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The Effects of Cognitive Training on Academic Self-Efficacy in College Students

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Abstract

Academic self-efficacy refers to students' beliefs in their competency to achieve an academic goal. Efficacious students tend to approach learning more effectively and outperform students with low academic self-efficacy. Low academic self-efficacy has been implicated in student underachievement in the U.S. college students. This study was the first to test cognitive training as a means to increase academic self-efficacy. The control group completed a placebo computer-based training regimen for eight weeks, while the experimental group completed an eight-week training regimen from Lumosity.com. Results confirmed that cognitive training improved students' cognitive functioning and academic self-efficacy. Limitations and directions for future research are also discussed.

Keywords:academic achievement; cognitive training; motivation, self-efficacy

1. Introduction

It is estimated that 50% of U.S. college students are underprepared for college and subsequently underperform [1]. Seventeen percent of U.S. college students have less than a 2.0 GPA at the end of their first year [2]. College student underachievement can also be costly.

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Thirty-once percent of students with full scholarships and 50% of students with partial scholarships lost their financial awards due to not meeting GPA requirements [2]. Underachievement can have significant impact beyond college. According to the National Association of Colleges and Employers Job Outlook survey in 2011, 77% of employers report that GPA is a major factor in screening applicants [3].

Research points to low academic self-efficacy as a leading factor in student underachievement [4]. Academic self-efficacy is defined as beliefs regarding one's competency to achieve an academic goal or task (e.g., study for a test), and it directly influences one's motivation, effort, and performance. This study was the first to test cognitive training (a.k.a. brain training) as a means to improve academic self-efficacy.

1.1 Academic self-efficacy

Academic self-efficacy refers to an individual's belief that he or she can successfully complete an academic task [5]. Academic self-efficacy is rooted in Bandura's social cognitive theory [6]. People contribute to their own motivation and growth through a process known as reciprocal determinism, which is the interplay among the following three factors: (1) behavioral, (2) personal, and (3) environmental [7]. A student's behaviors and choices in the classroom (i.e., their behavioral factor) are reciprocally influenced by their own beliefs, attitudes, and knowledge (i.e., their personal factor), as well as the responses and feedback they get from others (i.e., their environmental factor). As a student completes an academic task, he or she will experience a performance outcome – success or slow progress/failure. This performance outcome is a student's prior experience with a particular academic task. Prior experience is the most powerful source of self-efficacy [8].Success enhances self-efficacy, whereas repeated failures diminishes it [5]. For example, a student who believes she has high competency in mathematics might specifically seek out math classes, and she might be encouraged to continue to do so by others. This process might strengthen the student's beliefs in her math competency. In contrast, slow progress or failure will likely result in decreased academic self-efficacy and less motivation to perform the task again.

1.2 Academic self-efficacy and achievement

Why is academic self-efficacy of interest? Academic self-efficacy "is the single strongest predictor of GPA when examining academic success models, even taking into account high school academic performance and demographic variable [9]. Research confirms that academic self-efficacy predicts academic achievement [10, 11, 12, 13]. In addition, two separate meta-analyses, that both controlled for levels of educational attainment [12, 14], found moderate to large effect sizes for the relationship between academic self-efficacy and academic achievement. Clearly, academic self-efficacy is integral to academic achievement. Therefore, fostering academic self-efficacy should be of particular interest to educators and students alike.

1.3 Why self-efficacious students excel

Students with high academic self-efficacy use effective cognitive processes (e.g., self-regulation) [14], spend more time studying [15], and engage in activities that result in learning [16]. In addition, students with greater academic self-efficacy were more likely to have a constructive conception of learning, than those with lower academic self-efficacy [17]. In other words, efficacious students: (a) attributed academic success to effort, (b) reported a greater use of self-regulation strategies, (c) reported a deep-learning approach over a surface learning approach, and (d) reported more direction in their study process. Self-efficacious students view learning as within their control; therefore, they are more likely to persevere and continue to re-work problems until they are correct [18]. In contrast, students with low academic self-efficacy generally avoid challenging tasks, and they tend to select easier tasks because challenging tasks might lead to stress and depression [19].

1.4 Cognitive training

Cognitive training is essentially a computer-based "mental workout". It might resemble a video game in that the exercises are interactive and presented on computer screens. The main difference between cognitive training and traditional "video games" is that cognitive training exercises are specifically designed to enhance cognitive processes (e.g., memory, attention, and sensory processing) [20].

