variable made up of students' feelings about their academic success in the course are run.

Manuscript 2 examined (1) whether a better scale for grit can be created, (2) whether this new scale can predict success in a calculus course, and (3) whether grit is generalizable across gender and ethnicity. The new scale which was created was a "general grit scale" which is a single-factor 4-item scale focused on overlapping definitions of the two original facets of the Grit-O scale.

Exploratory factor analysis (EFA) was run with the general grit items and the new consistency of interest and perseverance of effort questions from paper 1. Confirmatory factor analysis confirmed the results of the EFA. Next, models with general grit, consistency of interest and perseverance of effort were run against the outcome variable of final exam grade in calculus. Finally, multi-group CFA was run to see if the different structures used in paper 2 were invariant across gender and ethnicity.

Both manuscripts focused on the construct of grit and how it is measured. The papers address several issues reported about the Grit-O and Grit-S scales in the literature such as the proposed hierarchal structure, the distinction of grit from conscientiousness, relation of grit with performance, and any group differences in the measure (Credé, Tynan, and Harms, 2017).

Chapter III.
Manuscript 1

The Structure of the Grit Scale: Examining the fit of the grit-o, grit-s, and new definition based grit scales

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Abstract

Non-cognitive traits have been studied for decades as potential predictors of academic success. Although researchers have found correlations with some personality traits and academic success, recently there has been an emphasis on a new trait: grit. Grit has been defined as passion and perseverance for long term goals and is presented as a trait which measures success in certain situations. Recent studies have questioned the factorial structure of the grit scale as a two-factor model or even a hierarchal model. The purpose of this study is to test the factorial structure of the Grit-O and Grit-S scales developed by Duckworth et al. (2007, 2009) and to compare the constructs of these grit scales with the personality measure of conscientiousness. The study will also present and test a new grit scale created by using definitions which are conceptually targeted toward the constructs of consistency of interest and perseverance of effort in an academic setting. Findings reveal the structures of the Grit-O and Grit-S scales as a hierarchal two-factor model are not justified and that other models, one with a variation of the original items and one with the newly written items have a better fit. Original grit questions were found to correlate higher with conscientiousness than the new questions. There were mixed results when using the different scales to predict students' feelings of success in their calculus course.

Keywords: grit, attitude, personality, persistence, academic success, STEM

Introduction

Introducing the Construct of Grit

Academic performance depends on both cognitive factors, such as intelligence, and non-cognitive factors, such as motivation. Researchers have been interested in non-cognitive traits to predict academic performance for some time now (Muenks, Wigfield, Yang, and O'Neal, 2017; Rimfeld et al., 2016; Chamorro-Premuzic and Furnham, 2003). One example for why non-cognitive traits should be studied is demonstrated in research showing that the correlation between academic performance and intelligence measures declines over time (Ackerman, Chamorro-Premuzic, & Furnham, 2011). Currently, universities base selection criteria on students' past academic performances (e.g., high school GPA, SAT, ACT). Even though a student may have good cognitive indicators (i.e., past academic performance) for success, many students are still unsuccessful in higher education (Ackerman, Kanfer, & Beier, 2013). This leaves non-cognitive traits as potential predictors of what differentiates the successful student from the unsuccessful one.

One non-cognitive trait, grit, has gained popularity recently as a predictor of success and performance. Grit has gained its momentum mostly due to the work of Angela Duckworth (Duckworth, 2016; Perkins-Gough, 2013). Early research on grit investigated why some individuals accomplish more than others of equal intelligence. Interviews with high-achieving individuals such as lawyers and business people indicated that these individuals had the common trait of setting extremely long-term goals for themselves and reaching those goals despite any setbacks or lack of positive feedback. The trait was dubbed "grit" and defined as "perseverance and passion for long-term

goals" while additional positive indicators involve "working strenuously toward challenges, maintaining effort and interest over years despite failure, adversity, and plateaus in progress" (Duckworth et al., 2007, p.1087).

Development of the Original and Short Grit Scales

The original grit scale was developed by first examining previous measures of personality traits. Studies on the Big-5 personality traits (Benet-Martínez & John, 1998) and achievement did not show very large correlations with success measures (Peterson, Casillas, & Robbins, 2006). However, of the Big-5 personality traits, conscientiousness had the highest correlation with academic success, ranging from approximately $r = .12$ to $r = .36$ (O'Connor & Paunonen, 2007). Duckworth et al. (2007) recognized that the achievement aspects of conscientiousness overlap with their definition of grit while the ability aspects of conscientiousness are distinct from grit. In the absence of an existing measure for grit, Duckworth et al. (2007) set out to create such a scale by starting with 27 questions which focused on an individual's ability to "sustain effort in the face of adversity." After eliminating some questions based on item-total correlations, reliability, and other considerations, exploratory factor analysis was performed to yield a 12-question grit scale, which is referred to as the original grit scale, or Grit-O. The Grit-O consists of two latent factors, consistency of interest (CI) and perseverance of effort (PE). Duckworth et al. (2007) used total scores from their 12-item scale as their measure of grit, although they claim grit is a two-factor structure.

In an effort to improve the Grit-O, Duckworth and Quinn (2009) initiated an analysis to identify a more efficient measure of grit, the short grit scale (Grit-S). Using item-level correlations with the outcomes from studies done for the original grit scale,

they ranked the items and kept four questions in each subscale (CI and PE) with the best rankings. Many papers use this scale to examine the "grittiness" of subjects with different outcomes measuring success from academic achievement (Rimfeld, Kovas, Dale, & Plomin, 2016) to exercise behavior (Reed, 2014).

Reasons for Studying Grit

Non-cognitive traits, such as grit, are important in helping researchers determine why some students succeed while others fail when general intelligence is equivalent. Standardized assessments such as SAT, ACT, and departmentalized placement exams are used to determine if students will have the cognitive ability to be successful in certain core classes, such as calculus. Despite the use of these assessments to place students into core mathematics classes, the failure rate in these classes is still above 25%, which in turn creates a nationwide crisis in STEM education success (Chen, 2015; Daempfle, 2003; Xue & Larson, 2015). Because calculus is a prerequisite for almost all STEM degrees, student achievement in this course is a primary focus of many educators and policy makers. Several reports (Bressoud, Mesa, & Rasmussen, 2015; Popham, 1999; Rasmussen et al., 2016) imply that there is more to student success in calculus than prior rote knowledge on the subject and that placement exams are not the sole indicator for success in mathematics.

Research into student achievement has been focusing more on personalities rather than intelligence alone. Ackerman et al. (2011) state that non-cognitive traits can influence how much time and effort students may put into acquiring the domain knowledge needed to perform well in a class. Traits such as grit may be able to tell us if students will procrastinate when given independent study assignments. Grit and self-

efficacy have been shown to be positively associated with motivation, time management, and study strategies (Wolters & Hussain, 2015). Even so, if students have the attitude and goals to do well and complete higher education, they may still exhibit achievement below that of their potential unless they have the skills to help them remain on track to accomplish said goals (Dweck, Walton, & Cohen, 2014).

In Goyer, Walton, and Yeager's (2020) proposed theory of goal channels, goal pursuit and attainment within the higher education setting is dependent on the *channel strength* provided by the institution attended. They theorize that colleges and universities that have clear attainment criteria and high expectations of their students in achieving these criteria as well as available structural goal supports for their students have higher channel strength towards degree completion goals. In their longitudinal study of over 2000 students and their pursuit of higher education goals, it was found that grit had a small but significant positive association with on track progress and degree attainment within four years for students within schools that had higher channel strength (Goyer, Walton, and Yeager, 2020).

Critiques of the Grit-O and Grit-S Scales

In both the Grit-O and Grit-S scales, grit is examined as two separate constructs but reported as a single score (Duckworth, Peterson, Matthews & Kelly, 2007; Duckworth & Quinn, 2009). Duckworth and colleagues state that they examined a higher-order factor structure with grit as the second-order factor and consistency of interest (CI) and perseverance of effort (PE) as the two first-order factors. They concluded that this model was the best fit using confirmatory factor analysis (CFA). However, the higher-order factor structure of grit was not confirmed in a meta-analysis

(Crede, Tynan, & Harms, 2017). More importantly, according to Kline (2015, p.319), second order CFA models must have at least three first-order factors to be just identified or overidentified in order for the second order paths or error terms be estimated. It is critical to note here that CFA analysis would not differentiate between a model with two correlated factors and a higher-order model with two first-order factors.

An alternative model that would satisfy Duckworth et al.'s claim that grit was a two-factor scale with an overall single grit score may be a nested (or bifactor) model. In this model, there is a general factor which is included and directly affects the items but is orthogonal to the other latent factors (Kline, 2015). Muenks et al. (2017) tested the bifactor grit model on both high school and college students and found that this model fit best for the sample of college students but the model did not converge for the sample of high school students.

Credé, Tynan, and Harms (2017) have also pointed out that it is important to investigate other personality traits similar to grit, such as conscientiousness. Their meta-analysis states that there is "almost no empirical investigation of the discriminant validity of grit from these other constructs." Duckworth et al. (2007) state that there is an "overlap" with grit and the achievement aspects of conscientiousness but they are different constructs due to the definition of grit. MacCann & Roberts (2010) claim "substantial overlap" of conscientiousness with grit and even suggest that grit may be a facet of conscientiousness.

Research Aims

This study aims to (1) examine the factorial structure of the Grit-O and the Grit-S scales, (2) determine if a new short grit scale based on a different modification of Grit-O

or the conceptual definitions of the grit factors creates a better model than the existing one, (3) analyze the correlations between the grit questions and the conscientiousness scale (from BFI) to test discriminant validity of the concepts, and (4) investigate the relationship between grit and feelings of success in calculus. Using confirmatory factor analysis, the current latent structures of grit was examined. Also, Peterson (2000) states that good survey questions should be relevant, specific and unambiguous, so by analyzing the definitions of grit and its factors, a new short grit scale was created and compared with the existing Grit-S scale. Previous studies have found high (i.e. $\rho > .80$) correlations between the grit scale and conscientiousness (Credé, Tynan, & Harms, 2017; Meriac, Slifka, & LaBat, 2015; Reed, Pritschet, & Cutton, 2013). However, those studies did not examine correlations among individual items or the separate factors of grit. Based on these findings, it was predicted that a significant positive correlation exists between the items in the conscientiousness scale and those on the Grit-O scale. Lastly, students were given three questions on how they feel about their performance in their calculus class and a latent variable called "feelings" was constructed based on the answers to these three items. Using structural equation models (SEM), the different grit models were compared to see which has the best fit with the prediction of students' feelings of academic success.

Method

Participants

Participants were 495 undergraduate college students who enrolled in an integral calculus course at a large southern urban university in the United States. The sample included 281(56.8%) males, 206 (41.6%) females, and 5 (1%) other gender. The average age of the participants was 21.14 (*sd* =2.30). The sample was ethnically diverse, which

included Asian (n = 155, 31.3%), Black/African American (n = 35, 7.1%), Hispanic/Latino (n = 163, 32.9%), White/ Caucasian (n = 107, 21.6%), and other races (n = 35, 7.1%) The majority of students were in their sophomore year (n = 231, 46.7%) while the rest were freshmen (n = 134, 27.1%), juniors (n = 100, 20.2%), seniors (n = 22, 4.4%), and post-baccalaureate (n = 5,1.0 %). Of those surveyed, 28.9% identified as first-generation college students. The majority (n=255, 51.5%) of students were majoring in the College of Natural Science and Mathematics and the second largest group of students had majors in engineering or technology (n=172, 34.8%). When asked if they had transferred from another college, 333 (67.3%) said "no."

Students were emailed a link to an online survey toward the end of the fall 2020 semester. Participants were informed in the email and again in the survey about the aims of the research and voluntary nature of participating. All participants indicated if they gave informed consent for taking part in the survey before starting the survey. Participants completed the survey outside of class. This study was approved by the university's Institutional Review Board. Students were given one week to complete the survey and received one bonus point on their final exam grade if they began the survey.

Measures

The Original (and Short) Grit Scale

The original grit scale (Grit-O) was developed by Angela Duckworth and colleagues

(Duckworth et al., 2007). The scale captures behaviors such as the ability to sustain effort in the face of obstacles (e.g. "I have achieved a goal that took years of work") and the consistency of interest in goals (e.g. "My interests change from year to year"). The

questionnaire contains 12 items on a five-point Likert scale ranging from 1 (*not like me at all*) to 5 (*very much like me*) with six items loading on each factor. Because all of the CI items were negatively written, these items were reverse-scored so that a higher score reflected a higher level of consistency of interest. According to Duckworth et al., the Grit-O scale had overall internal consistency of $\alpha = .85$ with the factors of CI and PE separately at $\alpha = .84$ and $\alpha = .78$ respectively (2007).

The short grit scale (Grit-S) used a subset of questions from the Grit-O scale. Two items were removed from each factor of the original grit questionnaire by Duckworth and Quinn (2009) based on correlations with outcome variables from their previous studies. The resulting 8 question form used the same five-point Likert scale as the Grit-O. Scores for both scales were calculated by averaging all responses. The internal consistency as reported by Duckworth and Quinn (2009) was $\alpha = .82$ for the whole Grit-S, $\alpha = .70$ for the PE factor, and $\alpha = .77$ for the CI factor. It was also reported that the Grit-S and Grit-O scales showed 1.3 and 2.0 (respectively) percent variance explained in educational attainment, 8.9 and 7.9 (respectively) percent variance in explained for higher grade point averages, 7.8 and 7.9 (respectively) percent variance explained for completion of training for West Point students, and 2.5 percent variance for each of the two scales explained for reaching final round of the National Spelling Bee.

