

Cognitive and Non-Cognitive Variables Affecting Academic Performance in College Students

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Abstract

Recent research indicates an important role for non-cognitive variables in learning by college students. The present study was conducted to explore the relationships among growth mindset, self-efficacy, grit, Lumosity cognitive training, and academic performance, particularly in underprepared college students. Results could suggest how to improve academic performance of these students. Out of 117 possible participants, 83 (47 males and 36 females) who were enrolled in either a general psychology (GP), a freshman seminar (FS), or a remedial study skills (RSS) course completed two surveys. One survey was sent within the first 4 weeks of the semester and a second during the last 3 weeks of the semester to measure growth mindset, self-efficacy, and grit. Between those surveys, Group RSS participated in Lumosity, a collection of web-based games, and underwent intensive growth mindset, grit, and self-efficacy interventions. Group GP had basic exposure to growth mindset concepts. Group FS was the control group with no interventions. When comparing beginning and end survey results, we found significant improvement in self-efficacy across Groups FS (paired samples Wilcoxon test, $p < 0.001$) and RSS ($p = 0.048$). Group FS significantly improved in grit ($p < 0.001$), and Group RSS showed almost significant improvement ($p = 0.087$). Group GP, which included more than 50% non-freshman, showed almost significant increases in grit ($p = 0.052$) but not in self-efficacy. In linear regression analyses, growth mindset and grit were significant predictors of self-efficacy. Lumosity cumulative performance, attention, and flexibility scores increased significantly (paired t-tests, $p < 0.025$) but were not predicted by our non-cognitive measures. In spite of improvements in non-cognitive variables, it is uncertain why the improvements occurred or whether they are predictive of cognitive performance. We hope to clarify these questions by analyses of the relationship between non-cognitive variables and grade point averages.

Keywords: Growth Mindset, Grit, Self-Efficacy

1. Introduction

The way we view learning and teaching is evolving to include new psychological concepts of the way we think and view ourselves. These approaches may benefit in understanding the different and effective ways to prepare the underprepared college student for academic success. Furthermore, comprehension and application of these approaches may increase cognitive abilities as a whole. In addition, the utilization and metamorphosis of a student's preconceived assumptions regarding their own capacity and ability to acquire new knowledge and skillsets may have a positive impact on a student's actual acquisition of and proficiency in a new skill or subject matter. The aforementioned concepts are ideas that characterize the present study. We have investigated the possibility that students' academic performance can be enhanced through cognitive games amassed with interventions intended to modify the students' way of thinking about their own abilities and motivations. The study described here was designed to examine the effects of two different types of interventions -- participation in Lumosity games and lessons to enhance self-efficacy, growth mindset, and grit.

1.1 Cognitive Training

Lumosity is a site that is meant to challenge your cognitive abilities through computer games that Lumosity scientists have designed¹. The motivating design is that humans can use simple but moderately interesting games to improve cognitive functioning. These games are comprised of activities to enhance abilities in five areas of cognition -- problem solving, speed, attention, memory, and flexibility. The Lumosity software calculates scores in each of these five areas, along with a Lumosity Performance Index (LPI), which is a composite score of overall cognitive ability. Although the formulas used to calculate these scores are unknown to this author, the resulting data did provide a basis for our investigation of how improvement on Lumosity games is related to the real-world outcomes of academic performance by underprepared college students.

The plethora of literature has been published to establish a critical groundwork on the effectiveness of cognitive training. A meta-analysis of this research suggests that there is some discord among the results -- some investigators find that cognitive training is a successful in producing the desired effects, others say it is inefficient². While an overview of studies regarding cognitive training indicates that aerobic exercise might be the best task to improve cognitive abilities³, this does not discount the benefits of the cognitive training. Most studies seem to agree that you need some sort of cognitive stimulation, but some forms seem to work better than others. Some research has had intriguing results supporting the effectiveness of cognitive training, the literature that counters it calls into question the methodology of the studies, such as the methods of measuring cognitive abilities and the tasks that are used to improve them⁴. Lumosity games can be a tool for increasing various core cognitive abilities, including speed of processing, working memory and fluid reasoning⁵. Participants in a recent study by Hardy and associates, comprising of over 10,000 recruited Lumosity account holders and members between the ages of 18 and 80, also reported improvements in cognitive functioning related to the ability to concentrate⁶. The participants in this study who went through cognitive training seemed to fare better than the group who utilized crossword puzzles for cognitive stimulation⁷. This result indicates that some forms of exercising cognitive functions are more useful than others, particularly that cognitive training can play a more beneficial role in exercise.

