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Predicting STEM performance in a Hispanic serving institution

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ABSTRACT

The present study examined the Big Five factor model of personality and cognitive ability as predictors of academic performance in a sample of non-traditional student STEM majors (n = 342) at a Hispanic-serving two-year college in the United States. Cognitive ability, Agreeableness, and Conscientiousness significantly predicted academic performance; however, main effects of Conscientiousness and Agreeableness were no longer significant after accounting for the interaction of Agreeableness with cognitive ability. Specifically, a significant interaction was observed on Agreeableness for individuals with higher cognitive ability (+1 *SD*). Findings indicate non-traditional STEM students high in cognitive ability may be influenced negatively in academic performance if they possess the trait of Agreeableness. This finding has implications for how personality moderates student academic performance within a non-traditional population quite differently from findings in other studies that have examined more traditional college-going students. Consequently, the present study suggests the interrelationship between Agreeableness and cognitive ability may be an important feature to consider in future work for two-year colleges attempting to retain and support non-traditional students in pursuit of STEM careers, which is particularly notable given the findings center around those with higher ability.

1. Personality and cognitive ability as predictors of STEM performance in a Hispanic serving institution

Postsecondary student enrollment, retention, and success in academic performance in Science, Technology, Engineering and Mathematics (STEM) fields is a significant concern for colleges and universities across the United States. Hispanic serving institutions (HSIs) consistently have lower enrollment, higher attrition, and lower success rates in STEM (Garcia & Hurtado, 2011; NSF, 2015). At the two-year college level 37.9% of Hispanic students enrolling in a STEM associate's degree program changed their major to a non-science field from 2003 to 2009, with 39.9% of Hispanic community college STEM students leaving postsecondary education altogether (Chen & Soldner, 2013). Moreover, the problem of student retention and performance in two-year colleges is amplified by academic deficiencies of students, since two-year colleges are mandated to accept virtually anyone desiring an education (Bettinger & Long, 2009).

Two-year institutions do not rely on standardized test scores or high school GPA to select students they believe will be successful. Instead, two-year college HSIs must implement and rely on mechanisms that support all incoming students despite academic shortcomings in order to retain and graduate as many students as possible in STEM programs. This is necessary to make STEM programs viable and increase access to an underserved population. For administrators and counselors at two-year HSIs, scrutinizing the target population for individual differences as antecedent indicators of obstacles in recruitment, retention, and student performance has become fundamental (Alfonso, 2006).

Traditionally, student performance in STEM has been related to and partially explained by the following three factors: demographics (Crisp, Nora, & Taggart, 2009), traditional pre-college variables (e.g., high school GPA, SAT, and ACT scores; Kaufman, Agars, & Lopez-Wagner, 2007), and math ability (Crisp et al., 2009; Kokkelenberg & Sinha, 2010; Nicholls, Wolfe, Besterfield-Sacre, & Shuman, 2010; Rohr, 2012). However, additional research has shown that in traditional student populations individual differences in personality traits, specifically the Big Five (Kaufman et al., 2007; McAbee & Oswald, 2013; Vedel, Thomsen, & Larsen, 2015), and cognitive ability are related to student performance at the university level (Ackerman, Kanfer, & Calderwood, 2013; Di Fabio & Palazzeschi, 2009; Robbins et al., 2004). Accordingly, investigating traits that have been shown to be related to STEM performance and retention may prove useful for two-year HSIs that do not have the luxury of setting cut-off scores on traditional pre-college readiness assessments (e.g., SAT and high school GPA) to improve institutional rates of student performance.

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To date, most studies have examined personality (Kaufman et al., 2007; McAbee & Oswald, 2013; Vedel et al., 2015) or cognitive ability (Ackerman et al., 2013; Furnham & Chamorro-Premuzic, 2004) separately as predictors of student performance. In some cases, studies have examined personality and cognitive ability together to predict student GPA (Pozzebon, Ashton, & Visser, 2014). However, most studies have been conducted strictly with a traditional college-attending population in four-year institutions. For example, Kaufman et al. (2007) found the Big Five explain a 0.06 change in R^2, but they only included non-cognitive factors to predict student performance in a four-year HSI. In the case of four-year institutions, HSIs have the ability to set a minimum required test score for admission (e.g., minimum SAT scores for admission), which excludes a large proportion of students requiring remediation. As explained above, the situation is quite different for two-year institutions. We were unable to locate any studies that specifically examined how and if personality and cognitive ability change in prediction when dealing with a unique, diverse population of non-traditional students present at two-year HSIs. Thus, the present study aims to examine how personality and cognitive ability can be used to predict the performance of STEM majored students in a non-traditional population at a two-year HSI, and if it is different from previous studies examining cognitive ability and personality with traditional students in four-year institutions.