New Grit Questions

When creating new grit questions, synonyms for grit, as well as definitions and synonyms for the two constructs of grit, consistency of interest (CI) and perseverance of effort (PE) were reviewed from dictionaries and thesauruses. Based on these definitions, three questions for each of the factors CI and PE were added. For these six new

questions, given in Table 1, the internal reliability for all six questions had Cronbach's alpha of $.82$ and individually had $\alpha = .77$ and $\alpha = .76$ for CI and PE respectively. More details on the development of this new scale is given below.

Conscientiousness Questions from The Big Five Inventory (BFI; Benet-Martínez & John, 1998)

The conscientiousness questions used in this survey included 9 items on a five-point Likert scale ranging from 1 (*disagree strongly*) to 5 (*agree strongly*) answering "How am I in general? Here are a number of characteristics that may or may not apply to you (e.g. 'Is a reliable worker'). Please select the statement that indicates the extent to which you agree or disagree with that statement." The questions came from the Big Five Inventory Questionnaire and had an internal consistency of $\alpha = .81$ (Benet-Martínez & John, 1998). Some of the questions were reverse coded so that a higher score indicated a higher level of total conscientiousness. For this study, the average of all of the conscientiousness items was used as well as scores from individual questions.

Other Questions

In order to determine how the students felt about their performance in their calculus class, questions were added to the survey to assess the extent of their understanding and achievement within the course created by the authors of this paper. There were three questions on a seven-point Likert scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). A sample question is "I will likely perform better than most students in this class." The scale reliability statistics for these three questions was $\alpha = .88$. It was also confirmed using exploratory factor analysis that these three items

loaded on a single factor with loadings all above .40 as suggested by Pett, Lackey & Sullivan (2003).

Development of New Grit Questions

In order to understand grit and its factors in detail, an extensive search of the various definitions and synonyms of grit, perseverance of effort, and consistency of interest was conducted. Of the definitions found in the research, a few converged on the concept of grit. Shechtman et al. (2013) define grit as "perseverance to accomplish long-term or higher-order goals in the face of challenges and setbacks, engaging students' psychological resources, such as their academic mindsets, effortful control, and strategies and tactics." This definition was very specific as to how the goals are achieved. Another clear definition of grit found in the research was "to sustain a focused effort to achieve success in a task, regardless of the challenges that present themselves, and the ability to overcome setbacks (Sturman & Zappala-Piemme, 2017)."

This concept analysis led to a new definition of grit and the creation of new grit questions aimed at the constructs of consistency of interest and perseverance of effort. Podsakoff, MacKenzie, & Podsakoff (2016) contend that it is just as important to understand the hypothetical constructs that make up the overall construct and that an item's membership in a category should be determined by the attributes it shares with other items in the same category. In writing these questions, the construct definitions for each factor provided guidance.

Grit is defined as "perseverance and passion for long term goals" by Duckworth et al. (2007). The passion part of this definition is represented by the consistency of interest (CI) construct. Passion as a personality trait represents an individual's drive to

maintain an intense positive emotional orientation towards any task or goal they choose to undertake from start to finish. For the new CI construct, three items were written to include statements regarding positive interest level maintenance toward goal completion.

For the perseverance part of the grit definition, the focus on this personality trait was to represent an individual's drive to pursue any task or goal they undertake to completion even when obstacles may be present. Three items were written for the new perseverance of effort (PE) construct which captured this meaning of perseverance – to continue towards a goal despite challenges. The new questions are given in Table 1.

Table 1.
New Grit Questions

Factor and New Item	Corrected Item-Total r	Cronbach's Alpha if Item Deleted
Consistency of Interest Items:		
My level of interest towards a goal tends to stay the same even over long periods of time. (CI7)	.612	.776
Even after working on a project for years, I still maintain the same amount of interest in it. (CI8)	.631	.772
My interest level for goals I set for myself doesn't change much, even over many years. (CI9)	507	.800
Perseverance of Effort Items:		
Despite experiencing setbacks, I keep trying until my goal is reached. (PE7)	.640	.772
When faced with a difficult challenge, I persist until I reach a solution. (PE8)	.527	.795
I'm the type of person who perseveres even under difficult conditions (such as learning disabilities, sickness, or other obstacles). (PE9)	.546	.791

Statistical Analysis

Before performing CFA on the items, missing data patterns and statistical assumptions were analyzed by using IBM SPSS 26.0 (2019). The amount of missing data per variable ranged from 0.2% to 1.6%. Missing data was list-wise deleted. The variables showed an acceptable range for asymmetry and kurtosis (George & Mallery, 2010), with skewness ranging from −1.079 to 0.165 and kurtosis ranging from −0.942 to 0.756. SPSS was also used to examine correlations among some of the items. Next, using

Mplus (Muthén & Muthén, 2018) version 8, CFA was performed on several different models of grit using single-factor, two-factor correlated and a bifactor model, this included the structures proposed by Duckworth and colleagues for both Grit-O and Grit-S. Several model fit indices were evaluated to assess the model data fit, including model chi-square statistic, comparative fit index (CFI), and Root Mean Square Error of Approximation (RMSEA; Steiger, 1990). Fit of the model was determined using recommendations of Hu and Bentler (1999) who state a CFI value of .95 or higher and RMSEA of .06 or lower indicates good model fit.

The Grit-O and Grit-S scales were examined first using the items proposed by Duckworth and colleagues. In each of the CFA analyses, the first item for each construct was set at a loading of one. The first step in the CFA on these items was to examine single factor models. The models for CI alone and PE alone for those questions from the Grit-O scale were examined separately as well as together on a single factor. This process was repeated for the questions on the Grit-S scale. Next, the two-factor correlated model for both Grit-O and Grit-S was investigated. Lastly, a bifactor model for each of Grit-O and Grit-S was tested. See Figure 1 for a diagram of a bifactor model.

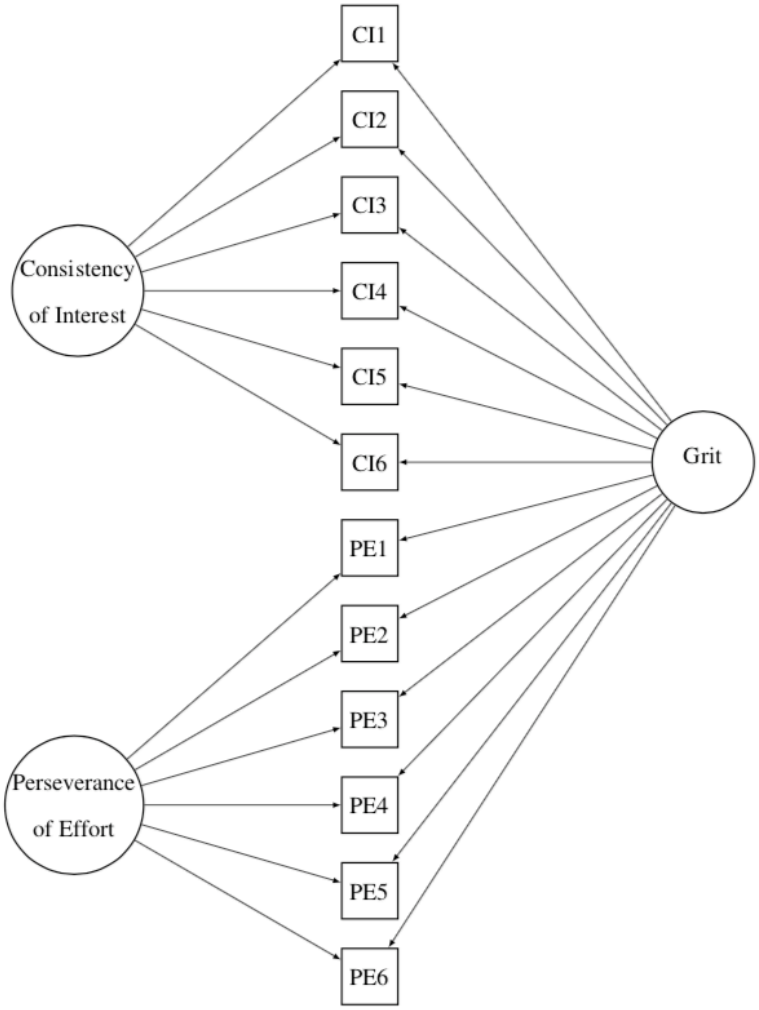
The new grit questions were tested in a similar fashion to the Grit-O and Grit-S questions. Single factor models were run with the new CI and PE questions. A two-factor correlated model with the new CI and PE was investigated as well as a bifactor model.

Correlations among questions from Grit-O and conscientiousness were analyzed using SPSS. Analysis was done by examining the correlations among and between these items. Overall correlations for each facet with conscientiousness were also examined.

This process was then repeated with the conscientiousness questions and the new grit items.

Finally, the different scales were tested with an outcome variable. The outcome variable for this data set was a latent variable made up of three questions loaded on a single factor indicating how the students felt about their performance in their calculus class at the time of the survey. Mplus was used to explore the relationship between the different scales and feelings on performance.

Figure 1.
Bifactor Model for Grit-O



Results

Research Aim 1: Confirmatory Factor Analysis

Confirmatory factor analysis on the Grit-O and Grit-S was tested in four ways: a) a single-factor model, b) separate CI and PE factors, c) a two-factor correlated model, and d) a bifactor model.

Grit-O Scale

Confirmatory factor analysis began with investigating the fit of the questions on the Grit-O scale. The first model involved loading all twelve questions on a single factor. This single factor model had a poor fit with $\chi^2(54, N = 495) = 628.353, RMSEA = .147$, (90% CI $= .136 - .157$), and $CFI = .609$. All items except one, "I become interested in new pursuits every few months", had a significant correlation with the factor. Next, the structure of each of the constructs of grit, consistency of interest (CI) and perseverance of effort (PE), was examined individually. Although neither was a good fit, the PE single factor structure had better fit than CI single factor did ($\chi^2(9) = 53.151$ vs. $\chi^2(9) = 87.147$). As Duckworth and colleagues stated, a better model was a two-factor model using CI and PE. In the article for the original grit scale, it was reported that the CFI of this two factor model was .83 and the RMSEA was .11 (Duckworth et al., 2007). Using this paper's data set, similar fit was found, $\chi^2(53, N = 495) = 304.882, RMSEA = .098$, (90% CI $= .087 - .109$), and $CFI = .828$. The two factors in the original paper correlated at $r = .45$, while this data indicated $r = .398$. Because it was stated in the Grit-O paper that total scores were used to measure grit, a bifactor model was investigated. Bifactor models are used when correlated specific constructs make up a more general construct (F. F. Chen, West, & Sousa, 2006). The bifactor model for the

Grit-O had a much better fit than the other models for these items with $\chi^2(42, N = 495) = 115.556, RMSEA = .060$ (90% CI $= .047 - .073$) and $CFI = .950$.

Grit-S Scale

The next models to be examined were the questions from the short grit scale. Duckworth and Quinn (2009) wanted a shorter scale so they deleted two questions from each factor which had the lowest correlations with past outcomes. Using these eight questions, the process used above on the original grit questions was repeated. All items were loaded on a single factor, then individually on their factors, and then finally a two-factor correlated model was run. Results showed the best fit model was the two-factor correlated model with $\chi^2(19, N = 495) = 65.749, RMSEA = .071$ (90% CI $= .052 - .089$) and $CFI = .941$. Interestingly, the CI single factor structure had better fit than PE single factor did ($\chi^2(2) = 3.263,\ CFI = .996$ vs. $\chi^2(2) = 3.644, CFI = .995$). The bifactor model for the Grit-S items was run but did not converge. See Table 2 for a summary of the fit indices from the CFA for Grit-O and Grit-S and Table 3 for standardized factor loadings and correlations.

