

Article

Brief Mindset Intervention Changes Attitudes but Does Not Improve Working Memory Capacity or Standardized Test Performance

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Abstract: There has been extensive research conducted on mindset and grit, involving both experimental and observational methods. However, the findings in the literature remain mixed. This should give educators and researchers pause from an intervention perspective—if we still do not have a good understanding of how mindset works, then more research is needed. We implemented a mindset intervention with undergraduate women to improve cognitive performance measures relevant to academic performance—working memory capacity and standardized test performance in math. To better understand how mindset interventions work, we also examined self-report measures (e.g., pertaining to academic attitudes and belonging) as well as post-intervention behavior. We expected the growth mindset intervention to significantly improve cognitive performance and to cause more positive academic attitudes and attitudinal change. The mindset intervention did change students' beliefs about ability and also caused students to report higher grit overall (no condition difference), and to feel less belonging in terms of connection to their university—which was not in line with our hypotheses. We also found that the growth mindset intervention had no significant effects on improving WMC or standardized test performance. We discuss the implications of these findings and make suggestions for future work in this area.



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1. Introduction

In the 2014 *New York Times* article “Who Gets to Graduate?”, Paul Tough describes research on graduation rates, showing that the biggest challenge for students is not simply making it to college but rather learning how to be successful once they get there. The article states that 40% of students have not earned their degree after six years, and additional research suggests that their likelihood of graduating depends on how much money their parents make. Tough argues that students struggle the most with their sense of belonging and beliefs about their abilities, so how students think about themselves, their status and position in college, and their abilities when faced with intellectual challenges are of great importance. With this in mind, the question becomes whether addressing these beliefs and attitudes may promote positive attitudinal shifts and help boost academic performance for students.

Many factors impact academic performance. Individual differences spanning backgrounds, abilities, goals, motivations, expertise, practice, and personalities have all been found to play a role [1–3]. One attitudinal factor has gained considerable momentum in the realm of academic performance—mindset. As defined by [4], mindset theory proposes that people hold varying beliefs about the malleability or rigidity of certain human attributes, such as intelligence. Dweck distinguishes these implicit theories between two main groups, fixed mindset and growth mindset, and suggests that one's mindset can also

impact performance. People with a fixed mindset, or entity theorists, believe that one's attributes are relatively stable or unchangeable. Research shows that people who believe their successes result from an innate, fixed ability do not appreciate challenges and are more often devastated by difficulties [4]. Fixed mindsets are thought to prime a "learned helplessness" orientation, which involves feeling powerless over failure and unable to change one's circumstances or performance [5]. On the other hand, people with a growth mindset, or incremental theorists, believe that they have the power to change or improve their abilities [6]. In turn, people with growth mindsets have been shown to be more apt to take on challenges and to respond more positively to failure.

Though the importance of mindset in understanding and predicting behavior extends beyond general academic performance [7,8], mindsets are most often studied in the context of education and academic achievement [9]. Within these domains, mindset has been examined through constructs like grade point average, standardized test performance, and IQ [10]. In academics, mindset theory posits that students with growth mindsets are more likely to be successful because of their propensity to persevere despite adversity in school [11]. For a student, a growth mindset is thought to address the inner forces or barriers that might restrain one's learning, such as worrying about ability or negative stereotypes [12]. In other words, growth mindsets may afford students the psychological tools to thrive under pressure, improve academic attitudes, and ultimately lead to enhanced learning and higher academic achievement [11,13].

2. Social–Psychological Mindset Interventions

The implications of mindset in academics have spurred a wave of attention, and mindset has become a staple of social–psychological interventions aimed at improving academic achievement. Mindset interventions aim to manipulate students' beliefs about learning and their intellectual ability. They try to instill a growth mindset in participants by conveying that challenges and setbacks are opportunities for growth and that the brain is like a muscle that gets stronger through hard work [14]. Social–psychological intervention research focusing on mindset claims that a shift in attitude is what helps students improve scores on cognitive performance measures in the short- and long term [12,15]. The methodology of these studies varies, spanning resource-intensive and context-specific remedies [12,16] to low-resource and scalable solutions [17]. Target populations also cover a wide age range, ranging from young children to college students [18].