1.1. Cognitive ability

The relationship between cognitive ability and student performance is well-documented (Di Fabio & Palazzeschi, 2009; Furnham & Chamorro-Premuzic, 2004; Harris, 1940; Robbins et al., 2004). Specifically, cognitive ability has been correlated with university-level statistic test scores, a STEM field (Furnham & Chamorro-Premuzic, 2004), and Fluid intelligence has been shown to be a substantial predictor of students' grade point average throughout school (Di Fabio & Palazzeschi, 2009). Additionally, Crystallized intelligence, as measured through Advanced Placement testing in high school, has been related to first-year undergraduate GPA (Ackerman et al., 2013).

1.2. The five-factor model of personality and academic performance

The relationship of the Big Five to academic performance has been documented by previous research (McAbee & Oswald, 2013; Vedel et al., 2015). Specifically, Poropat (2009) conducted meta-analyses relating the Big Five to academic performance in all academic levels and tertiary school. Poropat (2009) revealed that over 138 studies Conscientiousness ($r = 0.28$) was linked to the highest likelihood of academic performance, which has been shown repeatedly (Bidjerano & Dai, 2007; Kaufman et al., 2007; McAbee & Oswald, 2013; Stajkovic, Bandura, Locke, Lee, & Sergent, 2018). More specifically, Conscientiousness has been shown to be a substantial predictor of student GPA in STEM fields (Vedel et al., 2015). Additionally, Openness to Experience ($r = 0.06$) and Agreeableness ($r = 0.09$), tend to be also positively related (Poropat, 2009; Steinmayr, Bipp, & Spinath, 2011). Moreover, these correlations between academic achievement and personality remain after controlling for cognitive ability (Di Fabio & Palazzeschi, 2009; Steinmayr et al., 2011). While the relationship between the direct relationship between personality and academic performance is clear, research is needed to better understand the interaction between personality and cognitive ability in prediction of academic performance, specifically in STEM majors.

1.3. The interaction between personality and cognitive ability on academic performance

The theoretical interaction between personality and cognitive ability originated from Maier (1958) who posited that an interaction existed between motivation, measured by the Personality Research Form (Jackson, 1974) that is argued to load on a facet of Conscientiousness (Roberts, Chernyshenko, Stark, & Goldberg, 2005), and cognitive ability on job performance. Since then, studies have largely focused on the interaction between Conscientiousness and cognitive ability (e.g., Di Domenico & Fournier, 2015) in regards to academic achievement as measured by GPA. Among the Big Five, Neuroticism and Openness to Experience have been found to interact with cognitive ability (Zeidner, 1995). Bergold and Steinmayr (2018) have most recently investigated interactions between the Big Five and cognitive ability on a German high school sample through two studies. They found a significant moderation between Conscientiousness and cognitive ability on GPA in both studies, and a significant interaction with Neuroticism in study 2. However, Bergold and Steinmayr (2018) found mixed results regarding Agreeableness as there was a small negative interaction between Agreeableness and cognitive ability on GPA in study 1, but no construct level interaction in study 2. As such, it is important to further explore the interaction between personality and cognitive ability on academic achievement, specifically STEM performance.

1.4. Purpose of the present study

The present study aims to examine the additive (direct effects) and multiplicative (interaction effects) influence of the Big Five and cognitive ability on the performance of students majoring in STEM as measured by cumulative grade point average in a two-year HSI. We hypothesized, based on the relationships found in traditional student populations (e.g., Stajkovic et al., 2018; Vedel et al., 2015), that Conscientiousness, cognitive ability, and their interaction would be positive predictors of STEM performance within the unique population of non-traditional students containing over 50% Hispanic enrollment. However, due to the conflicting results regarding the remaining four personality traits across previous studies (McAbee & Oswald, 2013; Poropat, 2009; Stajkovic et al., 2018), we make no prediction on the directionality or influence of Neuroticism, Extraversion, Openness to Experience, and Agreeableness and aim to explore these relationships with STEM performance of a non-traditional population.