Table 2.
CFA Fit Indices for Grit-O and Grit-S

Model	Fit Indices			
Name	χ^2	df	RMSEA (90% CI)	CFI
Grit-O:				
Single Factor on Grit-O	628.353	54	.147 (.136, .157)	.609
Single Factor on CI alone	87.147	9	.132 (.109, .159)	.872
Single Factor on PE alone	53.151	9	.100 (.075, .126)	.935
Two Factor on CI with PE	304.882	53	.098 (.087, .109)	.828
Bifactor Model	115.556	42	.060 (.047, .073)	.950
Grit-S:				
Single Factor on Grit-S	171.099	20	.124 (.107, .141)	.810
Single Factor on CI alone	3.263	2	.036 (.000, .103)	.996
Single Factor on PE alone	3.644	2	.041 (.000, .107)	.995
Two Factor CI with PE	65.749	19	.071 (.052, .089)	.941

Table 3.
CFA Factor Loadings and Correlations for Grit-O and Grit-S

Model	Standardized Factor Loadings												Correlations
Name	PE1	PE2	PE3	PE4	PE5	PE6	CI1	CI2	CI3	CI4	CI5	CI6	CI & PE
Grit-O:													
Single Factor on Grit-O	.300***	.677***	.637***	.575***	.541***	.517***	.443***	.475***	.541***	.314***	.493***	.078	
Single Factor on CI alone							.491***	.631***	.534***	.609***	.720***	.462***	
Single Factor on PE alone	.282***	.753***	.545***	.643***	.675***	.622***							
Two Factor on CI with PE	.288***	.762***	.573***	.644***	.652***	.607***	.514***	.641***	.570***	.578***	.718***	.411***	.398***
Bifactor: all on Grit-O	.279***	.522***	.577***	.448***	.294***	.281***	.523***	.478***	.595***	.191**	.523***	-.011	
and on CI & PE	.139**	.499***	.250***	.425***	.685***	.519***	.185**	.403***	.207***	.698***	.493***	.674***	
Grit-S:													
Single Factor on Grit-S	.290***	.571***	.620***	.490***			.532***	.542***	.611***		.583***		
Single Factor on CI alone							.583***	.624***	.627***		.649***		
Single Factor on PE alone	.269***	.823***	.531***	.664***									
Two Factor CI with PE	.291***	.764***	.602***	.655***			.581***	.608***	.649***		.643***		.585***

*** p<.001, ** p<.001, * p<.05

Research Aim 2: New Short Grit Scale

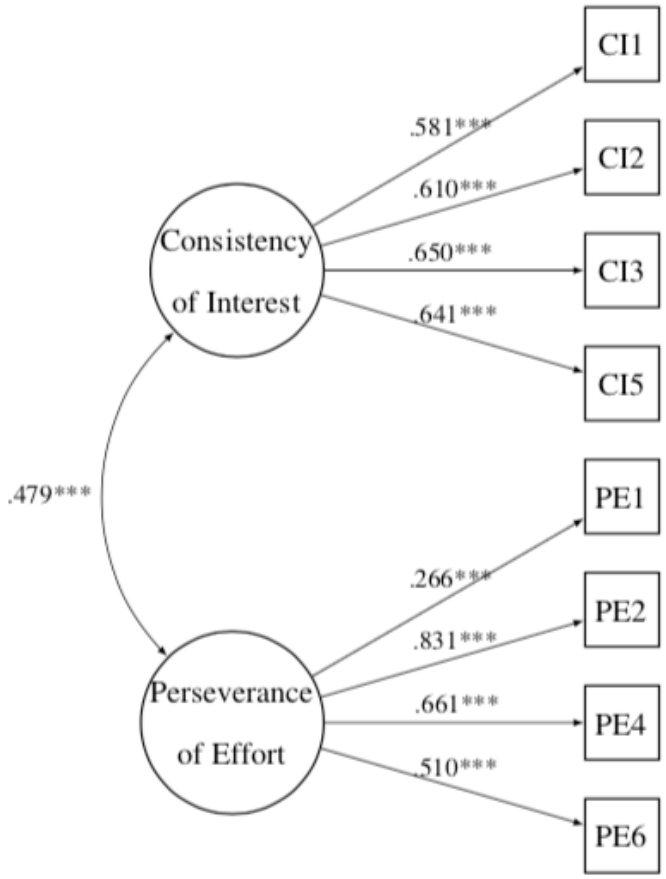
Alternative Grit-S Scale Based on Factor Loadings

To address the second research question of this paper, the two-factor correlated Grit-O was examined in more detail to see if there was a better fitting eight item scale. By running exploratory factor analysis with promax rotation (as suggested by Duckworth et al., 2007), it was confirmed that the items did load on their respective factors. Items with lowest loading from each factor group were dropped one at a time until two were dropped from each group. The dropped questions by this method were PE1 ("setbacks don't discourage me"), PE3 ("I finish whatever I begin"), CI1 ("new ideas and projects sometimes distract me from previous ones"), and CI3 ("I have difficulty maintaining my focus on projects that take more than a few months to complete"). This process did not lead to a better model fit with $\chi^2(19, N = 495) = 141.395, RMSEA = .114$ (90% CI = $.097 - .132$) and $CFI = .873$.

Using the values of the modification indices as suggestions for a lower chi-square value, CI6 ("I become interested in new pursuits every few months") being correlated with CI4 ("my interests change from year to year") and loading on PE would reduce the chi-square value significantly so CI6 was the first item dropped. Next PE5 ("I have overcome setbacks to conquer an important challenge") had a large modification index with PE6 ("I have achieved a goal that took years of work") and cross-loading with CI so PE5 was dropped. The dropping of these two items gave a better fit with $\chi^2(34, N = 495) = 124.880, RMSEA = .073$ (90% CI = $.060 - .088$) and $CFI = .914$. The next step involved dropping CI4 which had suggested correlation with CI5 ("I have been obsessed with a certain idea or project for a short time but later lost interest") and cross-

loading with PE. After dropping CI4, the modification indices suggested only correlation between PE4 ("I am diligent") and PE2 ("I am a hard worker") or cross-loading of PE3 on CI. Because the higher modification index was given for the cross-loading, PE3 was dropped. With the remaining eight items, two-factor CFA was run again and the model showed a very good fit with $\chi^2(19, N = 495) = 34.540, RMSEA = .041$ (90% CI $= .017 - .062$) and $CFI = .979$. A bifactor model was also run but did not converge. Figure 2 contains the standardized factor loadings and correlations for the CFA of the final version of the Alternative Grit-S scale.

Figure 2.
Standardized Factor Loadings and Correlations for Alternative Grit-S

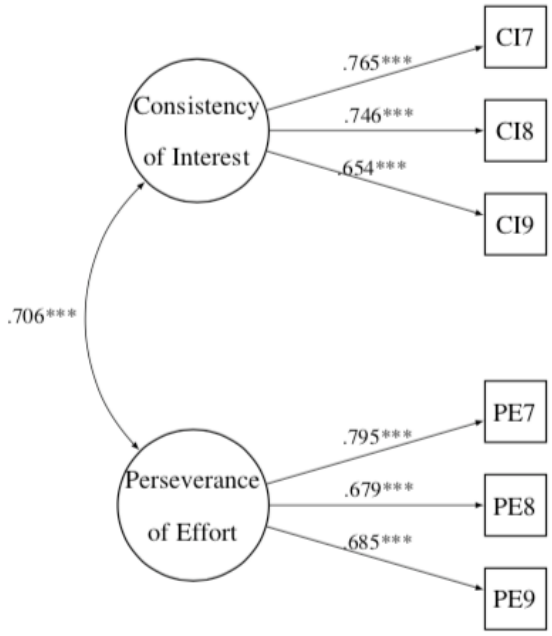


*** p<.001

Alternative Grit-S Scale Based on Definitions of Factors

Using the new CI and PE questions created using definitions discussed above, first exploratory factor analysis was run using a separate data set to ensure that the factor loading for each variable was larger than the error variance for that factor. Next, CFA was run in a similar fashion to the methods used for the Grit-O scale. The first model run had all six items loading on a single factor of grit. This model did not have a good fit with $\chi^2(9, N = 495) = 126.538, RMSEA = .163$ (90% CI $= .138 - .189$) and $CFI = .874$. However, the two-factor correlated model with PE and CI only had a good fit with $\chi^2(8, N = 495) = 20.829, RMSEA = .057$ (90% CI $= .027 - .088$) and $CFI = .986$. The bifactor model for the new CI and PE did not converge. Figure 3 contains the standardized factor loadings and correlations for the CFA of the final version of the Definition Based Grit Scale.

Figure 3.
Standardized Factor Loadings and Correlations for Definition Based Grit Scale



*** $p<.001$

Research Aim 3: Correlations

To address the third research aim of this paper, the discriminant validity of the Grit-O and Grit-S scales was examined using the correlations of grit scale items with conscientious items. With the exception of three items, the correlations between the original grit scale questions and the conscientiousness questions from the BFI were overwhelmingly significant. The question, “setbacks don't discourage me”, which is an item on both the Grit-O and Grit-S scale had insignificant correlations with two of the conscientiousness items, “does a thorough job” and “can be somewhat careless”. The consistency of interest item from the Grit-O scale, “my interests change from year to year” had an insignificant correlation with “is a reliable worker”. Lastly, the question “I become interested in new pursuits every few months”, a consistency of interest item which was only on the Grit-O scale, was insignificant with all conscientiousness items except “is easily distracted.” What was interesting about this item was that it was the only item on the grit scales that had a negative correlation with other items on the grit scale as well as with some items from conscientiousness. The correlation between the Grit-O items and conscientious, on average, was r =.23 while the average correlation that a Grit-O item had with the other Grit-O items was r = .24. None of the individual correlations were higher than r = .45.

When comparing the correlations which the original grit items had with conscientiousness, all of the grit items had at least one correlation with conscientiousness higher than some of the correlations with items in their same factor group. In fact, the CI item “new ideas and projects sometimes distract me from previous ones” had a correlation with conscientiousness item “is easily distracted” higher than all other grit

items. Similarly, the PE item “I finish whatever I begin” correlated higher with three items from the conscientiousness scale than any other grit item. All correlations for the original grit questions and the conscientiousness scale are in Table 4.

Table 4.
Correlations of Grit-O with Conscientiousness

Question (Item)	CI1	CI2	CI3	CI4	CI5	CI6	PE1	PE2	PE3	PE4	PE5	PE6
New ideas and projects sometimes distract me from previous ones. (CI1)	1	.373**	.387**	.192**	.350**	.140**	.178**	.214**	.282**	.194**	.123**	.101*
I often set a goal but later choose to pursue a different one. (CI2)	.373**	1	.365**	.397**	.422**	.248**	.040	.216**	.324**	.172**	.137**	.135**
I have difficulty maintaining my focus on projects that take more than a few months to complete.(CI3)	.387**	.365**	1	.226**	.414**	.150**	.234**	.284**	.327**	.246**	.213**	.200**
My interests change from year to year. (CI4)	.192**	.397**	.226**	1	.453**	.465**	.013	.091*	.179**	.060	.047	.084
I have been obsessed with a certain idea or project for a short time but later lost interest. (CI5)	.350**	.422**	.414**	.453**	1	.331**	.119**	.257**	.353**	.164**	.055	.111*
I become interested in new pursuits every few months. (CI6)	.140**	.248**	.150**	.465**	.331**	1	-.001	-.083	.039	-.127**	-.163**	-.132**
Setbacks don’t discourage me. (PE1)	.178**	.040.	.234**	.013	.119**	-.001	1	.225**	.194**	.140**	.230**	.120**
I am a hard worker. (PE2)	.214**	.216**	.284**	.091*	.257**	-.083	.225**	1	.430**	.550**	.473**	.423**
I finish whatever I begin. (PE3)	.282**	.324**	.327**	.179**	.353**	.039	.194**	.430**	1	.355**	.329**	.335**
I am diligent. (PE4)	.194**	.172**	.246**	.060.	.164**	-.127**	.140**	.550**	.355**	1	.391**	.350**
I have overcome setbacks to conquer an important challenge. (PE5)	.123**	.137**	.213**	.047	.055	-.163**	.230**	.473**	.329**	.391**	1	.545**
I have achieved a goal that took years of work. (PE6)	.101*	.135**	.200**	.084	.111*	-.132**	.120**	.423**	.335**	.350**	.545**	1
Conscientiousness: How I am in general?												
Does a thorough job	.191**	.179**	.189**	.091*	.160**	.074	.068	.282**	.278**	.317**	.240**	.199**
Can be somewhat careless	.331**	.294**	.210**	.198**	.307**	.055	.032	.306**	.314**	.264**	.155**	.175**
Is a reliable worker	.125**	.199**	.180**	.053	.181**	.009	.106*	.384**	.320**	.356**	.318**	.228**
Tends to be disorganized	.269**	.332**	.311**	.101*	.227**	-.005	.104*	.318**	.409**	.302**	.177**	.179**
Tends to be lazy	.271**	.230**	.315**	.133**	.235**	-.027	.109*	.433**	.375**	.330**	.268**	.257**
Perseveres until the task is finished	.172**	.271**	.253**	.155**	.216**	.079	.170**	.347**	.400**	.303**	.371**	.263**
Does things efficiently	.217**	.185**	.230**	.102*	.180**	-.060	.115*	.336**	.333**	.312**	.205**	.284**
Makes plans and follows through with them	.218**	.271**	.262**	.131**	.217**	-.024	.134**	.367**	.446**	.421**	.301**	.288**
Is easily distracted	.400**	.348**	.404**	.226**	.367**	.107*	.092*	.281**	.355**	.217**	.099*	.144**

*p < .05 **p<.01

Next, the correlations between the factors were analyzed. The correlation between PE from Grit-O and conscientiousness was the highest at $r = .812$, while CI from the Grit-O correlated with conscientiousness at $r = .592$ and the correlation between CI and PE was $r = .422$. For the Grit-S factors, PE still had the highest correlation with conscientiousness, $r = .885$. CI from the Grit-S correlated at $r = .684$ with conscientiousness while the correlation between the two Grit-S factors was $r = .615$.

For the new grit questions, correlations among the new CI and PE questions were computed with the nine conscientiousness questions. The correlation between the new grit items and conscientious, on average, was $r = .24$ while the average correlation that a

new grit item had with the other new grit items was *r* = .42. The only item on the new scale which had any correlations higher compared to correlations with other questions on the new grit scale was the CI item "my interest level for goals I set for myself doesn't change much, even over many years." This item did correlate higher with the other CI items in the new scale though. See Table 5 for correlations between the new grit items and conscientiousness.

When examining the correlations of the factors of the new grit scale with conscientiousness, conscientiousness had the lowest correlations with these new grit factors. Conscientiousness had a correlation of *r* = .655 with PE and *r* = .522 with CI. The correlations between the factors of the new grit questions were *r* = .701 for PE with CI.