1.2 Self-Efficacy, Growth Mindset, and Grit

Affective variables or non-cognitive variables, such as self-efficacy, growth mindset, and grit, may also influence academic performance. Self-efficacy is the belief one has in their own ability “to organize and to execute” a plan to attain a goal⁸. Cassidy⁹ has shown that self-efficacy training can enhance certain responses to adversity and improve academic resilience. In a meta-analysis of the academic self-efficacy literature, similar results were found for the relationship between academic self-efficacy and academic performance¹⁰. Having a growth rather than a fixed mindset has been found to promote the enhancement of an ability¹¹. A growth mindset is the belief that one’s intelligence is malleable¹². Essentially, it is a belief that one can do better with effort, as opposed to helplessly believing that one will never get better grades, or get to the next level in a game, etc. In relation to cognitive training, this could be the belief that the cognitive training will actually aid in the improvement of cognitive functions (a growth mindset), or that it is a “waste of my time” and one may as well click through the game (a fixed mindset). Another important aspect of improving a student’s academic performance is the concept of grit. This is the idea of sticking it out and working hard to obtain a goal¹³. There is evidence that grit predicts the ability to overcome challenge and obstacles¹⁴. Intervention focusing on these concepts could result in the development of cognitive functions.

1.3 Hypotheses

The present study was designed to investigate the effects of cognitive training and mindset interventions in underprepared college students. The overarching goal was to understand if cognitive training, specifically Lumosity, could actually benefit the cognitive abilities of underprepared college students, resulting in an improvement in academic performance. In addition, improvement in academic performance should also be a response to non-cognitive variables, which should be affected by the interventions put into place. Seeing these real world outcomes would be indicative of the effects of the intervention and cognitive training, and would further encourage the usage of these tools to help aid improvement in students’ performance.

Considering the results of previous studies, such as cognitive abilities being enhanced by Lumosity in older adults¹⁵, greater cognitive improvement due to Lumosity than due to another form of cognitive stimulus (crosswords)¹⁶, and unpublished work conducted at Bethel College regarding cognitive training, the prediction was that all of the Lumosity

scores would increase over time. The analyses were also designed to explore possible relationships between the Lumosity scores and non-cognitive variables. The expectation was that the remedial study skills group (Group RSS) would show the greatest improvement in the non-cognitive variables due to the participation in self-efficacy, grit, and growth mindset interventions. The last exploratory analysis looked into whether any of the cognitive or non-cognitive variables were predictive of the participants' semester grade point averages.

2. Methodology

2.1 Participants

Group RSS (remedial study skills) had 24 participants, 3 females and 21 males, 16 of which were used in analyses. Group FS (freshmen seminar) had 74 participants, 38 of whom were female and 36 were male. Group GP (general psychology) had 19 subjects, 11 females and 8 males. While Group RSS and Group FS were all-freshmen groups, Group GP had 9 freshmen but 10 upperclassmen.

2.2 Procedure

At the beginning of the 2015-16 school year we distributed a self-efficacy, growth mindset, and grit survey to all of the freshmen at Bethel College. Group FS served as a control group. The professors of the freshmen seminar course were instructed to encourage their students to participate and take the survey. The subjects in this course had no directed cognitive training or growth mindset intervention. Group GP, students in a General Psychology course, naturally received some explicit instruction on affective variables, but had no directed cognitive training. Each group took the same survey at the beginning of the academic year, approximately within the first four weeks.

Group RSS was the condition of primary focus. As students in a course of remedial study skills, the participants in this group are considered “underprepared college students.” The criterion of this course was that students came in with low high school grade point averages and/or standardized test scores and might have needed extra help to get through college-level courses. This group initiated Lumosity cognitive training at the start of the school year along with a curriculum consisting of units of growth mindset training, both of which continued regularly throughout the semester. Again, the same survey was administered at the start of the academic year as with the other conditions.