2. Method

2.1. Educational institution

The host two-year college is a mid-sized institution (approximately 10,000 students), serving a student body comprised of a substantial portion of non-traditional students. Specifically, the mean age of the student body is 25.9 years. The student population is ethnically diverse (54.4% Hispanic, 20.8% African American, 9.7% White, 9.4% Pacific Islander, and 6.0% other), and the college is recognized by the U.S. Department of Education as a HSI. Further, the college draws from a population that is substantially economically disadvantaged, evidenced by the fact that the most recent data (2015–2016) reveals 30.8% of the student population received the need-based Pell grant and 50.5% of the STEM Student Population received the need-based Pell grant. In addition, 84.6% of the student population attends part-time which is higher than the state average of 76.2%, and nearly 40% of the first year student population is performing under the state average for Developmental Education in Math, Reading, and Writing.

2.2. Participants

Participants (n = 390) enrolled in STEM programs at a two-year college in the southern United States. From this sample, 48 participants did not complete the survey or answered uniformly on each measure (e.g., five participants answered “1” on every item). There were no substantial demographic differences between the original sample and the remaining 342 participants. From the remaining sample, 65.9% of the sample was Hispanic, 9.2% was Caucasian, and 15.9% Black. Additionally, 54.5% were women and the mean age of the sample was 21.1 years ($SD = 5.8$ years). The mean GPA was 2.97 ($SD = 0.61$) on a 4.0 scale, and the mean number of credit hours completed was 44.8 h ($SD = 36.9$ h).

2.3. Procedure

Students participated in-group and individual sessions at the beginning of the semester. During the group sessions, participants completed five questionnaires while the individual sessions consisted of special reasoning tests. Researchers collected demographic information (e.g., gender, ethnicity, and age) and contact information to follow-up with participants for further information. Moreover, participants received an ID number used during all tests, questionnaires, and analyses. Consequently, the aggregate data used in the present study remained anonymous throughout, with no unique identifiers of individual participants.

2.4. Measures

2.4.1. STEM major student performance

Measured by students' cumulative grade point average (GPA) at the conclusion of their program.

2.4.2. The Big Five factors of personality

A 50-item self-report questionnaire was used to measure the five factors of personality. The five factors: *Neuroticism*, *Extraversion*, *Openness to Experience*, *Agreeableness*, *and Conscientiousness* are evaluated through items selected from the International Personality Item Pool (IPIP; Goldberg, 1992). Items are on a 5-point Likert scale ranging from “Strongly Disagree” to “Strongly Agree.” The alpha coefficients ranged 0.76 to 0.85 with Openness to Experience being the lowest and Neuroticism being the highest.

2.4.3. Barratt simplified measure of socioeconomic status (BSMSS)

Based on marital status, education level, and occupation of self, spouse, and parents, the BSMSS is a modification to the classical Hollingshead Four-Factor Measure of Social Status (Barratt, 2006; Hollingshead, 1975). Specifically, it measures socioeconomic statuses (SES) in relation to education, household income, and occupation on a continuous scale where total scores range 8 (low SES) to 66 (high SES).

2.4.4. The wonderlic personnel test

A 50-item test administered over 12 min designed to measure cognitive ability with a strong correlation to the WAIS-R ($r = 0.92$; Wonderlic, 1992). Scores range from 0 to 50 with items including word and number comparisons.

2.4.5. Shipley-2

A revised and re-standardization of the *Shipley Institute of Living Scales* used to assess cognitive function of ages 7–89, it measures *crystalized and fluid intelligence* through three tests: vocabulary, abstraction, and block. The test is scored by combining two scores (verbal and block), each with a mean of 100 and a standard deviation of 15. These measures can be used to approximate general cognitive ability (Shipley, Gruber, Martin, & Klein, 2009). The test-retest coefficients across all three categories ranged from 0.74 to 0.94 across a two-week interval demonstrating stability (Kaya, Delen, & Bulut, 2012).

2.4.5.1. Shipley-2 vocabulary. Measures *crystalized intelligence* through a 40-item dichotomous multiple-choice exam where respondents have 12 min to choose the answer that means the same or is nearly the same as the word provided. In the present sample $\alpha = 0.69$.