Table 5.
Correlations of Definition Based Grit Questions with Conscientiousness

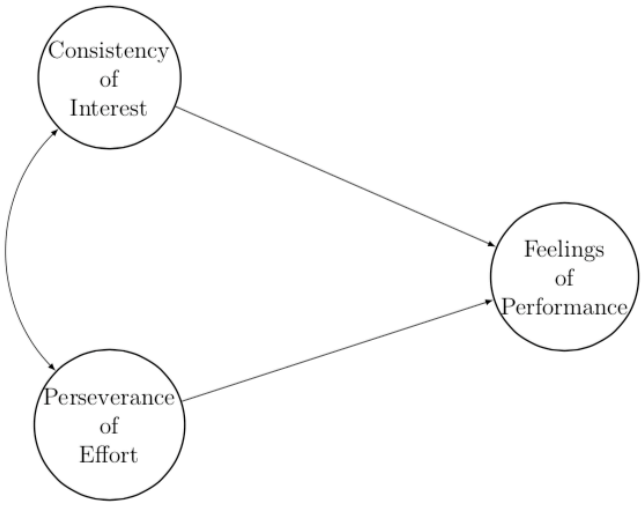
Question (Item)	CI7	CI8	CI9	PE7	PE8	PE9
My level of interest towards a goal tends to stay the same even over long periods of time. (CI7)	1	.552**	.537**	.453**	.337**	.337**
Even after working on a project for years, I still maintain the same amount of interest in it. (CI8)	.552**	1	.482**	.464**	.378**	.398**
My interest level for goals I set for myself doesn't change much, even over many years. (CI9)	.537**	.482**	1	.340**	.220**	.285**
Despite experiencing setbacks, I keep trying until my goal is reached. (PE7)	.453**	.464**	.340**	1	.536**	.530**
When faced with a difficult challenge, I persist until I reach a solution. (PE8)	.337**	.378**	.220**	.536**	1	.497**
I'm the type of person who perseveres even under difficult conditions (such as learning disabilities, sickness, or other obstacles). (PE9)	.337**	.398**	.285**	.530**	.497**	1
Conscientiousness: How I am in general?						
Does a thorough job	.103*	.126**	.03	.236**	.239**	.242**
Can be somewhat careless	.252**	.163**	.121**	.232**	.194**	.242**
Is a reliable worker	.201**	.220**	.141**	.294**	.281**	.303**
tends to be disorganized	.255**	.254**	.168**	.222**	.167**	.287**
tends to be lazy	.282**	.294**	.155**	.311**	.301**	.291**
perseveres untll the task is finished	.202**	.265**	.213**	.385**	.340**	.364**
does things efficiently	.266**	.250**	.147**	.199**	.259**	.251**
Makes plans and follows through with them	.288**	.358**	.221**	.336**	.315**	.348**
Is easily distracted	.284**	.249**	.191**	.189**	.188**	.137**

*p < .05 **p<.01

Research Aim 4: The Grit Scales Predicting Students' Feelings of Success

Using structural equation modeling, the structures for Grit-O, Grit-S, the alternative Grit-S, and the new grit scale were regressed on an outcome variable assessing students' feelings about their class performance were used. Three questions indicating how students felt about their ability to do well, master material, and perform better than others were loaded onto a latent factor called feel. All models had latent variables of CI and PE correlated with feelings of performance as the outcome variable.

Figure 4.
Structural Model Used



Beginning with the original grit model as a two-factor correlated model, the model fit was below adequate with $\chi^2(87, N = 495) = 349.653, RMSEA = .078$ (90% CI $= .070 - .087$) and $CFI = .890$ and estimate for the standardized slope of PE was $\beta = .347$ (p<.001) and CI was $\beta = .149$ (p<.01). For the Grit-S two-factor correlated model, there was a good fit with $\chi^2(41, N = 495) = 93.685, RMSEA = .051$ (90% CI $= .037 - .065$) and $CFI = .969$ but the estimate for the slope of feel on CI was not significant (β =.098, p= .189). The alternative Grit-S scale had a better fit with

$\chi^2(41, N = 495) = 62.026, RMSEA = .032$ (90% CI $= .014 - .048$) and $CFI = .987$ with good estimates for feel on PE (β =.339, p<.001) and on CI ($\beta = .160$, p<.05). The definition based grit scale consisting of the new grit questions had a good fitting model with $\chi^2(24, N = 495) = 41.639, RMSEA = .039$ (90% CI $= .017 - .058$) and $CFI = .990$ and a strong estimate for feelings on PE (β =.394, p<.001), however, the estimate for CI was insignificant (β =–.080, p=.374). See Table 6 for all results.

Table 6.
Standardized Model Results

Model			Estimate	S.E.	Est./S.E.	Sig.	χ^2	df	RMSEA	CFI
Grit-O	FEEL on						349.653	87	.078	.890
		CI	.149	.057	2.601	.009				
		PE	.347	.054	6.472	.000				
	CI with									
		PE	.401	.052	7.642	.000				
Grit-S	FEEL on						93.685	41	.051	.969
		CI	.098	.074	1.314	.189				
		PE	.386	.070	5.497	.000				
	CI with									
		PE	.584	.051	11.479	.000				
Alt Grit-S	FEEL on						62.026	41	.032	.987
		CI	.160	.064	2.508	.012				
		PE	.339	.060	5.621	.000				
	CI with									
		PE	.481	.052	9.320	.000				
New Grit-S	FEEL on						41.327	24	.038	.991
		CI	-.080	.089	-.889	.374				
		PE	.394	.087	4.539	.000				
	CI with									
		PE	.703	.038	18.507	.000				

Discussion

The current study investigated the current grit scales developed by Duckworth and colleagues using confirmatory factor analysis and examined the correlations of items in this scale with conscientiousness from the Big-5 inventory. Results of CFA revealed

that a bifactor model is the best model fit for the original grit scale items and a two-factor correlated model has a very good fit for the Grit-S. However, there is a better short grit scale when the elimination of questions is based on factor loadings and modification indices. For the models that fit well, the rank order from highest to lowest are the two-factor correlated Definition Based Grit Scale, the two-factor correlated alternative Grit-S, the bifactor model for Grit-O, and the two-factor correlated Grit-S model.

Other papers have tested the structure of the original and short grit scales with similar results to this paper. Consistent with other studies (Muenks et al., 2017; Duckworth et al., 2007) the one factor structure showed poor fit for both scales. The "two-factor hierarchical" structure of grit referred to in the research (Duckworth et al., 2007; Duckworth & Quinn, 2009) is not a valid model (Kline, 2015, p.319) so it is most likely that the original grit research was referring to a two-factor correlated structure. This structure fit the model well for the Grit-S scale but not the Grit-O. The fit was even better for the alternative Grit-S created from factor loadings and modification indices of the original grit scale. Other studies confirm that the two-factor correlated structure of Grit-S is a good fit (Datu, Valdez, & King, 2016; Muenks et al., 2017) but to date, other studies creating an alternative Grit-S as done in this paper have not been found.

When checking the discriminant validity of the Grit-O items against conscientiousness, the intercorrelation between the Grit-O items and conscientiousness items was r =.23 while the average correlation that a Grit-O item had with the other Grit-O items was r = .24. Even though the correlations that the Grit-O items had, on average, with its own items was higher than the average correlation with conscientiousness, it was not higher by much. For the new grit questions written based on the definition of grit, the

correlation between items in that scale was r =.42 while the correlation between the new grit items and the conscientiousness items was r =.24. The average correlation for the conscientiousness items within their group was r = .32. When correcting for unreliability, the Grit-O vs. conscientiousness relationship has ρ=.84 which is lower than other studies have reported (Crede, Tynan, & Harms, 2017). The new grit questions with conscientiousness has a disattenuated correlation of ρ = .65 with n = 495.

Analysis of the relationships with the factors CI and PE with feelings on performance in calculus, the different models all yielded different results. The best model for prediction of feelings of achievement in calculus was the alternative Grit-S (versus Grit-S: $\Delta\chi^2 = 31.659, \Delta df = 0$). For all models, PE was significant but two of the models had insignificant estimates for the path from CI to feelings, the Grit-S scale and the new Grit-S scale. The new grit items estimated a negative relationship between CI and feelings of performance. Even though this estimate was non-significant, the suggestion of a negative relationship may be because the wording of the new CI items was very specific regarding keeping a maintained focus on goals and not wavering. This result is consistent with results of Tang et al., (2019) in their study of goal commitment, grit, and academic outcomes. They found that even though goal commitment had a positive relationship with CI, both the direct and indirect paths (through CI) to school GPA had negative values. This may indicate that too high of a level of CI may hinder goal adjustment when it is appropriate for situations. According to Brandtstädter and Rothermund (2002), lack of goal adjustment can lead to feelings of frustration and distress. Future research should examine if there is a threshold value for CI in which goal adjustment is hindered.

Through the research on the theory of goal channels, grit has been shown to have a positive relationship with retention within universities which exhibit strong channel strength (i.e. have more resources for students which help direct goal attainment; Goyer, Walton, & Yeager, 2020). However, grit was measured with only four questions from the Grit-S scale – three of which were from the perseverance of effort facet. Re-evaluation of grit in this context using the new short grit scale introduced in this paper may give different results.

Finally, the bifactor model results for the Grit-O items indicate that the inclusion of a general grit significantly improves explaining the item correlations beyond that of a correlated two factor model of the grit facets of PE and CI. This would suggest it may be beneficial to develop a general grit item independent of those measuring PE and CI.

This paper has contributed to the literature on grit by creating new questions for the latent variables of CI and PE. Using definitions and item analysis, these new items tap into what the constructs are meant to measure according to their names and the overarching definition of grit. However, when these items are used to predict feelings of success in a calculus class, the variable CI is not significant. This is consistent with some studies conducted using CI and PE as separate measures which attempt to predict academic success using those factors from either the Grit-O or Grit-S scales (Chang, 2014; Datu, Valdez, & King, 2016; Muenks et al., 2017).

This study focused on college students in calculus, although results may be different if the survey were given to students in different subject areas. Much of the research on grit involves success for students at different levels such as high school, undergraduate college level, and graduate college level so testing the new grit models on

different academic levels would also be a contribution. Another limitation of this study is that results were measured at only one point in time which assumes that grit is invariable across time; a longitudinal study should be done to test this theory.

Overall, this paper offered several contributions to the literature by analyzing the factor structure of the grit questions and creating new grit scale questions based on definitions of grit. Most specifically, this study verified that the original and short grit scales are not hierarchical (instead they are two-factor correlated models), that there are other models which have a better model fit than the Grit-S, and that the original grit items are significantly correlated with the personality trait of conscientiousness. Also shown in this study is that perseverance of effort correlates more strongly with feelings of academic success in calculus than does consistency of interest.

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Chapter IV.
Manuscript 2

Gritty Times Call for Gritty Measures: Examining grit and student success in calculus

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Abstract

Grit is a non-cognitive trait in which someone demonstrates having passion and perseverance for long-term goals. The main measures of grittiness are the original grit scale (Grit-O) and the short grit scale (Grit-S) developed by Duckworth and colleagues (2007, 2009). Both of these scales are made up of two factors – consistency of interest (CI) and perseverance of effort (PE). A majority of papers reporting on grit use either the Grit-O or Grit-S either as a single averaged score or by using CI and PE separately (but not weighted). Because of the inconsistency in the use of these scales, studies have not shown consistent outcomes in academic settings. The current study will present and test a new grit scale based on new CI and PE questions (presented in paper 1) and a third factor of general grit. The general grit scale was developed using a top-down approach based on construct definitions. The scale is validated and tested on an outcome variable, final exam score in a calculus class. It is shown that general grit can be used in a scale with CI and PE or alone. The general grit scale is also tested across gender and ethnicity to see if it is generalizable across groups. Results show the general grit scale model has a good fit and is generalizable across both gender and ethnicity. General grit is also shown to be a good predictor of final exam grade in a college course and fully mediates the impact of CI and PE.

Keywords: grit, attitude, personality, persistence, academic success, STEM

Introduction

In an effort to increase the retention rate of college students, educational research is focused on predictors of success, especially in core courses. Non-cognitive predictors are a particular focus of interest due to their potential malleability (Gabrieli, Ansel, & Krachman, 2015; Garcia, 2016). Several studies have shown that non-cognitive traits such as self-control, grit, anxiety, curiosity, and conscientiousness may contribute to a student's ability to sustain effort at academically demanding tasks (Barrett, 2014; Gutman & Schoon, 2013; West et al., 2016).

According to a meta-analytic study by Credé, Tynan, and Harms (2017), grit has been among the most prevalent of these traits in recent publications on non-cognitive measures of success. However, concerns have been raised as to the validity of the higher order factor model of grit and how the overall score of grit is reported in research (Credé, 2018). Credé (2018) goes on to say that "revisiting the measurement of grit may help researchers arrive at a more accurate understanding of the role of grit in determining performance", and that there are several ways this could be done.

Currently, most research on the trait of grit uses either the Grit-O or Grit-S scale (Duckworth et al., 2007; Duckworth & Quinn, 2009). Prior research which uses these scales report responses differently, with some using an average score of all items and others using sub-scores from the two facets of these scales. Cross (2014) reported that average Grit-O score had a significant relationship with GPA of online doctoral students while a similar study of online undergraduate students (Buzzetto-Hollywood et al., 2019) reported no significant relationship with average Grit-O and academic achievement. Another study on college students (Almeida et al., 2019) showed none of the correlations

exploring the relationship of cumulative GPA with average Grit-O, PE, or CI produced significant results while another (Hodge, Wright, & Bennett, 20108) showed significant correlations between grades and both CI and PE. Other studies which used CE and PI scores separately reported academic achievement had significant correlations with PE and not CI (Datu, Valdez, & King, 2016; Palisoc et al., 2017; Rimfield et al., 2016).

One reason for the mixed results given from studies on grit may be the use of a single score to represent a construct which consists of two facets. Using a unidimensional score on a multi-faceted scale has been shown to have mixed results in studies (Smith, McCarthy, & Zapolski, 2009). Smith and colleagues go on to say, "elements of composites can, and do, act differently from one another, so analysis of composite scores combines the potentially different roles of its elements." This implies that the use of composite scores for scales that have multiple facets can lead to ambiguous conclusions.