About three weeks before the end of the Fall 2015 semester, we asked that the participants in all conditions repeat the survey. In January of 2016, we gained access to the participants' Fall 2015 semester grade point averages, which were based upon the grades of all the classes that each participant was enrolled in. When all the data were available, a multitude of correlational analyses' and two-sample tests were executed. In order not to miss potentially important relationships in this exploratory study, we decided to use p-values that were not corrected for the number of tests conducted, however a standard 0.05 p-value cutoff was used. Some participants had to be dropped due to not completing the initial and the post survey; thus, we had usable data from 17 participants (3 females, 14 males) in Group RSS, 50 (24 females, 26 males) in Group FS and 16 (9 females, 7 males) in Group GP. A diagram summarizing the procedure is shown in Figure 1.

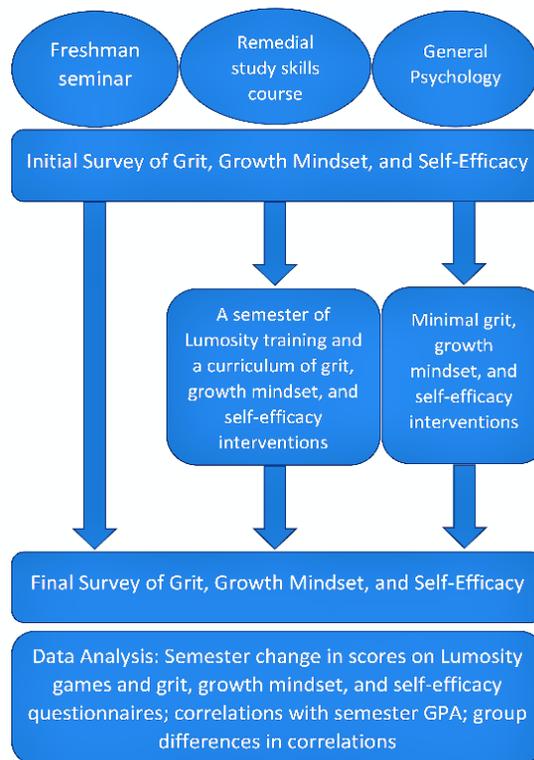


Figure 1. Procedure Outline

2.3 Instruments

R¹⁷ and R Commander¹⁸ were used to conduct statistical tests and create the graphs of the data. In addition, the Lumosity website was used to potentially increase cognitive functions and abilities, allowing access to the website's scores for use as the measures of cognitive ability for the analysis.

The survey was a combination of self-efficacy, growth mindset¹⁹, and grit surveys²⁰, used in previous experiments to assess the individual's perception of how much they affirm various statements to measure these non-cognitive variables. Included in the survey was an additional question asking if you affirm the statement "Through hard work and effort, you can increase your basic intelligence significantly." This survey was done in a rating or Likert-type scale fashion. The ratings such as "Strongly Agree" to a statement affirming growth mindset were coded with the highest point, 6. Ratings such as "Strongly Disagree" to an affirming statement would receive a 1. When the statement or question was not affirming growth mindset the codes were reversed with "Strongly Disagree" being a 6 and "Strongly Agree" being a 1. For self-efficacy, the scale was between 1 to 5, with 1 being "Not at all confident" and 5 being "Completely Confident" if the statement was affirming the non-cognitive variable. The scale was reversed if it was not affirming self-efficacy. Lastly, grit questions were coded on a five point scale with 1 being "Not like me at all" and 5 being "Very much like me" if grit was being affirmed and again the scale was reversed if grit was not being affirmed. All of the participants had composite scores for each non-cognitive variable, which were calculated by summing the codes to the questions related to that specific variable. This overall score can be interpreted with the higher scores being a stronger affiliation with that non-cognitive variable, and lower scores being a weaker affiliation. It was this score that was utilized in our analyses' as measures of the non-cognitive variable.