Furthermore, social–psychological interventions like these take hold through recursive processes that tap into students' motivation, behavior, and self-perception in context and over time [12,19]. These interventions are intended to support lasting academic improvement through attitudinal shifts and self-perpetuating behavioral cycles, altering the way a student approaches challenges and encouraging resiliency. Changing the meaning attributed to academic challenges makes it possible for students to shift their perspectives and to approach future challenges with a different belief system [12]. The key to these belief-altering tactics is that they are properly timed and implemented in a way that keeps students from feeling targeted as "low achieving" [20]. Though these interventions remain a popular approach for addressing issues related to attitudinal change and performance, a better understanding of the relationship between mindset interventions and measures of cognitive ability is still needed.

3. Inconsistent Effects of Mindset Interventions and the Role of Individual Differences

Mindset interventions have demonstrated an inconsistent degree of efficacy [21–23]. Yeager and Walton [12] claim that mindset interventions are remarkable tools for boosting academic achievement measures like GPA and test scores, and ref. [24] found that a short mindset intervention raised grades in lower-achieving students and increased enrollment in advanced math courses when the intervention message was congruent with peer norms. On the other hand, some recent research suggests that the claims pertaining to mindset's influence over measures of cognitive ability are too bold and that the investment in mindset

interventions should be tempered [25]. A large mindset intervention study delivered in 101 schools throughout England found that students who received the intervention did not significantly improve in verbal or quantitative domains compared to students who did not receive the intervention [26]. Other researchers have also found no association between mindset and improvements in reading abilities [27]. Furthermore, comprehensive meta-analyses by [21] suggest weak and unreliable effect sizes across interventions, except for populations from low-SES households or those at risk of failing.

It is still unclear whether mindset interventions boost academic performance for everybody, and replicability and generalizability remain significant concerns within the current mindset intervention literature. As previously mentioned, these interventions take hold through self-perpetuating cycles of attitude change, so individual factors and the contexts in which they are applied might be involved in the differential responses. For instance, some work shows that these interventions have the strongest effect on poorly performing, at-risk, and low-SES populations [9,17,21], as well as students facing situational challenges, like school transitions [28]. Other work stresses the importance of investigating the roles of age or developmental stage in the effectiveness of non-cognitive or attitudinal-based interventions [2].

Despite the inconsistencies, the prospect of mindset interventions as feasible, scalable, and resource-efficient tools to improve academic achievement is worthy of consideration. The value of these interventions is further emphasized by the potential long-term outcomes of one's academic trajectory. For example, poor performance in school puts students at risk of fewer job prospects, worse health, and higher incarceration rates [29], an issue underscored by the approximate 20% of U.S. students who will not finish high school on time [30]. Therefore, the potential of mindset interventions to bolster measures of cognitive ability may extend far beyond academics to reduce the risk factors associated with inequality [31].

The inconsistent findings in the mindset literature, coupled with the potential for mindset to alleviate long-term negative effects in academics and beyond, highlight the importance of understanding when, how, and for whom mindset interventions work. In order to answer these questions and elucidate the boundary conditions relevant to mindset interventions, we must first consider the general and specific cognitive outcomes and attitudinal factors of greatest interest. The present study focuses on standardized test performance in math and working memory capacity (WMC). We also explore the effect of mindset on various attitudinal survey measures and attitudinal change in order to provide further clarity. Given the underrepresentation of and unique challenges for women in STEM areas [31–33], we focused our research on the domain of math in a sample of people who identify as female. As such, we will next discuss previous research on mindset and the cognitive factors of WMC and standardized test performance, focusing on women's math performance.

4. Mindset, Test Performance, and Working Memory Capacity

Targeted measures of cognitive ability and academic performance following social-psychological interventions vary, but examining standardized test performance is common practice [15,34]. Although standardized tests have been criticized and higher education institutions' overreliance on test scores is waning [35], standardized testing is still a widely accepted measure of academic performance and plays a significant role in the admissions processes of many post-secondary and graduate education institutions [36]. Furthermore, the number of students who take these tests continues to grow. In 2019, over 2.2 million people—the largest group ever—took the SAT, and around 675,000 people take the general GRE annually [37]. We employ standardized test performance in the current study based on the acceptance of these tests as markers of cognitive ability and the vast number of students whose future prospects heavily depend on these measures.