Although there is an abundance of literature on relationship of grit and outcomes such as academic success (Credé, Tynan, and Harms, 2017; Lam & Zhou, 2019), evidence of theoretical backing of this relationship is inadequate. Some researchers have hypothesized that possessing the trait of grit would enhance and promote a deeper level of engagement in tasks or effort towards goals and thus be positively correlated with outcomes such as academic success (Hodge, Wright, & Bennett, 2018; Silvia et al., 2013). While other studies which have investigated grit's relationship with goal theory and growth mindset have showed that only the PE facet of grit positively effects academic outcomes (Tang et al., 2019).

Based on the mixed reporting of results in studies on grit, the first goal of this paper will be to create a new general grit scale. This new measurement will be designed

based on an examination of current definitions of grit. This new scale will then be tested to see if it predicts outcomes of academic success better than the current models. Using multi-group invariance tests, the generalizability of the measures is tested across gender and ethnicity.

Grit: Definition and Measurement

The idea of grit was developed with the goal of finding a trait that would predict success among top achievers, independent of cognitive ability. In the effort of defining grit, Duckworth and colleagues (2007) interviewed high-achieving professionals in fields such as medicine, academia, and law. They defined grit as "perseverance and passion for long-term goals" and that it also includes the traits of "working strenuously toward challenge, maintaining effort and interest over years despite failure, adversity, and plateaus in progress" (Duckworth et al., 2007, p.1087).

In 2007, Duckworth, Peterson, Matthews and Kelly developed what is now labeled as the original grit scale (Grit-O). The Grit-O scale is a two-factor scale consisting of twelve items which attempt to capture the ability to persevere in the face of adversity (e.g., "I have achieved a goal that took years of work") and to maintain a consistent level of interest in those goals (e.g., "My interests change from year to year", reverse coded). The two factors of the Grit-O were labeled as perseverance of effort (PE) and consistency of interest (CI) and each factor consisted of six items. In their analysis of the scale, Duckworth et al. concluded that neither factor was more predictive than the other in relation to the outcomes of success (such as educational attainment and program retention) and thus used a single total grit score from the full twelve-item scale for analyses.

Despite this conclusion that neither factor (CI or PE) was a better indicator than the other in predicting a person's overall grittiness (Duckworth et al., 2007), Duckworth and Quinn reported in 2009 that "the differential predictive validity of these two factors for various outcomes was not explored." In an effort to resolve this issue as well as improve the model fit of the Grit-O, Duckworth and Quinn (2009) developed the eight-item short grit scale (Grit-S). The Grit-S was developed by re-examining the studies done in the development of the Grit-O and ranking correlations of items within each factor (CI and PE) with outcomes. Four items with the highest-ranking correlations for each factor was retained. This new model reported higher internal consistency and an overall better model fit than the Grit-O (Duckworth & Quinn, 2009). The Grit-S model was labeled as a second-order model; however, other studies have verified that it is a two-factor correlated model based on the number of constructs (cite paper 1, Credé, Tynan, and Harms, 2017).

Other attempts to create new measurements of the concept of grit have included adding new facets or creating new questions for the existing facets (cite paper 1; Clark & Malecki, 2019; Datu, Yuen, & Chen, 2017). George (2021) examined an alternate creation of the Grit-S scale using factor loadings and modification indices and created new CI and PE questions for grit. These new scales had good model fits and showed strong relationships with students' feelings of success in a college calculus class.

Grit as a Predictor of Success

Many studies have examined grit using the Grit-O or Grit-S scales in the context of academic success outcomes with differing results (Almeida, 2016). Some articles reported results on the individual facets of grit while others used a total score or average score of all items. When separated into individual facets (CI and PE), these two factors of

grit appear distinct from each other (Duckworth & Quinn, 2009; Datu, Valdez, & King, 2016). They may also have different relations with outcomes measuring success. Several studies have cited that perseverance of effort was more highly correlated with success than consistency of interest (Datu, Valdez, & King, 2016; Kalia, Fuesting, & Cody, 2019).

In contrast, several other studies have examined *total/average* grit score from Grit-O or Grit-S in relation to academic success, such as grade point average (GPA) and achievement test scores. These studies have typically found no or limited evidence of links between grit and success. In a study of first year pre-university science students in Montreal, grit (as measured using total/average Grit-O) was found to have no significant correlation with high school grade point average (GPA) (Bazelais, Lemay, and Doleck, 2016). Furthermore, grit was also not a significant predictor of success in an entry physics course when controlling for high school GPA using hierarchical multiple regression. Another study examined achievement among math and science high school students using Grit-O (Al-Mutawah & Fateel, 2018). In calculating the grit score of students, they used the average responses from all of the questions from the grit scale. Their results showed that students' average grit score was positively and significantly correlated with math achievement but not with science achievement.

In a study of students attending a small private university, researchers examined grit using Grit-O, GPA, academic commitment, and sense of belonging (Buskirk-Cohen & Plants, 2019). They found no significant correlations between grit and GPA. Similarly, Almeida, Byrne, Smith, and Ruiz (2019) performed ordinary least square regression using grit score (calculated by averaging answers to the Grit-O scale) and other variables

such as campus involvement and transfer status on first generation college students' college GPA. This study determined that neither grit nor either of its facets (CI or PE) were significant in predicting GPA.

The mixed results of grit's prediction of academic success may be due to how the grit score was reported. Although both Grit-O and Grit-S are recognized in the literature as two-factor models, many researchers treat the grit scale as unidimensional and report a single grit score found by finding an unweighted average of all items. Psychometricians argue that if one uses single unidimensional scores on multidimensional scales, one has created a heterogeneity problem at the scale level (Smith, McCarthy, & Zapolski, 2009). In fact, when averaging scores across a multi-faceted scale, the resulting score can reflect different combinations of construct scores for different respondents within the sample. This would be problematic when trying to use an average score for a multidimensional model when predicting outcomes.

Development of a General Grit Scale

Although grit was introduced as a single construct by Duckworth, Peterson, Matthews, and Kelly (2007), defined as "trait-level perseverance and passion for long-term goals", it is currently measured as a two-factor structure. The creators claim that having a two-factor structure is consistent with the theory of grit existing as a "compound trait comprising stamina in dimensions of interest and effort" (Duckworth & Quinn, 2009). The current grit scale consists of separate facets of consistency of interest (CI) and perseverance of effort (PE), however, a major issue arises because a single grit score is most often reported, without weighting of items based on facets (Al-Mutawah and Fateel, 2018; Almeida, Byrne, Smith, and Ruiz, 2019; Duckworth & Quinn, 2009; Tyumeneva

Kardanova, & Kuzmina, 2019). Again, this is problematic because the impact of the individual facets will be lost. In other words, this would lead us to wonder if a person high in grit because they score high in perseverance or consistency of interest or both. Another issue that may arise from having grit measured as a latent variable comprised of two facets is that may be difficult to understand what the overall latent variable represents (Little, Cunningham, Shahar, & Widaman, 2002). In other words, it is unclear whether the two facets are each necessary and/or sufficient for someone to be considered to have grit.

Because grit scores are often reported as a single average score of all items, a single-factor structure should be a good model. However, it was found by some studies that grit, as measured by Grit-O or Grit-S, cannot be modeled well with a single factor (cite paper 1 and Disabato, Goodman, & Kashdan, 2019). This leads the question of whether new grit items can be constructed in a way that will give a more global unidimensional assessment that encapsulates the PE, CI, and other proposed facets. Some papers have created new grit scales based on the current grit scales by adding another facet to the structure (Clark & Malecki, 2019; Datu, Yuen, & Chen, 2017). Clark and Malecki (2019) developed an academic grit scale, aimed at youth populations with the facets of resilience, determination and focus. Datu, Yuen, and Chen's triarchic grit scale (2017) used the Grit-S scale facets (CI and PE) along with questions aimed at a third facet called "adaptability to situations." However, these adaptations do not address the need for a unidimensional scale. The existence of a single unidimensional scale would allow for the determination of the relative contribution of PE, CI, and other recent facets

of grit. To date, no research has been found which has created a unidimensional generalized grit scale, leading to the current effort to develop such a scale.

Since grittiness is often considered and operationalized as a single construct, the unidimensional grit scale was designed to use a homogenous set of items that encapsulates the evaluations of CI, PE, and any potential facets of grit. The existence of a general grit representing the summary aggregation of grit facet would imply its role as a mediator. In other words, this new scale should significantly, if not completely, reduce the direct impact of CI and PE on any outcome variables. In order to test this hypothesis that a single construct measure of grit exists with the attributes stated above, a single-factor general grit scale was created.

In creating a new grit scale, a conceptual analysis of the trait of grit was done. According to McDonald (2013, p.201), "the most informative validating evidence [of a model for measurement of an abstract concept] would come from a conceptual analysis of item content in combination with the use of the factor model." In other words, in order to measure grit, the concept of grit itself and the way that researchers use data collected from a grit measure are equally important. Also, Smyth (2016) states that an analysis plan should be implemented before writing survey questions. The plan in this study was to use a top-down approach to developing questions aimed specifically at measuring grit with a single construct.

Because studies have shown concern about whether Grit-O and Grit-S measure the psychological construct of grit, the wording of items in both individual facets of grit (CI and PE) were analyzed. In order to understand these two facets and the overall concept of grit, research was conducted into the definition and intended use of the

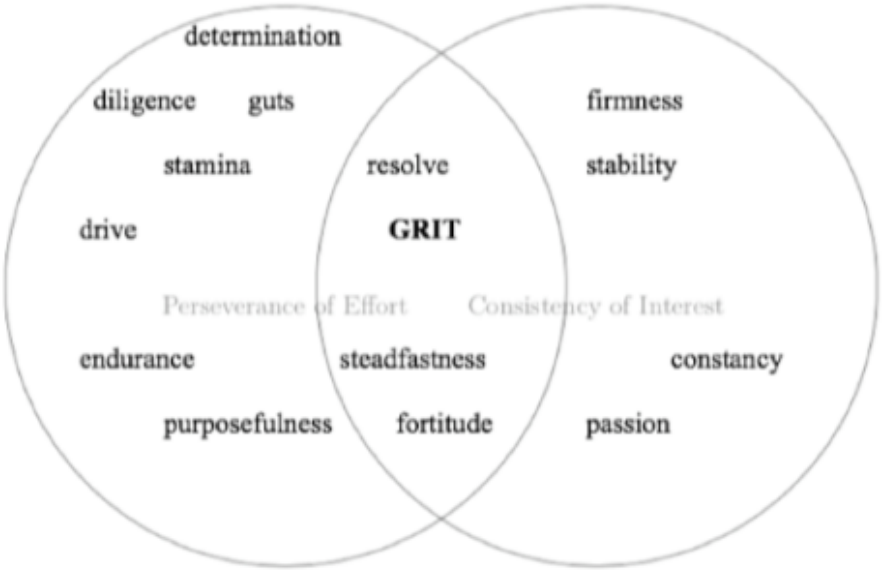
measurement of grit. Some definitions given in papers on grit included "working strenuously toward challenges, maintaining effort and interest over years despite failure, adversity, and plateaus in progress" (Duckworth et al., 2007, p.1087), "perseverance to accomplish long-term or higher-order goals in the face of challenges and setbacks, engaging students' psychological resources, such as their academic mindsets, effortful control, and strategies and tactics" (Shechtman et al., 2013, p.1), and the ability "to sustain a focused effort to achieve success in a task, regardless of the challenges that present themselves, and the ability to overcome setbacks" (Sturman & Zappala-Piemme, 2017, p.2).

Synonyms of the constructs of grit were investigated to find overlapping terms that would help with defining grit more precisely, see Figure 1. After analysis of synonyms and definitions, it was concluded that for the purposes of this research that the definition of grit to be used when creating general grit questions is "a non-cognitive trait in which someone demonstrates firm resolve toward achieving a long-term goal." Using this definition and synonyms of grit, as well as the overlapping synonyms of the constructs of the grit scale, four questions attempting to tap into the single construct of grit were carefully worded. These new questions were labeled as general grit (GG).

Table 1.
New General Grit Questions

Factor and New Item	Corrected Item-Total r	Cronbach's Alpha if Item Deleted
General Grit Items:		
In general, for any new project I undertake, I would describe myself as being tenacious toward its completion. (GG1)	.598	.762
Overall, people describe me as the type of person that will stick it out to the end for any project I start. (GG2)	.646	.738
In general, I would describe myself as having a gritty personality that helps me get through any project or task from start to finish. (GG3)	.606	.758
I have firm resolve in achieving my long-term goals. (GG4)	.618	.752

Figure 1.
Venn Diagram of Synonyms



Research Aims

When comparing grit to other predictors of success, such as cognitive ability, the relations are modest (Credé, Tynan, and Harms, 2017). Nonetheless, because significant achievement requires persistence and perseverance on difficult tasks such as problem solving in mathematics, grit (or at least one of its facets) may be an important predictor for success (Dweck, Walton, & Cohen, 2014). Therefore, this study examined (1) whether a better scale for grit can be created, (2) whether this new scale can predict success in a calculus course, and (3) whether grit is generalizable across gender and ethnicity.

In summary, because of studies showing different significance in prediction of outcomes between the two current facets of grit, consistency of interest (CI) and perseverance of effort (PE), a scale focused solely on a single global assessment of grit which encompasses both CI and PE is in order. The utility of this scale will be applied in a model predicting final exam scores for students in calculus. The model was then tested

across gender and ethnicity to see if there were any invariance in the measurement.