2.4.5.2. Shipley-2 block patterns. Measures *fluid intelligence* in the visual/spatial domain through 12 black and white block patterns for a total of 26 items, where scores range from 0 to 26 (Shipley et al., 2009). The 12-minute timed test requires the participant to complete the block pattern by selection one of four answer choices such that the larger block pattern matches a smaller complete pattern. In the present sample $\alpha = 0.88$.

Table 1
Descriptive statistics for all continuous variables (n = 342).

Variable	Mean (*SD*)	Skewness	Kurtosis
GPA	2.97 (0.651)	−0.845	0.910
Cognitive Ability	100.50 (15.03)	−0.293	−0.106
Shipley Block Patterns	16.41 (5.08)	−0.397	−0.236
Shipley Vocabulary	25.86 (5.03)	−0.476	0.438
Wonderlic	19.13 (5.50)	0.431	0.102
Neuroticism	23.46 (7.97)	0.368	−0.387
Extraversion	32.52 (8.46)	−0.262	−0.308
Openness to Experience	36.10 (7.17)	−0.698	0.251
Agreeableness	36.73 (7.31)	−0.901	0.597
Conscientiousness	35.00 (8.27)	−0.539	−0.231

Note. *SD* = Standard deviation.

3. Results

3.1. Data analysis

All variables were examined for normality, homogeneity of variance, the presence of outliers, and missing values on each individual variable. Descriptive statistics are presented in Table 1. Shipley and Wonderlic scores were combined into one cognitive ability score with a mean of 100 and a standard deviation of 15 because the educational institution switched cognitive ability measures in the last year of the study. Following this, regression was used to predict STEM major performance using IBM SPSS Statistics, Version 25.

3.1.1. Predicting STEM majored student performance in a HSI

Personality and cognitive ability were regressed on STEM majored student performance as measured by GPA, F (6, 335) = 2.210, $p = .042$, $R^2 = 0.038$. Adjusted $R^2 = 0.021$ indicating 1.7% shrinkage in explained variance occurred due to a theoretical correction for sampling error. Correlations between variables are reported in Table 2 and the regression model is reported in Table 3.

Out of the Big Five, Conscientiousness ($\beta = 0.012$, $r_s = 0.180$, $p = .043$) and Agreeableness ($\beta = -0.178$, $r_s = -0.409$, $p = .031$) had the largest structure coefficients and strongest prediction of student academic performance. However, the structure coefficient for Conscientiousness was small suggesting it explains unique variance beyond Agreeableness and cognitive ability. Additionally, cognitive ability was a statistically significant predictor that could account for 44.5% of the explained variance in the model, $\beta = 0.141$, $r_s = 0.667$, $p = .012$. Moreover, when the analysis was controlled for sex and SES, there were no significant differences and 0% change in R^2. Adding sex and SES after personality and cognitive ability provided no additional explained variance. Sex differences were explored by testing interactions between sex and the predictor variables. These interaction analyses revealed no statistically significant interactions and a 0.014 change in R^2.

3.1.2. Interactions between personality and cognitive ability on STEM performance

Hierarchical regressions were then conducted to test interactions between the Big Five and cognitive ability for each of the Big Five in addition to the original regression model after centering each predictor with specific results for Agreeableness provided in Table 3.

No significant interactions were identified for four of the Big Five dimensions (Neuroticism, Extraversion, Openness, and

Table 2
Correlation matrix for personality and cognitive ability with STEM Success.

	1	2	3	4	5	6	7
GPA	–						
Cognitive ability	0.130*	–					
Neuroticism	−0.029	0.056	–				
Extraversion	−0.023	−0.045	−0.040	–			
Openness to experience	−0.014	0.159**	0.141**	0.680**	–		
Agreeableness	−0.080	0.029	0.126*	0.571**	0.702**	–	
Conscientiousness	0.035	−0.017	−0.035	0.533**	0.624**	0.638**	–

Note. *$p < .05$; **$p < .01$.

Conscientiousness). However, after including the interaction between Agreeableness and cognitive ability, the overall model explained an additional 1.44% variance in STEM performance, F (7, 334) = 2.608, $p = .012$, $R^2 = 0.052$, $\Delta R^2 = 0.014$. The main effects of Agreeableness ($\beta = -0.155$, $r_s = -0.351$, $p = .060$) and Conscientiousness ($\beta = 0.137$, $r_s = 0.154$, $p = .071$) were no longer significant predictors in the model; however, cognitive ability remained significant, $\beta = 0.123$, $r_s = 0.572$, $p = .030$.