Previously, it was believed that cognitive capacities (e.g., intelligence, memory, attention, and sensory processing) are fixed at a young age. However, there is now evidence that cognitive capacities are adaptable [21] and that cognitive training (i.e., exercising the brain) can effectively improve these capacities. For example, cognitive training has been shown to enhance processing speed [22], attention [23], and working memory [24]. Cognitive training rests on neuroplasticity, which is the idea that the human brain is capable of forming new neural connections and neural reorganization [25]. Research has also shown that 12 weeks of cognitive training with a Tetris-like game resulted in more cortical thickness in the temporal, parietal, and frontal cortices [26]. These results are corroborated by other studies that found increased neural activation in the parietal and frontal lobes [27, 28].

Research confirms that cognitive training can improve academic performance. One study tested the effects of cognitive training on performance with a sample of 22 young adolescents who suffered from poor working memory [29]. Results showed the students experienced significant gains in working memory and academic performance, and the gains were sustained for six months after treatment. Another study tested the effects of cognitive training with a sample of 1305 students between the ages of eight and fifteen [30]. Results showed that cognitive training led to improvements in processing speed, attention, memory, mental flexibility, and problem solving; all of which are processes necessary for academic success [31].

1.5 Cognitive training and academic self-efficacy

Research has only just begun to investigate the impact of cognitive training on psychological constructs that are linked to academic achievement; the present author was able to locate only one such study [32]. The researchers tested the influence of cognitive training on self-esteem. Seventy-one students (average age 10.5 years) were assigned randomly to one of three groups: a) computerized cognitive training, b) paper and pencil cognitive training, or c) no cognitive training (control group). Dependent variables included mental computation speed and self-esteem. The self-esteem measure included 44 items divided among three scales: global self-esteem, academic self-concept, and mathematics self-concept. Results suggested significant improvement in mental computation speed for the computerized and paper/pencil cognitive training groups only. Results also showed a significant increase in global self-esteem for the computerized cognitive training group, but not for the paper/pencil group or the control group.

Although, the aforementioned study was innovative, there was one significant limitation that likely influences the impact of the findings – self-esteem might not have been the most appropriate measure in relation to cognitive training or academic achievement. In fact, some studies actually show an inverse relationship between self-esteem and academic performance[33]. Results from a meta-analysis of studies that involved self-beliefs (i.e., self-esteem, self-concept, and self-efficacy) confirmed thatacademic self-efficacy is the best predictor for academic achievement, compared to self-esteem or self-concept [34]. The researchers concluded that self-esteem is too broad to predict specific skills, such as academic aptitude.No study has explored the effects of cognitive training on academic self-efficacy.

1.6 Purpose and predictions

The purpose of this study was to determine if cognitive training could improve students' academic self-efficacy. This study centered on two research questions. The first research question was: *What effect does cognitive training have on students' cognitive functioning?* Based on past research [22, 23, 29, 30], it was predicted that cognitive training would improve cognitive functioning. The second research question was: *What effect would cognitive training have on academic self-efficacy?* Cognitive training taps performance outcomes from prior experience, which is the most influential source of self-efficacy [8]. Subsequently, it was predicted that cognitive training would be associated with higher academic self-efficacy.

2. Methods

2.1 Participants

Fifty undergraduate students from a public university in the northeast United States were assigned randomly to one of two equally sized groups (i.e., control group or experimental group). Participants were mostly female (n = 38) and sophomores (n = 49). Participants were enrolled in a psychology course and completed the study as part of the university's research requirement. The average age of the participants was 19 years old (age range 18-20 years).

2.2 Materials

2.2.1 Computer training

The training for the control group included a computer-based game that is readily available for personal computers. The control group completed 15-minute training sessions each day for a period of eight weeks. The control group accessed their training via an online program. The program logged the participants' training. The experimenter reviewed the log daily to ensure the control group completed their required training sessions. Their training consisted of a game in which participants used a slingshot to "launch" a small animal towards larger animals that are positioned on stationary objects like bricks and logs. The object of the game is to destroy the large animals by either using the small animal to directly hit the large animal or using the small animal to knock objects (e.g., bricks, logs, and blocks) onto the large animal, thereby destroying it. As the participant advances through the levels of the game, the number of large animals increases and their positioning gets more difficult to target. This game was intended as a placebo computer-based treatment. It was selected because it was interactive (similar to the cognitive training exercises) and because it would likely hold the participants' attention for their required training sessions.

2.2.2 Cognitive training

The experimental group trained using Lumosity, a commercially available web-based cognitive training program available from www.lumosity.com (Lumos Labs Inc., San Francisco, CA). The experimental group completed 15-minute training sessions on a daily basis. The experimenter ensured the experimental group completed the training sessions daily as instructed. Training sessions consisted of four game-like exercises designed to target cognitive domains including attention, working memory, processing speed, and problem solving. Participants completed the cognitive training on their personal computers at times that were convenient to them. Upon logging in to the website, the program delivered the four exercises and immediate visual and auditory feedback was provided regarding performance.