3. Results

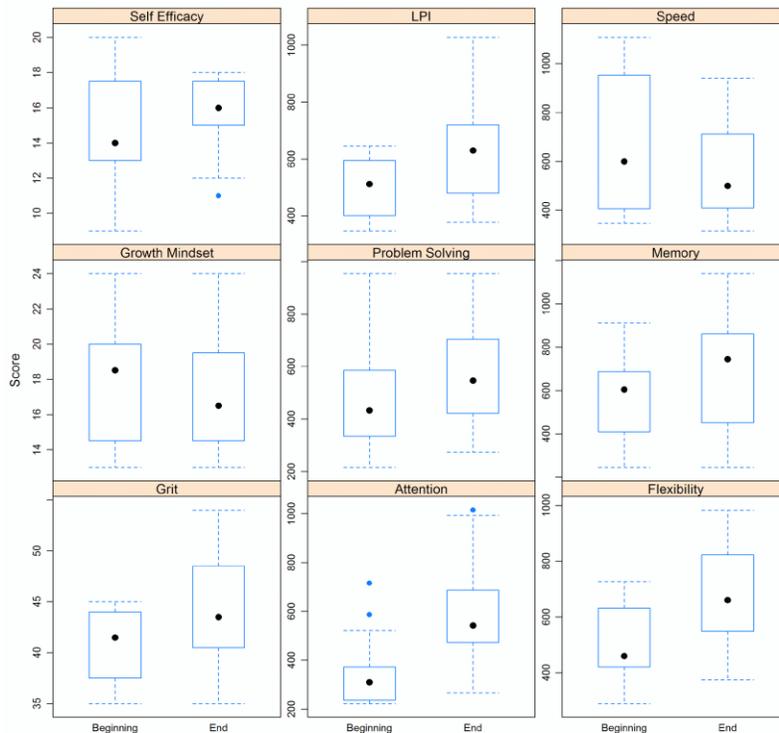


Figure 2. Boxplots showing scores at the beginning and end of the semester for both non-cognitive (the three panels on the left) and cognitive game variables within Group RSS

The series of boxplots above (Figure 2) show the beginning-to-end changes within Group RSS for all of the studied variables. Using a paired-samples Wilcoxon test (due to the non-normal distributions) we analyzed the before and after scores from the survey and the cognitive games with a 0.05 p-value cutoff. Significant changes were found in all of the cognitive variables: LPI (Wilcoxon $V = 1$, $p < 0.0001$), Problem Solving (Wilcoxon $V = 14$, $p < 0.01$), Attention (Wilcoxon $V = 2$, $p < 0.0001$), Speed (Wilcoxon, $V = 103$, $p < 0.02$), Memory (Wilcoxon $V = 10$, $p < 0.02$), Flexibility (Wilcoxon $V = 0$, $p < 0.001$). The non-cognitive or affective variables did not significantly increase over time. Although self-efficacy appeared to have improved as the semester went on it was not significant (Wilcoxon $V = 27.5$, $p = 0.12$). There was no significant change for growth mindset. The growth in regards to grit came very close to significance (Wilcoxon $V = 26$, $p = 0.06$). These results indicate that the intervention employed in this study was not successful in changing growth mindset, although grit and self-efficacy may have been slightly enhanced.

It is important to note that while the changes in all of the cognitive variables were statistically significant, Speed significantly decreased. It may be that this reduction arose from participant's efforts to improve the other aspects of performance. By slowing down, participants were able to maintain their attention on the training. Figure 3 shows the correlation between the change in speed and semester GPA, $r = 0.376$, $p = 0.15$. This shows that although there were overall decreases in their performance, there is a possibility that the less of a decrease you have the higher the participant's GPA.

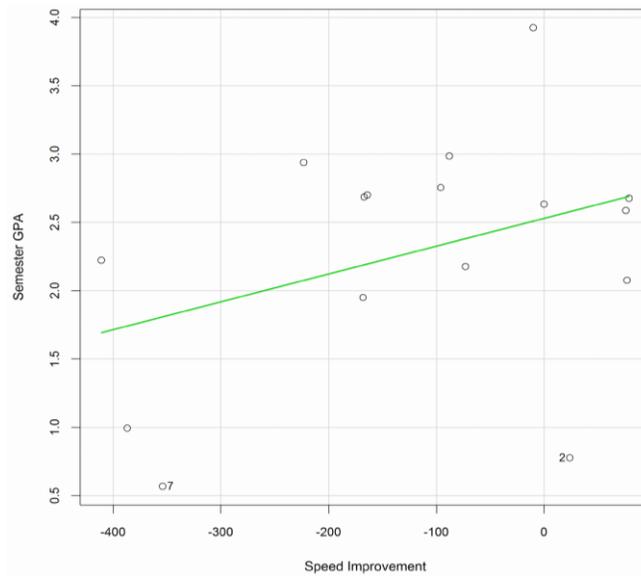


Figure 3. Scatterplot showing the moderate relationship between semester GPA and the improvement of the speed variable