Simple slope analysis reveals association between STEM performance and Agreeableness was stronger at higher levels of cognitive ability as shown in Fig. 1. More specifically, the group with higher cognitive ability (+1 *SD*) had the strongest association between Agreeableness and STEM performance ($t = -2.969$, $p = .003$). Additionally, there was a statistically significant interaction for the average cognitive ability group ($t = -1.963$, $p = .050$); however, the low cognitive ability group (−1 *SD*) had no significant relationship between Agreeableness and STEM performance, $t = -0.479$, $p = .632$. Furthermore, the region of significance for the association between Agreeableness and STEM performance began at a centered cognitive ability score of 105.5, suggesting a significant correlation between Agreeableness and STEM performance for students with cognitive ability > 105.5 (Fig. 2).

4. Discussion

The present study makes three unique contributions: (a) the outcome of academic performance was limited to only students participating in STEM academic programs; (b) the study sample represents two-year college students, which are rarely studied for individual differences and could be argued to possess greater variation in cognitive ability due to the (lack of) screening measures for admission at two-year colleges, as well as a substantial portion of the sample being Hispanic; and (c) we possessed individual differences measures on both cognitive ability and personality of participants. Our initial analysis provided marginal support for the direct role of personality variables and cognitive ability in the prediction of academic performance. Specifically, Conscientiousness and cognitive ability, as hypothesized, both positively predicted STEM performance albeit the effect size was small. This result is consistent with prior studies on the importance of Conscientiousness (Bidjerano & Dai, 2007; Kaufman et al., 2007; McAbee & Oswald, 2013; Vedel et al., 2015) and cognitive ability (Ackerman et al., 2013; Di Fabio & Palazzeschi, 2009; Furnham & Chamorro-Premuzic, 2004) in prediction of academic performance. Interestingly, Agreeableness was the strongest predictor of STEM performance among the personality variables – it had both the largest structure coefficient and beta weight. Additionally, when controlling for demographic variables, each demographic variable (e.g., sex and SES) explained < 2% of the variance explained in STEM performance in the model. These results suggest personality and cognitive ability are not strong predictors of STEM student success in non-traditional populations seen in two-year HSI institutions. It is worth nothing that Neuroticism, Openness to Experience, and Extraversion had particularly small beta weights and structure coefficients meaning that they did not account for any unique variance explained. It is likely that, in this sample, they do not adequately help predict STEM majored student performance, which is further reinforced by the low correlations with GPA seen in Table 2.

When examining interaction effects, only Agreeableness provided incremental prediction (1.44%) in performance of STEM majors above and beyond cognitive ability. This result is supported by the findings from study one in Bergold and Steinmayr (2018) which found a significant pattern between high Agreeableness, cognitive ability, and academic performance. However, the present results did not find an interaction between Conscientiousness and cognitive ability in prediction of academic performance found in previous studies (Bergold & Steinmayr, 2018; Di Domenico & Fournier, 2015).

Table 3
Hierarchical regression model of personality and cognitive ability on GPA (n = 342).

	R^2	ΔR^2	*b*	*SE*	β	r_s	${r_s}^2$	*p*
Step 1	0.038							0.042*
Neuroticism			−0.001	0.005	−0.006	−0.147	0.022	0.917
Extraversion			0.001	0.006	0.014	−0.118	0.014	0.859
Openness to experience			−0.001	0.008	−0.016	−0.072	0.005	0.863
Agreeableness			−0.016	0.007	−0.178	−0.409	0.167	0.031*
Conscientiousness			0.012	0.006	0.153	0.180	0.032	0.043*
Cognitive ability			0.006	0.036	0.141	0.667	0.445	0.012*
Step 2	0.052	0.014*						0.012*
Neuroticism			−0.002	0.005	−0.027	−0.126	0.015	0.631
Extraversion			0.001	0.006	0.007	−0.101	0.010	0.930
Openness to experience			−0.003	0.008	−0.030	−0.061	0.003	0.744
Agreeableness			−0.014	0.007	−0.155	−0.351	0.123	0.060
Conscientiousness			0.011	0.006	0.137	0.154	0.024	0.071
Cognitive ability			0.080	0.037	0.123	0.572	0.327	0.030*
Cognitive ability × Agreeableness			−0.010	0.005	−0.123	−0.632	0.399	0.028*

Note. b = unstandardized coefficients; SE = standard error; β = standardized coefficients; r_s = structure coefficients; ${r_s}^2$ = squared structure coefficients. *$p < .05$; **$p < .01$.