The exercises used in this study were selected on the basis that they target specific key cognitive areas shown to impact educational achievement [35, 36]. For example, speed of processing, working memory, and attentional control are cognitive abilities that have been associated with success in multiple academic disciplines including math, science, and reading achievement. Furthermore, the Lumosity exercises are based on well-studied tasks routinely used in the field of cognitive psychology and have been designed to adapt to the individual students' performance such that each exercise begins at the same level of difficulty and becomes more difficult according to performance. This study used the following exercises from Lumosity: (a) Speed Match, (b) Memory Matrix, (c) Playing Koi, and (d) Rain Drops (described in detail below and shown in Figures 3-6). Previous studies have used Lumosity to demonstrate improvement in cognitive performance on standard neuropsychological assessments in a variety of population groups, including school-aged children [30].

Speed Match is a computer-based adaptation of the classic N-back (N=1) task that has been used to assess working memory and speed of processing [37]. In this task participants were presented with a series of colored shapes in rapid succession (e.g., a blue square, followed by a red triangle). Using their mouse, participants needed to quickly indicate whether the current shape matches the previous shape. The speed of presentation increases as the exercise progresses.

Memory Matrix is a computer-based adaptation of the Corsi block-tapping task that has been used to assess visual-spatial working memory span [38, 39]. In this task participants were presented with a matrix (grid) of brown blocks and target blocks that are simultaneously highlighted blue for two seconds. Participants needed to recall the target blocks that were previously highlighted blue and response by using their mouse to click on the blocks that they believed were briefly highlighted blue. The difficulty increases by the number of blocks in the matrix and the number of blocks the participant is asked to recall.

Playing Koi is a computer-based adaptation of the multiple object-tracking task[40] that has been used to assess attention, or the ability to focus on relevant information while ignoring irrelevant distractions. In this task, participants were presented with an image of a koi pond. Participants needed to “feed” each fish only one food pellet while simultaneously attending to the whereabouts of the other identical moving fish so as to avoid “over feeding” each koi – they cannot feed one fish two times. The exercise is difficult because all the koi are identical and are moving. The exercise gets increasingly difficult by the number of koi in the pond and the speed at which they move.

Raindrops is an arithmetic problem-solving task in which participants were presented simple arithmetic operations encased in falling raindrops. Each raindrop contained a mathematical equation that required addition, subtraction, multiplication, or division. For example, a raindrop could contain the following problem: “10 – 2 = ?”. Participants needed to mentally solve the equation by entering the answer with their keyboard before the raindrop hit the ground. The speed of the raindrops and the number of raindrops simultaneously on the screen increases as the game progresses.

2.3 Measures

2.3.1 Cognitive Function

Cognitive functioning (e.g., working memory, cognitive flexibility, and attention) was assessed with the Trail Making Test – B (TMT – B). The Trail Making Test was originally developed in 1944 as part of the U.S. Army’s individual assessment and has since become part of several neurological assessment batteries [41]. There are two parts of the test, A and B. In part A, test takers essentially “connect the dots” that are numbered from 1 to 25 and scattered on a page. In part B, the dots on the page include both numbers and letters, and test takers must connect the dots by alternating numbers and letters in sequential order (e.g., 1-A-2-B). The experimenter administered and scored the TMT-B. Test takers are scored by the time it took them to complete the trail [41]. Research confirms that TMT-B provides a reliable measure of cognitive functioning [42].

2.3.2 Brain Performance Index

The experimental group’s cognitive performance was evaluated via Lumosity’s Brain Performance Index (BPI). BPI s a normalized measure of game performance used throughout the Lumosity training system that makes it possible to compare across games. The system creates an internal percentile table generated by using max gameplay scores from users who have played a minimum of three games and are between the ages of 14 and 80. BPI ranges from 0-1700. BPI requires the use of Lumosity’s cognitive training program; therefore it could only be calculated for the experimental group. BPI was measured before and after treatment.

2.3.3 Academic self-efficacy

Academic self-efficacy was assessed by the Self-Efficacy for Learning Form (SELF). The SELF is a 57-item questionnaire designed to assess students' certainty about their ability to cope with academic challenges (e.g., trouble focusing, or missing a class) [43]. Participants rate each item on an 11-point Likert scale ranging from "definitely cannot do it" to "definitely can do it". The items make up the five subscales including, reading, studying, test preparation, note taking, and writing. The following are sample questions from the five subscales: (a) Reading – When you don't understand a paragraph you have just read, can you clarify it by careful re-reading, (b) Studying – When you are trying to understand a new topic, can you associate new concepts with old ones sufficiently well to remember them, (c) Test Preparation – When you have to take a test in a school subject you dislike, can you find a way to motivate yourself to earn a good grade, (d) Note-Taking – Your teacher's lecture is very complex, can you write an effective summary of your original notes before the next class, and, (e) Writing – When you find that your first draft of a paper is wordy, ungrammatical, or confusing, can you revise it so that it is completely clear and grammatical.