We focus on standardized test performance in the domain of math because of its pertinence in academic achievement. Additionally, math performance is important to

focus on in the context of mindset because of the perception that math ability is innate and highly indicative of one's intelligence, as well as the stereotypes about women's math performance, which likely contribute to the gender gap in math [13,15,24,33]. Seminal work in mindset theory also focuses on math performance. For example, ref. [32] note that the abrupt conceptual transitions that occur during new topics in math make it a particularly challenging subject for students, so they examine whether one's attitudes toward new and confusing material influences performance. They found that when confronted with confusing material, people with a more "mastery-oriented" (i.e., growth) mindset performed better than people with a more "helpless" (i.e., fixed) mindset. Importantly, mindset did not predict performance when the material was not difficult, ultimately suggesting that mindset is most important in challenging or confusing domains, like math. Furthermore, after teaching a growth mindset theory of intelligence to struggling junior high students, ref. [13] found that students were more motivated in their math class and even reversed their downward performance trajectory in math, but students in the control group who were taught other useful information instead of a growth mindset theory of intelligence continued their downward trajectory. Additionally, while investigating the effects of mentorship and messages on student achievement gaps, ref. [15] found that when students were taught about the malleability of intelligence or that academic challenges are common and surmountable, the discrepancies between women and men's performance in math disappeared. More recently ref. [38] found that growth mindsets are beneficial for both genders in math, but women demonstrate a greater effect of math achievement, which was explained by the increased expectancy beliefs (i.e., confidence in one's ability to succeed; ref. [39] for women with greater growth mindsets. Together, these studies emphasize the importance of studying mindset not only in the context of math but also in populations that are underperforming or underrepresented (e.g., women in math) due to educational inequities.

In addition to focusing on performance in math, we also explore WMC because it is an academically relevant outcome that, to our knowledge, has been largely understudied in the mindset literature. Working memory represents our ability to attend to a task while storing, retrieving, and updating other information simultaneously [40,41]. As the capacity component of working memory, WMC defines the parameters by which people employ cognitive resources and has been found to vary across individuals [42,43]. WMC is typically assessed via automated complex span tasks, such as the operation span (OSPAN) and reading (RSPAN) span, which require people to solve math problems or read sentences, respectively, while remembering lists of letters. Further, WMC assessed via complex span tasks has been found to be an important factor in academic performance and has been shown to be highly related to measures of intelligence, long-term memory and retention, and cognitive control abilities, and it even supports mental resilience during identity-threatening experiences that typically undermine performance for women and minorities [44–47]. WMC is also commonly used as a subtest in the Wechsler Adult Intelligence Scale and thought by some to be a malleable cognitive factor that can be improved by both cognitive and non-cognitive training approaches [5,48]. As such, WMC is a reliable predictor of cognitive ability and linked to many of the same performance outcomes in academic settings as mindset.

However, research surrounding the relationship between mindset, WMC, and performance enhancement remains conflicting. Some research suggests that there is no correlation between mindset and WMC performance or mindset and improvement in WMC following training exercises designed to boost WMC [49]. Others have shown that people with a growth mindset improve less than people with a fixed mindset during WMC training [50]. On the other hand, some have found that people with more malleable views of intelligence show greater improvement following WMC training than their fixed-mindset counterparts [51]. Not only are these findings mixed, but they also only explore the role of mindset as a predictor of WMC, or improvement in WMC, when people were training on a WMC task.

Moreover, it is important to better understand the role of WMC in the context of mindset and cognitive performance considering the extensive literature demonstrating the central role of WMC in the control of cognition in performance contexts. We know that WMC is key to helping individuals to control the use of their cognitive abilities through focusing their attention [52], inhibiting task irrelevant information [53], and maintaining focus in the process on goal achievement [44]. WMC also helps to support performance on challenging math problems and standardized test performance in both quantitative and verbal reasoning, depending on the extent of task demands and situational pressures [45,54,55].

The implications of WMC in controlled cognition can be informative for interventions by shedding light on which conditions and to what extent both mindset and WMC can help improve performance. Taken together, evidence suggests that WMC predicts performance on a wide range of cognitive tasks and remains a critical factor of academic achievement in a number of domains, but to our knowledge no current studies explore how mindset interventions affect WMC and what role this might play in subsequent academic achievement, such as standardized test performance in math. For these reasons, WMC performance, measured through RSPAN and OSPAN, is a worthwhile cognitive factor to investigate through mindset intervention. Next, we will consider previous research on student attitudes in relation to mindset and academic success, seeing as mindset has been linked to more positive academic attitudes and attitudinal change is thought to help improve performance.

5. Mindset and Attitudinal Measures

Given previous research investigating the role of attitudinal and non-cognitive factors in addition to cognitive factors in the mindset literature [10], we also focus on mindset's effect on attitudinal survey measures and attitudinal change. Attitudinal measures help provide a more comprehensive understanding of the relationship between mindset and measures of cognitive ability, namely WMC and standardized test performance. Since mindset is thought to influence performance through peoples' beliefs about themselves and their abilities, examples of theoretically relevant measures include grit, anxiety, and questions surrounding students' feelings of belonging and academic attitudes in school. These measures not only provide more nuance to our understanding of mindset interventions' effects but also permit inquiries into the individual differences in baseline academic attitudes and beliefs that could influence a mindset intervention's efficacy.