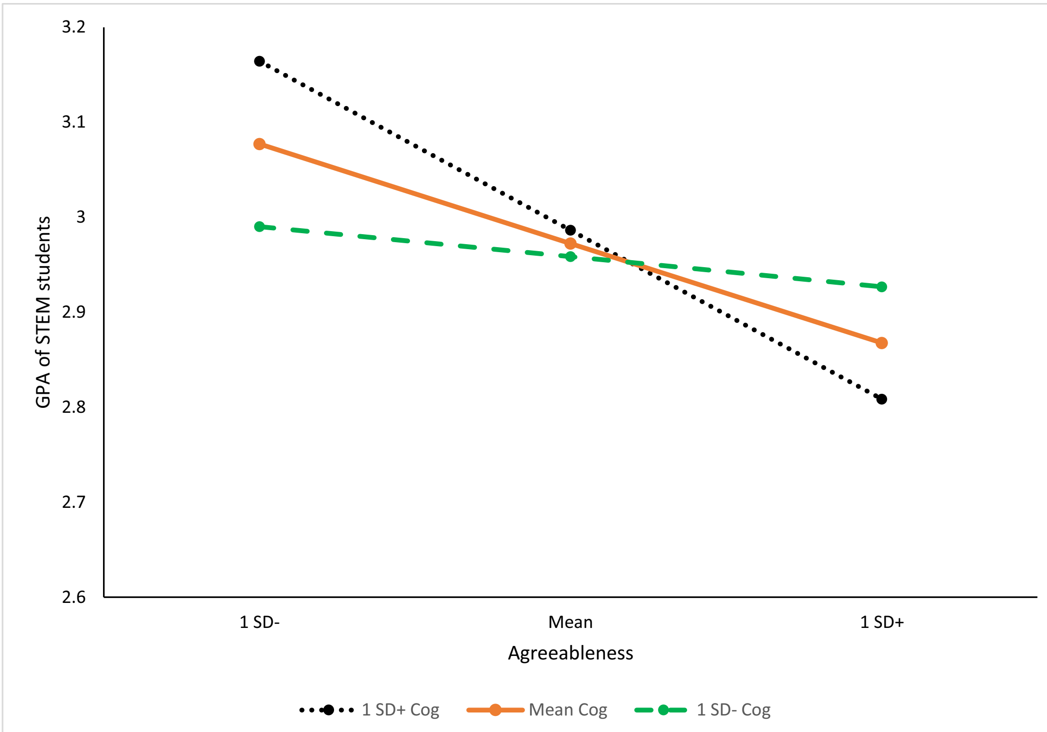

Fig. 1. Interaction between Cognitive Ability and Agreeableness on GPA of STEM Students.