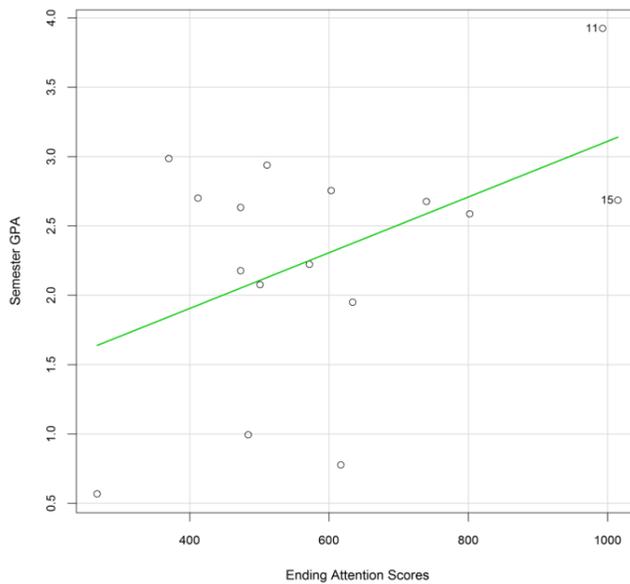


Figure 4. Scatterplot showing the moderate relationship between semester GPA and ending attention scores

Attention had a nearly significant correlation with semester GPA. There is a moderate positive correlation, $r = 0.48$, $p = 0.062$, between the two variables (Figure 4). This result indicates that if an individual has higher attention scores, they tend to have a higher GPA.

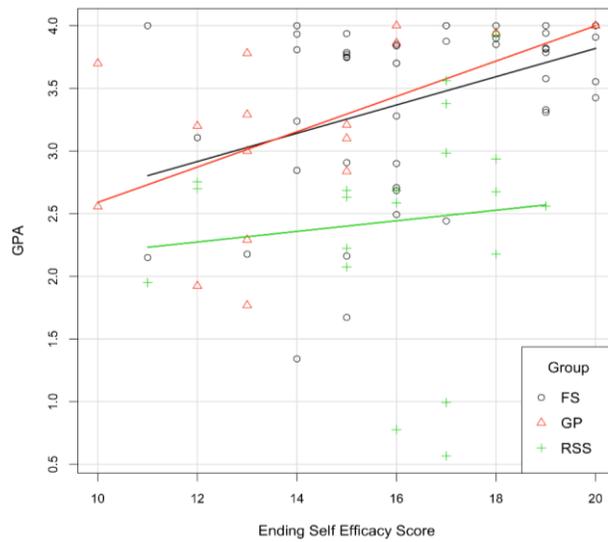


Figure 5. Scatterplot showing the different relationships between semester GPA and ending self-efficacy scores within each group

There were many correlational analyses' run to test whether semester GPA correlates with the end scores of any of the non-cognitive variables. These analyses' were run for group comparisons. Two of the three the non-cognitive variables were positively correlated in at least one of the groups. Figure 5 shows the correlation between semester GPA and self-efficacy. Group GP had the strongest positive correlation, $r = 0.52, p < 0.04$; Group FS with a positive moderate correlation, $r = 0.39, p < 0.01$, while the Group RSS had almost no relationship, $r = 0.11, p = 0.653$. The only group for which this relationship was not significant was Group RSS.