Method

Participants

Participants were 826 undergraduate college students who enrolled in either integral or multivariable calculus course at a large southern urban university in the United States. The sample included 485 (58.7%) males, 331 (40.1%) females, and 10 (1.2%) who preferred not to identify their gender. The average age of the participants was 20.11 (*sd* =2.26). The sample was ethnically diverse, which included Asian (n = 276, 33.4%), Black/African American (n = 59, 7.1%), Hispanic/Latinx (n = 241, 29.2%), White/ Caucasian (n = 186, 22.5%), and other races (n = 64, 7.7%) The majority of students were in their sophomore year (n = 457, 55.3%) while the rest were freshmen (n = 167, 20.2%), juniors (n = 151, 18.3%), seniors (n = 36, 4.4%), and post-baccalaureate (n = 12,1.5 %). Of those surveyed, 27.7% (n=229) identified as first-generation college students. Sixty percent (n=495) of the students were in integral calculus while the rest (40%, n=331) were in multivariable calculus. The largest group (n=360, 43.6%) of students were majoring in the college of Natural Science and Mathematics and the second largest group of students had majors in engineering (n=290, 35.1%) or technology (n=90, 10.9%). When asked if they had transferred from another college, 576 (69.7%) said “no” and the rest said “yes”.

Students were emailed a link to an online survey in the fall semester. Participants were informed in the email and again in the survey about the aims of the research and voluntary nature of participating. All participants could indicate if they gave informed consent for taking part in the survey before starting the survey. Participants completed the

survey outside of class. This study was approved by the university's Institutional Review Board. Students were given one week to complete the survey and received one bonus point on their final exam grade if they began the survey.

Measures

Student information data included gender, race/ethnicity, student's academic level, major of study, and whether they were a first-generation college student. Also reported was the percentage of work completed in their calculus class, final exam grade, and final course grade. Students answered three questions about how they feel about their performance in calculus. These three questions were measured on a seven-point Likert scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). A sample question was "I will likely master the materials taught in this class." The scale reliability for these three questions is α = .88. Also included were questions on grit which consisted of the 12-item original grit scale developed by Duckworth et al. (2007), three additional questions to measure perseverance of effort (PE), three additional consistency of interest (CI) questions (cite my paper 1 here), and four new general grit (GG) questions. These questions were measured on a five-point Likert scale ranging from 1 (*not like me at all*) to 5 (*very much like me*). The four new GG questions showed good internal consistency ($\alpha = .80$). See Table 1 for the correlations and Cronbach alpha values of the new GG items.

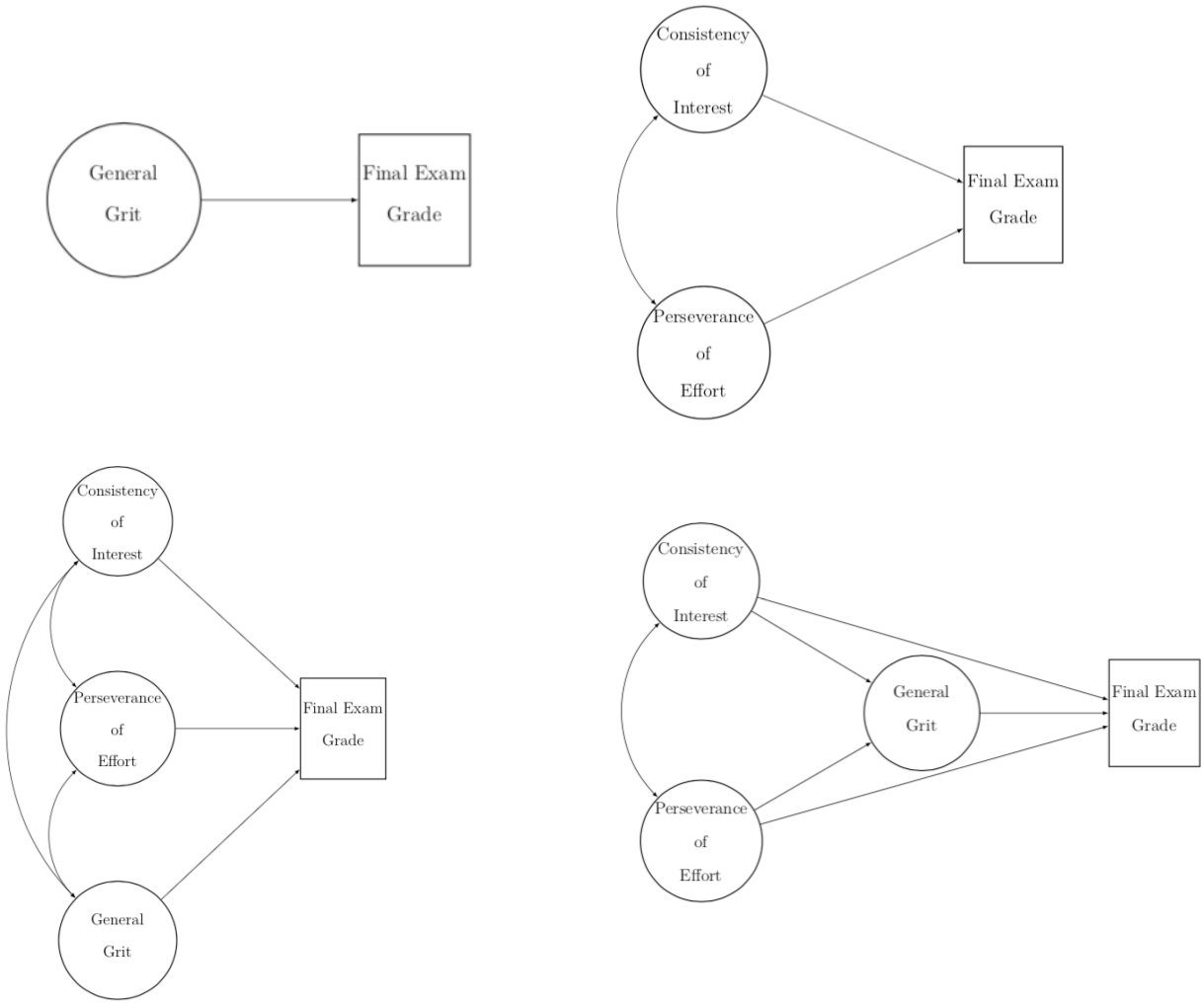
Statistical Analysis

First, missing data patterns and statistical assumptions were analyzed by using IBM SPSS 26.0 (2019). The amount of missing data per variable ranged from 0.2% to 1.4%. Because the study had more than 800 respondents, missing data was list-wise

deleted. The variables showed an acceptable range for asymmetry and kurtosis (George & Mallery, 2010), with skewness ranging from $-.470$ to $-.039$ and kurtosis ranging from $-.522$ to $-.185$. Next, using Mplus (Muthén & Muthén, 2018) version 8, exploratory factor analysis (EFA) was run on the newly created GG questions on half of the respondents to confirm that the factor loading for each variable was larger than .4 (Pett, Lackey & Sullivan, 2003). Next, using the new grit questions written for CI and PE (cite paper 1) as well as the general grit questions, EFA was run these for three factors in order to confirm that the factor loading for each variable was larger than .4 and that each of the three facets loaded on to a separate factor. Using the other half of the data set, confirmatory factor analysis (CFA) was run and model fit indices were evaluated to assess the model data fit, including model chi-square statistic, comparative fit index (CFI), and Root Mean Square Error of Approximation (RMSEA; Steiger, 1990). Fit of the model was determined using recommendations of Hu and Bentler (1999) who state a CFI value of .95 or higher and RMSEA of .06 or lower indicates good model fit.

The next steps in the analysis involved using different structural equation models with the outcome variable of the final exam score of the students in their calculus class. Four such models will be run. One with CI and PE on the outcome variable, one with only GG and the outcome variable, and one with the three latent variables CI, PE and GG in a hierarchical model as the independent variables. A final model which will be tested is a mediation model with GG as the mediator for CI and PE on final exam grade. This mediation model is chosen because GG is related to the other facets conceptually and according to Chin (1998), it is considered a second order factor in relation to CI and PE.

Figure 2.
Structural Models



Finally, multi-group confirmatory factor analysis (MGCFA) will be run using gender then ethnicity as grouping variables. MGCFA will determine if the new scales elicit similar responses across the groups. Models will be run with and without constraints and model fit indices will be examined.

Results

Research Aim 1: A new grit measurement model

Before running any analysis, responses from 11 participants were excluded due to missing answers to some questions. EFA was run on the newly created GG questions on half of the respondents (n = 406) and it was confirmed that the factor loading for each variable was larger than the error variance for that factor. Next, using the new grit questions written for CI and PE (cite paper 1) as well as the general grit questions, EFA was run for these three factors. It was confirmed that the factor loading for each variable was larger than the error variance for that factor and that each of the three facets loaded on to a separate factor. Finally, CFA was run with the other half of the respondents (n = 409). The χ^2 value for this new three-factor correlated model was 55.938 with 32 degrees of freedom. Comparing that to the two-factor model with CI and PE alone (cite paper 1), the χ^2 difference in the models is 42.168 with difference in degrees of freedom of 24, which is significant at the $p < .05$ level. The Root Mean Square Error of Approximation (RMSEA) of this three-factor model was .043 (90% $CI = .023 - .061$) and the comparative fit index (CFI) was .985. Table 2 contains the fit indices and Table 3 shows the standardized factor loadings and correlations for these models.

Table 2.
CFA Fit Indices for New Grit Questions

Model	Fit Indices			
Name	χ^2	df	RMSEA (90% CI)	CFI
Single Factor GG	.587	2	.000 (.000, .068)	1.000
Two-factor CI with PE	13.770	8	.042 (.000, .079)	.993
Three-factor CI, PE, GG	55.938	32	.043 (.023, .061)	.985

Table 3.
CFA Factor Loadings and Correlations for New Grit Questions

Model	Standardized Factor Loadings										Correlations		
Name	GG1	GG2	GG3	GG4	CI7	CI8	CI9	PE7	PE8	PE9	CI & PE	CI & GG	PE & GG
Single Factor GG	.656***	.731***	.680***	.686***									
Two-factor CI with PE					.688***	.758***	.690***	.775***	.786***	.695***	.700***		
Three-factor CI, PE, GG	.646***	.728***	.648***	.724***	.696***	.752***	.689***	.787***	.771***	.697***	.701***	.733***	.945***

*** p<.001, ** p<.001, * p<.05

Research Aim 2: Predicting success in calculus

Using structural equation modeling, the final exam grade for the calculus class was used as an outcome variable since it was given after administration of the questionnaire. Using the general grit scale (GG) on its own with the outcome variable of final exam grade, the model fit was very good with $\chi^2(5, N = 816) = 8.022, RMSEA = .027$ (90% CI $= .000 - .061$) and $CFI = .997$ and the variance of the final exam grade explained by GG was $r^2 = .049$. General grit was positively related to final exam grade ($\beta = .222, p < .001$).

Using the new CI and PE questions (George, 2021), a two-factor correlated model was tested here with the outcome variable of final exam grade. For this model, the fit was good with $\chi^2(12, N = 816) = 43.469, RMSEA = .057$ (90% CI $= .039 - .075$) and $CFI = .981$, however, CI was not a significant predictor of final exam grade ($\beta = -.026, p > .05$). Despite this, PE was a significant predictor of final exam grade ($\beta = .173, p < .01$) and the amount of variance explained by this model for the final exam grade was .024 (p <.05). Next, GG was added to this model to make a three-factor correlated model to predict final exam grade. The model fit was very good with $\chi^2(39, N = 816) = 94.502, RMSEA = .042$ (90% CI $= .031 - .053$) and $CFI = .984$. Although GG and CI had significant relationships with final exam ($\beta = .559, p < .01$ and $\beta = -.151, p < .05$), PE did not ($\beta = -.249, p > .05$). It is also noteworthy that both paths from PE to final exam and CI to final exam had negative estimates.

Lastly, a mediation model which included CI, PE, GG and final exam grade was run next. In this model, GG was selected as a mediator because it was developed as a summary grit trait that encapsulates both conceptual facets of CI and PE. The model was

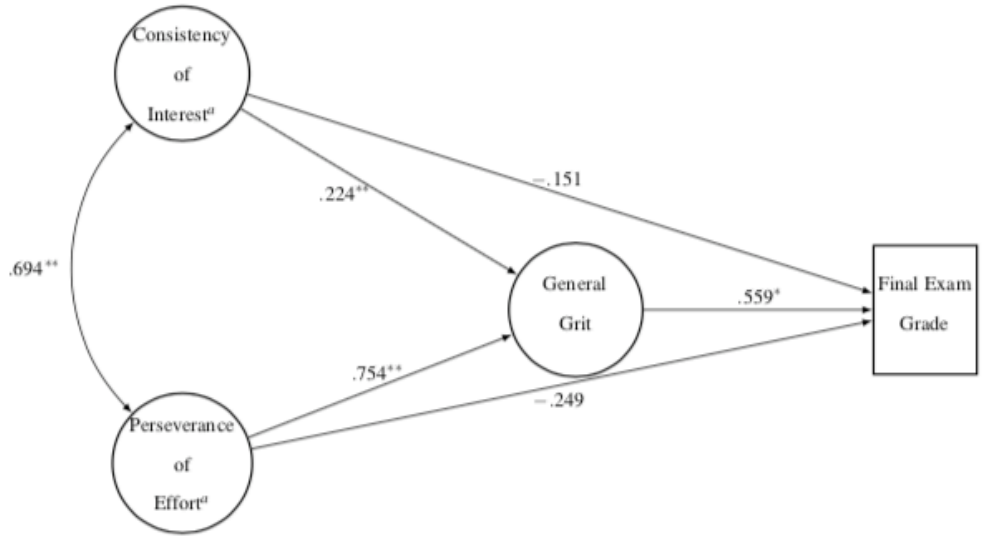
a good fit with $\chi^2(39, N = 816) = 94.502, RMSEA = .042$ (90% CI $= .031 - .053$) and $CFI = .984$ and based on the results, GG is a full mediator of CI and PE. Table 4 and Figure 3 summarize the results of this model.