The SELF was found to have high internal consistency reliability, with a Cronbach's alpha of .96 [43]. In addition, the SELF has high validity as it reliably predicted students' GPA ($r = .68$), judgments of responsibility for academic outcomes ($r = .71$), and the quality of students' homework ($r = .75$) [43]. Participants completed the SELF on a computer using an online survey program. The experimenter scored the results from the survey.

2.4 Procedure

This study included the following three phases (i.e., pre-test measure, intervention, and post-treatment measure) that occurred over a period of eight weeks. Prior to the start of the study, participants were only told that the experimenter was investigating how students learn. During the pre-test measure, all participants completed the TMT – B and SELF. Next, the intervention phase lasted for a period of eight weeks. The control group completed computer-based training via an online program. The experimenter ensured that all control group participants were completing the required daily training sessions. The experimental group completed 20 hours of cognitive training via the Lumosity website, which yielded the experimental group's individual BPI. The experimenter received was able to confirm that each participant was completing the exercises on a daily basis as required. The post-treatment measurement occurred after the eight-week treatment phase. All participants completed the TMT – B, and SELF again. There was no attrition for either group for the three phases of the study.

2.5 Data analysis

Analysis of Covariance (ANCOVA) with Bonferroni Correction was used to analyze post-measurement scores from the TMT-B and the SELF, while controlling for the pre-test scores of each scale. A paired-sample t-test was used to analyze pre and post-training BPI data. Levene's test of equality of error variances and estimates of effect sizes were also calculated.

3. Results

3.1 Academic self-efficacy

Analysis confirmed that the two groups were equivalent on academic self-efficacy prior to treatment, $F(2, 46) = .257$, $p = .934$. Both groups scored similarly on their academic self-efficacy for reading, studying, test preparation, note taking, and writing.

ANCOVA for the SELF subscales revealed significant differences on three subscales, while controlling for the pre-test scores. The experimental group scored significantly higher than the control group on self-efficacy for Reading, $F(1, 49) = 29.238$, $p< .001$, Test Preparation, $F(1, 49) = 18.478$, $p<.001$, and Writing, $F(1, 49) = 4.343$, $p = .042$. The effect sizes (i.e., Cohen's d) were 1.15, 1.04 and 0.50, respectively, and indicated a large to medium effect with the experimental group outperforming the control group. The note taking and studying subscales violated Levene's test of equality of error variance, and were therefore not included in the ANCOVA.

Table 1 Post-training Means (and *Standard Deviations*) for Self-efficacy for Learning Form (SELF)

Self-Efficacy	Experimental Group	Control Group	Effect size
Reading*	(M = 92.48, *SD* = 17.88)	(M = 73.77, *SD* = 14.33)	1.15
Studying*	(M = 121.92, *SD* = 22.60)	(M = 98.63, *SD* = 18.47)	1.12
Test-Preparation*	(M = 94.60, *SD* = 16.88)	(M = 77.74, *SD* = 15.48)	1.04

** Significant difference at p < .01*

3.2 Trail Making Test-B

Results for the TMT – B did not show differences either between or within-groups. Results from the ANCOVA showed no difference between the two groups for post-treatment measurement when controlling for the pre-test scores. Furthermore, paired-sample t-tests showed that the control group scored similarly before treatment and after treatment, and the experimental group scored similarly before and after treatment.

3.3 Brain performance index

There was a significant change in BPI for the experimental group with respect to pre and post-treatment measurements, $t(24)$ 12.94, $p<.001$, with higher BPI scores at the end of the training period (post-treatment) compared with scores at the beginning (pre-treatment). The mean for pre-treatment BPI was 181.67 (*SD* =

25.37) and the mean post-treatment BPI was 931.88 (*SD* = 294.94). Cohen's *d* was 1.049, indicating a large effect size. This finding confirms that the participants were actively engaged in the training and that their performance on the games improved over time.

4. Discussion

This was the first study to test cognitive training as a means to improve academic self-efficacy. The findings of the present study will be discussed relative to the two research questions that guided this study.