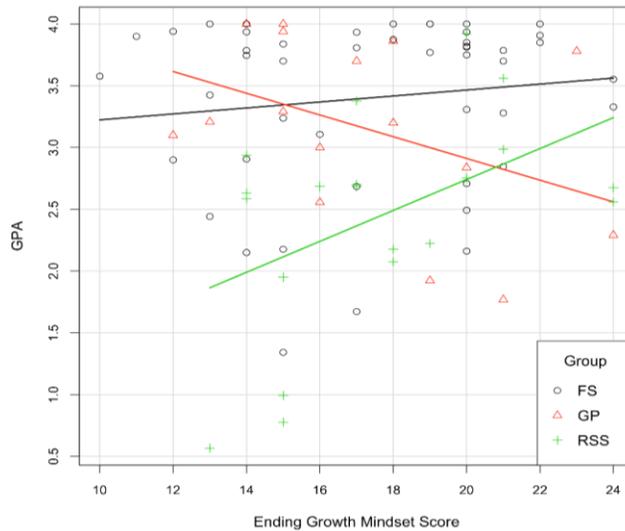


Figure 6. Scatterplot showing the different relationships between semester GPA and ending growth mindset scores within each group

Semester GPA and ending growth mindset score (Figure 6) had a positive relationship in Group FS, $r = 0.13, p = 0.400$, and RSS, $r = 0.47, p = 0.035$, and negative in Group GP, $r = -0.42, p = 0.107$. Group GP was a deviant and will be discussed in the conclusions. As for Group RSS, the higher the growth mindset score, the higher the GPA. This group did not increase in their growth mindset, nor were their scores higher than the other groups. These results indicate that the more of a growth mindset an underprepared college student has, the more capable they are of a higher

GPA. This was the group that showed little relationship of GPA to self-efficacy (Figure 5), suggesting that their grades are more because of their belief in their ability to change rather than their ability to control the outcome.

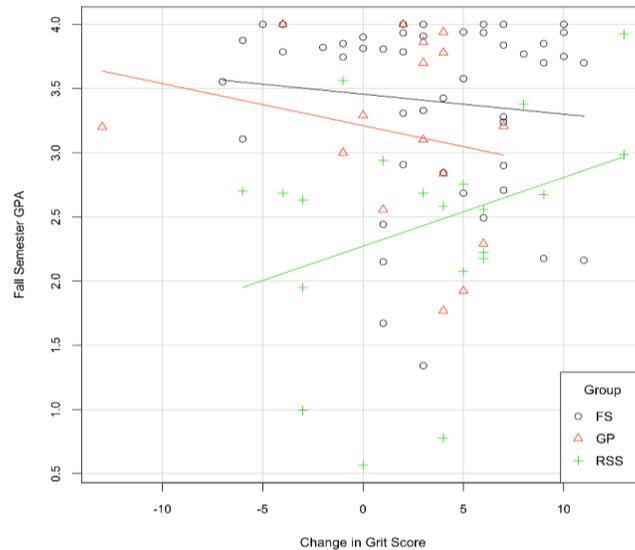


Figure 7. Scatterplot showing the different relationships between semester GPA and improvement in grit scores within each group

The analysis of ending grit scores revealed no relationship to semester GPA. In order to add another dimension of analysis to the study, we explored possible correlations between semester GPA and the change in grit scores. A positive relationship was discovered in the RSS group, $r = 0.34$, $p = 0.145$. Group GP, $r = -0.220$, $p = 0.423$, and Group FS, $r = -0.110$, $p = 0.468$, both had a negative relationship between GPA and change in grit score. Although the relationship between semester GPA and grit in Group RSS was not significant, it does indicate that these individuals gained motivation to work hard and tough it out through the course of the semester. This acquisition allows them to put forth more hard work to achieve the better grades, while the other groups' academic performance appeared not to be affected by changes in grit.

Lastly, analyses' were conducted to explore the interdependent relationships among the non-cognitive or affective variables. Overall, self-efficacy was predicted by both grit and growth mindset in correlational analyses. The relationship between self-efficacy and grit was positive and weak, $r = 0.264$, $p = 0.006$. The relationship between self-efficacy and growth mindset was also positive and weak, $r = 0.237$, $p = 0.015$. Even when correlational analyses' were run accounting for the different conditions, all of the mostly moderate correlations were significant. Only Group GP was not significant for the correlation of grit and self-efficacy. These results indicate an interconnectedness among the concepts.