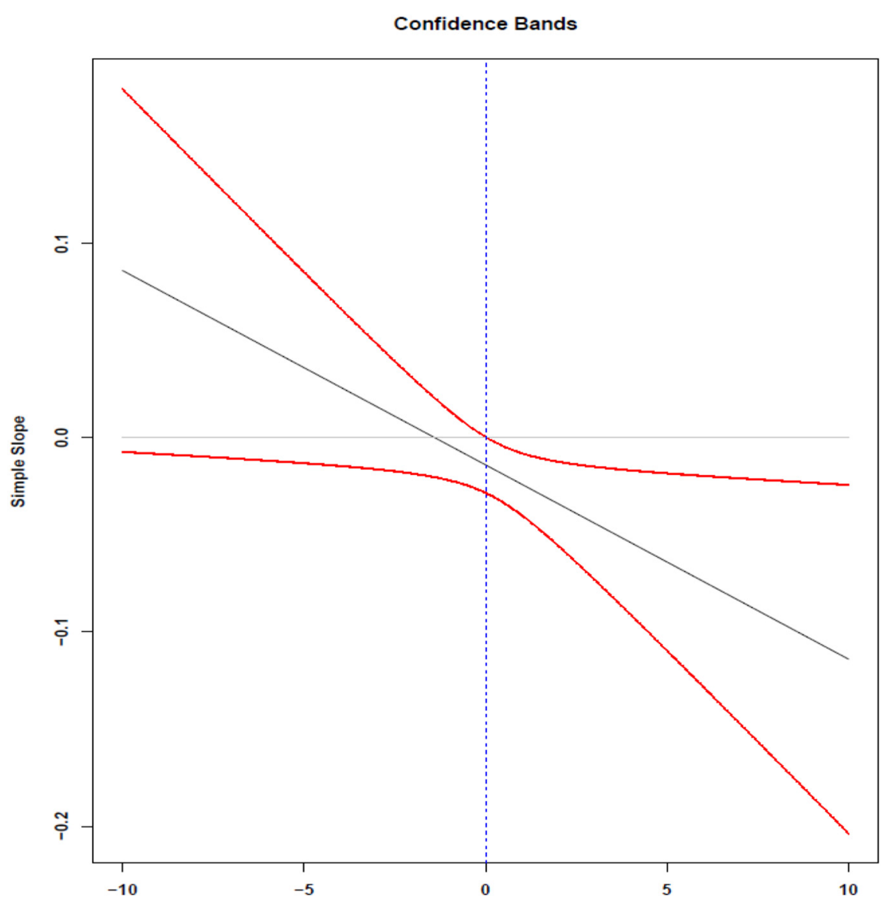

Fig. 2. Region of significance of cognitive ability.

Interestingly, there was a significant relationship between Agreeableness and cognitive ability once individuals were slightly above mean cognitive ability (> 105.5). This is perhaps the first direct replication of this interaction originally reported by Bergold and Steinmayr (2018). This replication with a largely Hispanic sample comprised of STEM majors suggests high Agreeableness is detrimental to academic performance among students with average or high cognitive ability, likely made possible by observing students with greater variance in cognitive ability. We consider it plausible that students high in cognitive ability that also possess the trait of Agreeableness may encounter incompatibility in performance in STEM courses where objectivity is preferred over learning from others, particularly in group projects or with lab partners. It is conceivable that such students acquiesce to findings suggested by others. As for the pernicious drop in academic performance below even those students that possess low cognitive ability, students with high cognitive ability may experience performance anxiety in STEM courses, spending excessive time preparing for tests or working on tasks that do not pose great difficulty.

Given the nature of the sample for the present study, we cannot ignore the possibility of this interaction effect in relation to Hispanic culture and/or first generation college goers. We postulate it is plausible these groups possess an achievement goal framework known as performance-avoidance (Elliot & McGregor, 2001; Van Yperen, 2006) at the upper end of the cognitive ability continuum, where incompetence relative to others is avoided, resulting in anxiety, negative affectivity, amotivation and lower performance attainment. Agreeableness has been shown to be related positively to mastery-approach goals and negatively related to performance-approach goals, where "agreeableness could be fundamental in explaining how people act socially in achievement contexts" (McCabe, Van Yperen, Elliot, & Verbraak, 2013, p. 704). How performance- vs. mastery-approach goals are associated with cognitive ability is uncertain, thus more research in this area with these populations is warranted since the implications would be important for HSIs in how they approach retention in STEM and student performance in terms of academic achievement.

The lack of prediction from trait-based identification (i.e., personality and cognitive ability) that are relatively stable over time (Aschwanden, Martin, & Allemand, 2017; Costa & McCrae, 1988) highlights the importance of focusing on other permeable external factors that could lead to the success and retention of non-traditional students seen in two-year institutions. Consequently, the results tend to support the yearly $100 million invested into broad-based retention strategies HSI programs implement through Title V grants (U.S. Department of Education, 2015). These strategies can be particularly useful for identifying external factors needed to aid and support potentially at-risk students to help colleges regularly and accurately identify who needs more resources to succeed. While these institutions provide a variety of remedial activities/courses, and support options for students and in particular STEM students, knowing who is likely to require more support permits intervention before the student truly becomes "at risk."

A limitation of the present study is that previously identified factors that influence STEM student performance are not identified in the model including mathematic ability, motivation, high school GPA, ACT/SAT scores, and AP test scores (Crisp et al., 2009; Kaufman et al., 2007). Future studies could look to include these individual-level variables and college-level variables to create a better model in predicting STEM performance. Additionally, future research should examine other external mechanisms that help universities and colleges identify students that are potentially at risk for failure in STEM classes or ways to institutionalize preemptive support to maximize participation and completion of STEM programs. Helping students before they need real help is important if they are to pursue and integrate into STEM fields.

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