4.1 The effect of cognitive training on cognitive performance

The prediction that cognitive training would improve cognitive functioning was partly confirmed. Although no differences were found within groups or between groups on the trail-making test, the experimental group saw gains in cognitive functioning as measured by BPI. More specifically, improvements were found in attention, memory, processing speed, flexibility, and problem solving. These results are contradictory in that both the trail-making test and BPI measure similar cognitive functions. Therefore, one might have expected to see a significant improvement on both measures instead of just one. Two conclusions can be drawn from these findings.

First, the fact between-group differences were not found on the trail-making test might (albeit inadvertently) support the methodology of this study. Recall that both groups completed the Trail Making Test –B, but only the experimental group was able to complete the BPI. The lack of difference between groups on the trail making measure supports the idea that the two groups were similar in cognitive functioning abilities. If the experimental group’s trail-making scores were improved in addition to BPI, one could argue that random selection did not occur and/or the experimental group consisted of intellectually superior students. Rather, the two groups scored similarly both before and after treatment on the trail making measure, which supports the claim that the two groups were intellectually similar.

Second, the experimental group’s contradictory results on the trail-making and BPI measures might support the idea that cognitive training is domain specific. Perhaps the type of attention, mental flexibility, and problem solving measured by the trail-making and BPI measures are different. More research is needed to test whether the skills enhanced by cognitive training transfers to other areas.

4.2 The effect of cognitive training on academic self-efficacy

The prediction that cognitive training would improve academic self-efficacy was confirmed. Results showed a significant gain in academic self-efficacy for the experimental group on the post-treatment measurement. They reported greater competence in their abilities for reading, studying, test-preparation, and note taking, compared to the control group. There are two possible explanations for the link between cognitive training and academic self-efficacy.

First, recall that the most influential source of academic self-efficacy is prior experience, and that past success on a task tends to improve one's academic self-efficacy [8]. The experimental group experienced significant gains in cognitive functioning (e.g., attention, memory, processing speed, mental flexibility, and problem solving), and these improvements occurred as the participant engaged in the cognitive training exercise. The participant was well aware of their performance as they completed the exercise; they knew if they succeeded and if they failed. For example, gameplay for each exercise was dependent on the participant's performance. If the participant did well, the game would continue and increase in the level of difficulty. If the participant played poorly, the game would decrease in difficulty and/or end. In addition, the cognitive training exercise generated a score for each participant and show how his or her scored ranked in comparison to others. Therefore, it is possible that the experimental group's success in the cognitive training exercises had a positive influence on their academic self-esteem, as per Bandura's social cognitive theory and notion of reciprocal determinism.

Second, the cognitive improvements experienced by the experimental group (i.e., attention, memory, processing speed, flexibility, and problem solving) go hand-in-hand with their enhancements in academic self-efficacy (i.e., reading, studying, test-preparation, and note taking). For example, reading is associated with working memory [44], attention [45], and processing speed [46]. In addition, note taking involves the processes of memory [47], attention [48], and processing speed [49]. Therefore, it makes sense that students who experienced enhanced abilities in attention, memory, processing speed, flexibility, and problem solving would likely feel more efficacious in their academic skills.

4.4 Implications

Two implications can be drawn from the results. First, students should be encouraged to participate in cognitive training. Participants in this study who completed the cognitive training saw improvements in attention, memory, processing speed, flexibility, and problem solving – all of which are important cognitive processes involved in learning, studying, and greater academic performance [31].

Second, teachers should encourage students to participate in cognitive training, and possibly even incorporate cognitive training into their lessons. There is empirical evidence thatstudents prefer multimedia over traditional learning [50], and thatit enhances learning[51]. Therefore, educators could encourage students at any level (i.e., early education through college) to complete cognitive training as an in-class or home exercise.

4.5 Limitations and future research

There are three limitations that might narrow the generalizability of the results, yet they serve as suggestions for future research. First, it is uncertain what is the "correct" amount of cognitive training needed to raise one's academic self-efficacy, or how stable the effect. Cognitive training has never been used before to improve academic self-efficacy. Future research should seek to determine the minimum training hours needed to increase and maintain academic self-efficacy. Second, improvement in cognitive performance was not studied alongside actual academic performance. It is possible that the improvement in cognitive performance was domain-specific and related to the particular types of activities found in Lumosity's exercises. The question still remains as to whether the improvements experienced by the experimental group transfer to other tasks, such as performance in their various classes. Further research should include actual academic performance as a dependent variable. Third, this study did not investigate long-term effects of cognitive training. Participants completed the measures before and after an eight-week training regimen, but it unknown how long the boost in cognitive performance and academic self-esteem lasts. Future research should seek to determine the longevity of the improvements in cognitive performance and academic self-efficacy.

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