4. Discussion

As predicted, the scores on most of the cognitive game variables increased during the semester. The ultimate question in these investigations is if there are real-world consequences of this increase. The answer to this question is still unclear. In the analyses' for this study, we saw that attention scores could predict the participants' semester GPA. This finding indicates that attention-oriented cognitive training may actually lead to changes and have real world outcomes. These results could also indicate a level of seriousness taken to the task at hand, which could be a result of the decrease seen in speed. This conclusion is not necessarily mimicked among the other cognitive variables, since analyses' revealed increases but did not show a relationship with semester GPA. These findings do not necessarily discount the potential for real-world outcomes of the cognitive training since semester GPA may not be the most accurate representation of some of these cognitive functions.

In regards to the non-cognitive or affective variables, there seems to be an interesting interwoven relationship among the three. Both grit and growth mindset could predict self-efficacy. Essentially, if one of the scores is high for an individual, then more than likely the others will be high. This means if an intervention can improve one of these areas, then it could potentially increase another area. The intervention conducted for this study was unsuccessful in increasing the scores though there was some evidence for enhancement of grit and self-efficacy.

Although the intervention was unsuccessful, the findings were that having higher scores of the affective variables often meant you had a higher GPA. This relationship was present for both growth mindset and self-efficacy though not to the same degree in all groups. Another finding was that change in grit scores were positively associated with the participant's GPA at the end of the semester. Furthermore, the finding suggests that if an individual increases in grit, not necessarily that they naturally had more grit, they had more success in their classes. The lack of significant relationship between GPA and self-efficacy in Group RSS suggests a lesser emphasis on their ability to achieve good grades than in the other groups. This difference could in turn be due to the hardships that this group had endured in trying to get to where they are now, and in turn their perception of their own ability was not what drove them to achieve high grades.

The findings have several important implications. First, cognitive training could lead to real-world outcomes such as performance increase in an academic environment. Second, improving a student's grit, growth mindset, and self-efficacy could improve a student's GPA, though a better intervention should be devised for college students. Third, improving one of these non-cognitive (affective) areas can potentially improve the other areas. Fourth, just the effect of having an increase in a non-cognitive area, not necessarily high, can show real-world outcomes. These findings could be important to the understanding of how students grow, both affectively and intellectually.

There are a number of issues to take into consideration with this study. Group RSS and Group GP were both fairly small samples. This has the potential to skew results. Group RSS may not have valued classroom time as others do. This affected the level of seriousness given to the tasks prescribed and the level of attentiveness assigned to them.

Group FS was a very diverse group that encompassed almost all of the freshmen attending Bethel College. This meant that there was considerable potential for change. In some of the analysis, they definitely served as a fair baseline. However, in the analysis of self-efficacy, they improved. This could very well be due to a natural overall increase that freshman students experience throughout the semester. Group GP tended to deviate from expected patterns, in the growth mindset results in particular. This group differed in many ways from the other two. These inherent differences were confirmed by their very different responses to the questionnaire.

A recent meta-analysis of academic self-efficacy revealed that there are many potential moderating influences on self-efficacy, from the time the measures were taken to personality factors, such as conscientiousness and neuroticism, emotional states, and levels of motivation²¹. Aside from these mediating factors, there are potential bi-directional relationships between variables, the simple fact that researchers do not understand the mental processes underlying these so-called non-cognitive variables, and doubts about the reliability and validity of our measures of the variables²². The issue of measurement was echoed in another article by Duckworth and Yeager²³, which insisted that the methodology used to obtain quantitative data can be biased and subjective. To make matters worse, there is no standard by which to measure them, leaving different researchers using different strategies with no common base, and without any common terminology, as non-cognitive is a controversial term for these variables. In spite of these conceptual and methodological issues, our results suggest the possibility of cognitive enhancement in underprepared college students through a combination of cognitive games and non-cognitive interventions.

5. Conclusions

In summary, the results revealed several relationships among the variables. Almost all of the Lumosity performance scores or cognitive variables increased significantly as predicted. None of the non-cognitive variables increased significantly, but grit came close. Self-efficacy and growth mindset are significant predictors of GPA and change in grit indicated a possible trend. In addition, we also discovered that growth mindset and grit were significant predictors of self-efficacy. These results indicate that cognitive and affective interventions may be beneficial to an individual's cognitive and learning abilities. That these approaches can be utilized to help future students grow and change as a result of these interventions.

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