Table 4.
Structural Equation Model Results

Model	β GG	β CI	β PE	SE	R^2
Direct					
GG		.224**	.754**	.033	.854***
Final Exam	.559*	−.151	−.249	.032	.070*
Indirect					
GG					
Final Exam		.125*	.422*		

* p<.05, ** p<.01, *** p<.001

Figure 3.
Structural Model with General Grit as a Moderator



a. using new CI and PE questions. **p<.01, *p<.05

Research Aim 3: Differences across gender and ethnicity

To test if the factor structure of general grit is invariant across gender and ethnicity, a multi-group confirmatory factor analysis (MGCFA) approach was used to

compare by gender (and then ethnicity) on the factor loadings of general grit and then on the other models. In the first step towards testing the invariance of the general grit scale, the configural invariance (unconstrained) model was run. Single-factor models of general grit were estimated simultaneously within each group with the latent variable's variance fixed to 1 and the latent mean was fixed to 0 for identification in each group. As shown in Tables 5 and 6, the unconstrained models had good fit so the next steps involved running a series of model constraints to examine potential decreases in fit. The first constrained model was the metric invariance model which was run with factor loadings constrained across gender. The next step involved holding the means fixed, as well as the factor loadings. The differences in χ^2 values and degrees of freedom for each step were calculated by subtracting the χ^2 and degrees of freedom from the previous step and *p*-values were examined.

For the MGCFA analyzing gender, men served as the reference group in all invariance models. The χ^2 values exhibited nonsignificant differences in fit indicating structure invariance for gender for both factor loadings and latent means. As the results in Table 5 demonstrate, all invariance models also show strong fit indices for the data across gender for factor loadings and means.

In testing for invariance of the GG scale across ethnicity, a similar process was done. The groups for ethnicity included Asian, African American, Latinx, and White. The reference group for grouping by ethnicity was Asian. The χ^2 values for these models when factor loadings were constrained exhibited nonsignificant differences in fit indicating structure invariance for ethnicity. However, when both the means and factor loadings were constrained, all models except GG had significant χ^2 difference values. For

the purpose of the construction and validation of these scales, there is no a priori reason to assume that invariance across latent means needs to be shown. Results for invariance tests for ethnicity are summarized in Table 6.

Table 5.
MGCFA for Gender

Model	χ^2	*df*	*RMSEA* (90% CI)	CFI	$\Delta\chi^2$	Δdf	*p*-value
General Grit							
Configural Model	.982	4	.000 (.000, .028)	1.000			
Factor Loadings Fixed	3.033	8	.000 (.000, .016)	1.000	2.0510	4	.7264
Factor Loadings and Means Fixed	5.387	9	.000 (.000, .036)	1.000	2.3540	1	.1250
CI Alone							
Configural Model	.000	0	.000 (.000, .000)	1.000			
Factor Loadings Fixed	7.501	3	.061 (.000, .117)	.993	7.5010	3	.0575
Factor Loadings and Means Fixed	8.309	4	.051 (.000, .101)	.993	.8080	1	.3687
PE Alone							
Configural Model	.000	4	.000 (.000, .000)	1.000			
Factor Loadings Fixed	1.543	3	.000 (.000, .064)	1.000	1.5430	3	.6724
Factor Loadings and Means Fixed	3.846	4	.000 (.000, .074)	1.000	2.3030	1	.1291
Two-factor Correlated Model							
Configural Model	49.584	16	.072 (.050, .095)	.980			
Factor Loadings Fixed	58.138	22	.063 (.044, .084)	.979	8.5540	6	.2003
Factor Loadings and Means Fixed	60.530	24	.061 (.042, .081)	.978	2.3920	2	.3024
Three-factor Correlated Model							
Configural Model	120.592	64	.047 (.034, .059)	.983			
Factor Loadings Fixed	129.528	74	.043 (.030, .055)	.984	8.9360	10	.5382
Factor Loadings and Means Fixed	132.654	77	.042 (.030, .054)	.984	3.1260	3	.3726

Table 6.
MGCFA for Ethnicity

Model	χ^2	df	$RMSEA$ (90% CI)	CFI	$\Delta\chi^2$	Δdf	p-value
General Grit							
Configural Model	11.131	8	.046 (.000, .103)	.997			
Factor Loadings Fixed	21.508	20	.020 (.000, .067)	.998	10.3770	12	.5829
Factor Loadings and Means Fixed	26.000	23	.026 (.000, .068)	.997	4.4920	3	.2130
CI Alone							
Configural Model	.000	0	.000 (.000, .000)	1.000			
Factor Loadings Fixed	8.493	9	.000 (.000, .079)	1.000	8.4930	9	.4853
Factor Loadings and Means Fixed	27.680	12	.083 (.042, .124)	.974	19.1870	3	.0003
PE Alone							
Configural Model	.000	4	.000 (.000, .000)	1.000			
Factor Loadings Fixed	7.834	9	.000 (.000, .074)	1.000	7.8340	9	.5510
Factor Loadings and Means Fixed	16.728	12	.046 (.000, .093)	.993	8.8940	3	.0307
Two-factor Correlated Model							
Configural Model	73.935	32	.083 (.059, .108)	.974			
Factor Loadings Fixed	89.696	50	.065 (.043, .086)	.975	15.7610	18	.6092
Factor Loadings and Means Fixed	113.861	56	.074 (.054, .094)	.964	24.1650	6	.0005
Three-factor Correlated Model							
Configural Model	239.245	128	.068 (.054, .081)	.965			
Factor Loadings Fixed	269.986	158	.061 (.049, .074)	.965	30.7410	30	.4282
Factor Loadings and Means Fixed	295.032	167	.064 (.052, .076)	.960	25.0460	9	.0029

Discussion

Grit is a non-cognitive trait which has recently received extensive attention as a predictor of success and performance (Credé, Tynan, and Harms, 2017). The most common measurement of grit is the Grit-S developed by Duckworth et al. (2007, 2009). Although this scale has two sub-facets of grit, consistency of interest (CI) and perseverance of effort (PE), most literature use an unweighted average of all items while others report scores for CI and PE separately. This inconsistency in how the scores are reported leads to mixed results when determining if grit, as measured by Grit-O/S is a predictor of success.

Some theories, such the model of assimilative and accommodative coping, indicate that too much grit (i.e. too much “tenacious goal pursuit and persisting

commitment") can lead to dysfunctional side effects such as exhaustion of resources (Brandtstädter, 2009). Because of this, it is important for individuals to understand how to set attainable goals and know when to adjust goals as needed. In a study focusing on secondary students, Tang et al. (2020) found that when goals were academic, high commitment to those goals and high grit-PE equated with high achievement. Based on both of these findings, it may be crucial to teach goal setting and goal adjustment to students early on instead of trying to teach grit.

This paper explored the creation of a new scale to measure the non-cognitive trait of grit using a single factor model. Other research has modified or extended the existing Grit-O/S scales (Clark & Malecki, 2019; Datu, Yuen, & Chen, 2017), however, use of a single factor structure which addresses the conceptual definition of grit has not been found. This new general grit scale shows promise as a measurement of grit, a non-cognitive trait in which someone demonstrates firm resolve toward achieving a long-term goal.

Despite the fact that there exist many studies comparing grit with academic success (Al-Mutawah & Fateel, 2018; Duckworth et al., 2007), results of these studies vary. Some studies report that the facets of Grit-O give different estimates for success or that one of the facets is significant while the other is not (Datu, Valdez, & King, 2016; George, 2021; Kalia, Fuesting, & Cody, 2019). The meta-analysis on studies which used Grit-O or Grit-S reported grit exhibited a relation of $\rho = .18$ with overall academic performance and $\rho = .17$ with GPA criterion (Credé, Tynan, and Harms, 2017), however, this current study shows that grit when measured using the new general grit scale has a higher correlation ($r = .22$) with final exam grade in college calculus. It also

demonstrates that general grit fully mediates CI and PE in a structural model with final exam as the outcome variable. Future research is needed to test this new scale on other populations.

The development of a general grit scale provides the opportunity to assess the relative contribution of the PE and CI facets towards overall grit. For this study, the standardized path estimate of PE is more than 3 times that of CI. Within the context of this study, it would also suggest that simple averaging of the two facets would lead to a poor estimation of overall grit by severely underestimate the contribution of PE. The general grit scale will also allow testing of other proposed facets by estimating their predictive contribution above and beyond that of PE and CI.

Based on the results of comparing constrained and unconstrained models, it can be concluded that the factor loadings for the new scales are the same across gender as well as across ethnicity. The results of invariance across gender for the new CI and PE grit questions are consistent with results given by Duckworth and Quinn (2009) for the Grit-S scale, however, the Grit-S was not tested as a structure across ethnicity. Other studies have examined group differences in average grit (measured by Grit-S) with most reporting no differences by ethnicity (Eskreis-Winkler et al., 2014; Rojas et al., 2012; Warren & Hale, 2020).

Although the group tests for ethnicity showed no invariance when latent means were constrained with the factor loadings, it was observed that the Latinx group had the largest χ^2 contribution in the restricted means model for both CI and PE. When the latent means for this group were allowed to be freely estimated, the χ^2 differences were no

longer significant in any models for latent means and factor loadings. Based on these findings, examination of latent mean differences across ethnicities could be warranted.

There were two major limitations in this study. One was that the data for grit was measured by a self-reported scale. The other limitation of this study is that it was a cross-sectional study. Although the final exam was taken after the answers to the grit questions were obtained, measures such as class attendance and completion of homework were not so we cannot determine if grit predicts those items. For academic purposes, it would also be helpful to know if grit can change over time or if it is constant and immutable. This study also only focused on college students in calculus courses; results may be different across different subjects.

Overall, this paper offered contributions to the literature by development of a new single-factor measurement for grit, the general grit scale. The need for a single-factor scale was crucial because many papers used composite scores for the two-factor Grit-O/S measures. The use of composite scores for multi-faceted measures can lead to ambiguous conclusions in research (Smith, McCarthy, & Zapolski, 2009).

This paper demonstrated that general grit could be used alone or as a mediator with the facets of consistency of interest and perseverance of effort. Research has shown that shorter questionnaires are more likely to have higher participation rates (Galesic & Bosnjak, 2009). On its own, the new general grit scale, which consists of only four items, should elicit high participation in future studies.

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Chapter V.
General Discussion

This two manuscript dissertation focused on the construct of grit and how it is measured. Current grit measurements and structures were tested and compared with other models. It was shown that new measures for grit show good model fit and had less overlap with items from the conscientiousness scale. A general grit scale was created to overcome issues in reporting inconsistencies that were evident in the original and short grit scales. This new scale was developed to encapsulate both of the facets of the original measurement. General grit was shown to mediate CI and PE when in a structural model with an outcome of final exam grade. Multi-group CFA was performed to test invariance of the new measures across gender and ethnicity.

The main limitations of this study were that the grit responses were gathered via self-report from the students and that this was a cross-sectional study. Because the construct of grit involves staying focused on goals for long periods of time, more statistics should be gathered over the course of several semesters to test if students are persevering. Another limitation was that the sample involved only students in calculus II and III at a single university. Surveying a wider array of undergraduate courses will help diversify results.

This paper contributes to the study of non-cognitive traits within academic settings because it has helped give a more consistent measure of grit. Also, because the new general grit scale is much shorter than existing measures, surveys studying other non-cognitive traits which may affect academic performance can include these four items easily.

Next steps will include conducting a longitudinal study with the new grit questions as well as questions on attitudes towards STEM. I would like to broaden the pool of respondents by distributing surveys to other classes within the STEM curriculum as well.

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Appendix A: Survey Questions

Grit-O (Duckworth et al., 2007)

(those with * eliminated later for short scale)

1. I have overcome setbacks to conquer an important challenge. *

2. New ideas and projects sometimes distract me from previous ones.

3. My interests change from year to year. *

4. Setbacks don't discourage me.

5. I have been obsessed with a certain idea or project for a short time but later lost interest.

6. I am a hard worker.

7. I often set a goal but later choose to pursue a different one

8. I have difficulty maintaining my focus on projects that take more than a few months to complete.

9. I finish whatever I begin

10. I have achieved a goal that took years of work. *

11. I become interested in new pursuits every few months. *

12. I am diligent.

My Additional Questions for New Grit Scale

1. My level of interest towards a goal tends to stay the same even over long periods of time.

2. Despite experiencing setbacks, I keep trying until my goal is reached.

3. Even after working on a project for years, I still maintain the same amount of interest in it.

4. When faced with a difficult challenge, I persist until I reach a solution.

5. I'm the type of person who perseveres even under difficult conditions (such as learning disabilities, sickness, or other obstacles).

6. My interest level for goals I set for myself doesn't change much, even over many years.

7. In general, for any new project I undertake, I would describe myself as being tenacious toward its completion.

8. Overall, people describe me as the type of person that will stick it out to the end for any project I start.

9. In general, I would describe myself as having a gritty personality that helps me get through any project or task from start to finish.

10. I have firm resolve in achieving my long-term goals.

11. For each of the following descriptors, indicate how much it resembles you whenever you start a new project:
(a) Gritty

(b) Tenacious

(c) Determined

(d) Persistent

(e) Stubborn

(f) Plucky

Conscientiousness from BFI (Benet-Martínez & John, 1998)

How I am in general? Here are a number of characteristics that may or may not apply to you. For example, do you agree that you are someone who likes to spend time with others? Please select the statement that indicates the extent to which you agree or disagree with that statement.
1. Does a thorough job

2. Can be somewhat careless

3. Is a reliable worker

4. Tends to be disorganized

5. Tends to be lazy

6. Perseveres until the task is finished

7. Does things efficiently

8. Makes plans and follows through with them

9. Is easily distracted

Other Questions

1. I am doing well in this course

2. I will likely perform better than most students in this class.

3. I will likely master the materials taught in this class.

Demographic Survey

Instructions: Please answer the following demographic questions by choosing the option that best describes you by checking the boxes and filling in the blanks.

1. Please select you gender
(a) Male

(b) Female

(c) prefer not to answer

2. Which of the following best describe your race (check all that apply)? (a) Native Hawaiian or Other Pacific Islander
(b) Asian

(c) Black/African American

(d) Hispanic/Latino

(e) White/Caucasian

(f) American Indian or Alaska Native

(g) Other, specify

3. What is your age?

4. What academic-year is it for you at UH?

5. Are you the first person in your family to go to college?

6. What college is your major in?

7. Did you transfer to UH from another college?

(a) No

(b) Yes, I transferred here from a two-year college

(c) Yes, I transferred here from another four-year college

8. What is your current cumulative GPA?

9. How many hours per week do you study for this class?

10. What is your expected grade for this class?

From Math Department

1. Tests scores from class.

2. Percent of completed assignments.

3. Final class average.

Appendix B: IRB Approval Paperwork

UNIVERSITY of HOUSTON

DIVISION OF RESEARCH
Institutional Review Boards

APPROVAL OF SUBMISSION

December 1, 2020

Rebecca George

rgeorge5@uh.edu

Dear Rebecca George:

On December 1, 2020, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title of Study:	Grit and Conscientiousness in Academics
Investigator:	Rebecca George
IRB ID:	STUDY00002698
Funding/ Proposed Funding:	Name: Unfunded
Award ID:	
Award Title:	
IND, IDE, or HDE:	None
Documents Reviewed:	• IRB Grit, Category: IRB Protocol; • Grit Survey Consent Form, Category: Consent Form; • email, Category: Recruitment Materials;
Review Category:	Exempt
Committee Name:	Not Applicable
IRB Coordinator:	Sandra Amtz

The IRB approved the study on December 1, 2020 ; recruitment and procedures detailed within the approved protocol may now be initiated.

As this study was approved under an exempt or expedited process, recently revised regulatory requirements do not require the submission of annual continuing review documentation. However, it is critical that the following submissions are made to the IRB to ensure continued compliance:

- Modifications to the protocol prior to initiating any changes (for example, the addition of study personnel, updated recruitment materials, change in study design, requests for additional subjects)
- Reportable New Information/Unanticipated Problems Involving Risks to Subjects or Others
- Study Closure

UNIVERSITY of HOUSTON

DIVISION OF RESEARCH
Institutional Review Boards

Unless a waiver has been granted by the IRB, use the stamped consent form approved by the IRB to document consent. The approved version may be downloaded from the documents tab.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system.

Sincerely,

Research Integrity and Oversight (RIO) Office
University of Houston, Division of Research
713 743 9204
cphs@central.uh.edu
http://www.uh.edu/research/compliance/irb-cphs/

Email for survey:

Hello,

I am writing to you to request your participation in a brief survey. Your responses to this survey will help us evaluate student traits which influence student success and improve the teaching and support of STEM courses. The survey is brief and should take less than thirty minutes to complete. You can access the survey on your class's CASA webpage under "Online Assignments". Your participation in the survey is completely voluntary and all of your responses will be kept confidential. No personally identifiable information will be associated with your responses to any reports of these data. The UH Institutional Review Board has approved this survey. Should you have any comments or questions, please feel free to contact me at rgeorge5@uh.edu. Thank you very much for your time and cooperation. Feedback from students is very important to us to help with instructional and institutional improvements.

Thank you,

Rebecca George

PhD Candidate, Program of Measurement, Quantitative Methods and Learning Sciences
Psychological, Health and Learning Sciences
College of Education
University of Houston
Academic Professional
School of Mathematics
Georgia Institute of Technology

UNIVERSITY of HOUSTON
A CARNEGIE-DESIGNATED TIER ONE PUBLIC RESEARCH UNIVERSITY

Consent to Take Part in a Human Research Study

Title of research study: Grit and Conscientiousness in Academics
Investigator: Rebecca George, a PhD candidate in the Department of Psychological, Health & Learning Science, University of Houston

Key Information:

The following focused information is being presented to assist you in understanding the key elements of this study, as well as the basic reasons why you may or may not wish to consider taking part. This section is only a summary; more detailed information, including how to contact the research team for additional information or questions, follows within the remainder of this document under the "Detailed Information" heading.

What should I know about a research study?

- Someone will explain this research study to you.
- Taking part in the research is voluntary; whether or not you take part is up to you.
- You can choose not to take part.
- You can agree to take part and later change your mind.
- Your decision will not be held against you.
- You can ask all the questions you want before you decide, and can ask questions at any time during the study.

We invite you to take part in a research study about minority stress, achievement emotions, and academic engagement because you meet the following criteria:

- currently enrolled in the undergraduate course
- 18 years of age or older

In general, you will be given a survey loaded on CASA for your class.
There are no known risks to participate in the study.

Detailed Information:

The following is more detailed information about this study, in addition to the information listed above.

Why is this research being done?

This study aims to investigate students' grit, conscientiousness, and academic engagement.

How long will the research last?

We expect that you will be in this research study for 30 minutes.

How many people will be studied?

We expect to enroll about 500 people in this research study.

What happens if I say yes, I want to be in this research?

The data will be collected in the year of 2020. The total duration of an individual subject's participation in the study is about 30 minutes, with about 5 minutes to review the instructions for the survey and 25 minutes to complete the survey. All participants are surveyed only once. Participants will be invited to respond to a set of items via a CASA online assignment. The questionnaire consists of three sections, among which the first two sections measure personality traits and the last section asks you to report some basic demographic characteristics (e.g., gender, age).

What happens if I do not want to be in this research?

You can choose not to take part in the research and it will not be held against you. Choosing not to take part will involve no penalty or loss of benefit to which you are otherwise entitled.

If you are a student, a decision to take part or not, or to withdraw from the research will have no effect on your grades or standing with the University of Houston.

What happens if I say yes, but I change my mind later?

You can leave the research at any time and it will not be held against you. If you stop being in the research, already collected data may not be removed from the study record.

Is there any way being in this study could be bad for me?

There are no foreseeable risks related to the procedures conducted as part of this study. If you choose to take part and undergo a negative event you feel is related to the study, please inform your study team.

Will I get anything for being in this study?

There is no monetary or rewards compensation provided for participation in this research study.

Will being in this study help me in any way?

Though, findings of this study may provide important evidence to develop interventions aiming to promote academic success and mental health.

What happens to the information collected for the research?

Your taking part in this project is anonymous, and information you provide cannot be linked to your identity.

Who can I talk to?

If you have questions, concerns, or complaints, or think the research has hurt you, you should talk to the research team at rgeorge5@uh.edu.
This research has been reviewed and approved by the University of Houston Institutional Review Board (IRB). You may also talk to them at (713) 743-9204 or cphs@central.uh.edu if:
Your questions, concerns, or complaints are not being answered by the research team.
You cannot reach the research team.
You want to talk to someone besides the research team.
You have questions about your rights as a research subject.
You want to get information or provide input about this research.

PRINCIPAL INVESTIGATOR:
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Objectives

This study seeks to examine among college students:

- The factor structure of grit which measures peoples' perseverance and passion for long-term goals.
- To what extent grit and conscientiousness influences students' academic engagement.

It is hypothesized that:

- A three-factor model will demonstrate superior fit relative to the two- factor model structure for grit.
- High levels of grit will be positively related to academic success.
- Grit will be positively related to students' self-evaluation of their academic success.
- Grit will positively predict academic engagement.

Background

Non-cognitive traits have been studied for decades as potential predictors of academic success. Although researchers have found correlations with some personality traits and academic success, recently there has been an emphasis on a new trait: grit. Grit has been defined as passion and perseverance for long term goals and is presented as a trait which measures success in certain situations (Duckworth, Peterson, Matthews, & Kelly, 2007). Recent studies have questioned the validity of the grit scale as a two-factor model or even a hierarchal model (Muenks, Wigfield, Yang, and O'Neal, 2017) and how grit overlaps with the conscientious personality trait (Datu, Valdez, and King, 2016).

Grit is often a predictor of academic engagement (Rimfeld et al., 2016) and increasing empirical evidence has demonstrated that among undergraduate students, academic engagement is positively related to grade point average (GPA; Ketonen, et al., 2016), degree attainment (Flynn, 2014), critical thinking outcomes (Nelson Laird, et al., 2014), and early career earnings (Hu & Wolniak, 2013). Thus, a better understanding of predictors of academic engagement has profound implications for promoting undergraduate students' academic success.

This study contributes to the existing literature by attempting to validate the measurements of grit in the setting of academia. Through this, student success may be understood and supported in the context of grit, allowing for methods analogous from the workplace to academia to help students with lower grit scores.

Inclusion and Exclusion Criteria

Participants are undergraduate students at the University of Houston. Age of participants will be 18 years of age or older.

UH graduate students and individuals who are not undergraduate students at the University of Houston are excluded from the study. To exclude undergraduates whose ages are below 18 years old, the principal researcher will inquire about participants' age before they consent to do the survey.

This study excludes adults unable to consent, individuals who are not yet adults (i.e., infants, children, and teenagers), pregnant women, prisoners, students for whom I have direct access to/influence on grades, and economically and/or educationally disadvantaged persons.

Vulnerable Populations

The research involves no more than minimal risk to the subjects.

Number of Subjects

The expected number of participants to be accrued locally is approximately 500 (250 female undergraduate students and 250 male undergraduate students).

The number of subjects who are expected to be enrolled and screened is 550. The number of subjects needed to complete the research procedures is 500.

Advanced statistical techniques (i.e., Structural Equation Modeling (SEM)) will be utilized to analyze the collected data. SEM provides more accurate results relative to conventional methods such as multiple regression and analysis of variance (ANOVA). However, the prerequisite of the accuracy of SEM is large sample size. Given that all psychological assessments utilized in the study are Likert type scale, accurately quantifying such psychological constructs requires advanced statistical techniques such as maximum likelihood (ML) and mean- and variance-adjusted weighted least squares (WLSMV). A number of simulation studies have consistently shown that large sample size is needed for unbiased results (Flora & Curran, 2004; Forero, Maydeu-Olivares, & Gallardo-Pujol, 2009).

Recruitment Methods

LOCAL:

Participants will be recruited from undergraduate classes at the University of Houston through their math classes. Students will access the survey on CASA, the learning management system used by the University of Houston Mathematics department. Using this system will allow for the students to receive extra credit for doing the survey and also allow for the PI to get data on the respondents without identifications.

Study Timelines

The total duration of an individual subject's participation in the study is about 30-35 minutes. All participants are surveyed once. The data will be collected in the academic year of 2020-2021. Collecting data, analyzing data, and reporting results are expected to be done within one year.

Study Endpoints

N/A

Procedures Involved

A total of approximately 500 undergraduate students will be asked to voluntarily complete a survey of self-reported inventories, including a demographic questionnaire and a set of assessment designed to measure grit (21 questions), conscientiousness (9 questions), and beliefs on course performance (3 questions). Confirmatory factor analysis and structural equation modeling will be performed with Mplus to examine the research questions.

Setting

Participants will be asked to complete an online survey.
This study does not involve any community advisory board.

Risks to Subjects

The research involves no more than minimal risk to the subjects.

Potential Benefits to Subjects

There is no direct benefit to subjects.

Provisions to Monitor Data to Ensure the Safety of Subjects

The research involves no more than minimal risk to the subjects.

Withdrawal of Subjects

The survey is voluntary. Subjects are able to refuse to participate in the survey and terminate the survey at any time they want.

Costs/Payments to Subjects

Subjects participate on a voluntary basis.

Confidentiality

The survey does not include any items or questions that inquire about subjects' personal identities such as name, personal ID, and contact information. This study is anonymous.

Provisions to Protect the Privacy Interests of Subjects

N/A

Informed Consent Process

I will be following "SOP: Informed Consent Process for Research (HRP-090)." The PI or co-PI will explain the purpose of the study and make the participants understand what it would be like to take part in the research study before they do the survey. Subjects must first read the cover letter and then check on the "Agree" box to continue with the survey.

Process to Document Consent in Writing

The cover letter (attached in the SmartForm) includes information about the purpose of the research, the expected duration of the subject's participation, the procedures to be followed, and the contact information of the principal investigator and the IRB office for questions, concerns, or complaints about the research. In addition, the cover letter make it clear to the subjects that (1) participation is voluntary; (2) refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled; (3) the subject may discontinue participation at any time without penalty or loss of benefits to which the subject is otherwise entitled.

This study involves no more than minimal risk of harm to subjects. Because subjects need to complete the survey online, it involves no procedures for which written documentation of consent is normally required outside of the research context. Participants must check the online "checkbox" acknowledgement before they do the survey.

I request to waive the requirement to obtain written documentation of consent and will not be following "SOP: Written Documentation of Consent (HRP-091)."

Data Management

Data will be retained on a computer file kept on a password-protected server on CASA at the University of Houston for a minimum of 5 years following completion of the study. The Principal Investigator (i.e., Rebecca George) and Co-Investigators (Dr. Weihua Fan and Dr. Wynne Chin) have access to the de-identified data. Data will not be banked for future use beyond the purpose described in this study.

Analysis will be conducted using Mplus (Muthén & Muthén, 1998–2017). The factor structure of grit will be examined using confirmatory factor analysis (CFA). Structural equation modeling (SEM) will be performed to examine the hypotheses.

Sharing of Results with Subjects

N/A

Resources

This data will be used to help the College of Natural Science and Mathematics with placement of students as well as remediation of students.

I will devote the next few years to conduct and complete the research and get findings published in peer-reviewed journals.

Additional Approvals

N/A