Specifically, we focus on grit because of its theoretical proximity to mindset. Grit has been defined as the perseverance and passion for long-term goals [1]. In accord with grit theory, people who exhibit high levels of grit are more likely to persist through difficulties while people with low levels of grit are more likely to give up when faced with difficulties [1,56]. Similarly, mindset theory and research suggest that people with a growth mindset are more likely to seek challenges and persevere more than people with a fixed mindset [4,12]. Recent research has demonstrated a more nuanced relationship between grit and mindset. For example, ref [57] show that grit and mindset mutually predict each others' development during adolescence, and Zhao et al. [58] use structural equation modeling to suggest that a greater growth mindset predicts a sense of autonomy over one's learning, which in turn improves students' grit. Thus, manipulations that make mindsets more malleable may also increase one's grittiness. To our knowledge, no studies have examined how mindset manipulations influence grit and related attitudinal measures. Additionally, because academic challenges are thought to cause anxiety and impact students' feelings about belonging in an academic setting, we also explored the relations between these factors and mindset, providing additional contextual information to uncover potential individual differences involved in mindset interventions as well as elucidate whether mindset can lead to positive attitudinal change.

6. Purpose of the Present Study

The present study aims to provide a more nuanced understanding of the contexts in which transfer occurs between a successful mindset intervention and certain measures of cognitive performance in women. We implement a short mindset intervention in order to examine its effects on standardized test performance, WMC, and theoretically relevant attitudinal measures.

7. Hypotheses

Based on our research goals outlined above, we propose three hypotheses. First, participants in the growth mindset condition will show higher scores on WMC measures compared to the fixed mindset condition (Hypothesis 1). Second, participants in the growth mindset condition will perform significantly better on the math standardized test measure than participants in the fixed mindset condition (Hypothesis 2). Third, participants in the growth mindset condition will demonstrate increased persistence in the form of grit, more positive academic attitudes, and lower anxiety, while participants in the fixed mindset condition will exhibit the reverse (Hypothesis 3).

8. Material and Methods

8.1. Participants

Participants were drawn from the secondary data of a dissertation study that examined relationships between stereotype threat; mindset interventions; and cognitive, non-cognitive, and attitudinal differences ([59]; or see Supplementary Materials S1 for full methods and results). Ninety-nine subjects were invited to participate in the study. Based on subjects' failure to complete various measures and/or data missingness (e.g., incomplete tasks or submissions), there was a final sample of 81 subjects (30 White, 9 Black, 23 Asian, 9 bi-racial, 9 unreported, and 1 Other). Participants were students at a private university who identified as female and received credit toward a course requirement or USD 16 cash for their participation. Participants were randomly assigned to each condition.

8.2. Design

Based on secondary data from the original dissertation study ([59]), the current study focuses on the effect of the mindset manipulation on cognitive performance outcomes using a between-subjects design (Mindset: Fixed vs. Growth). The original study included a 2(Condition: Threat vs. Control) $\times$ 2(Mindset: Fixed vs. Growth) factorial design that manipulated the effects of gender stereotype threat and mindset on cognitive performance in women. However, the stereotype threat manipulation failed to induce a stereotype threat effect in the initial study, so this factor was collapsed (see Supplementary Materials S1 for more information).

8.3. Data Analysis Plan

Based on the between-subjects design, we used *t*-tests to test for differences between conditions.

Statistical Power

Given previous research [10,13,18] and the observed significant effects of mindset intervention between either growth and fixed or growth and control conditions, it was expected that at least $n = 79$ total subjects [18] would be required. Additional research was used to motivate this work that found significant differences in performance between mindset conditions when $n = 86$ [10] and $n = 91$ [13] total subjects were recruited. Based on these studies and the *pwr.t.test* function in the *pwr* package in R [60], the original study found that for between-group differences, one could expect an effect size to range from $d = 0.59$ [13] to $d = 0.63$ [18] in order to correspond to the minimum of 80% statistical power. The more conservative effect size estimate ($d = 0.59$) motivated the recruitment of at least $n = 90$ total subjects ($n = 45$ per condition).

8.4. Procedure

Upon entering the research lab, participants completed a battery of baseline measures. First, participants were given a baseline WMC test on the RPSAN, followed by several pre-manipulation surveys on a battery of non-cognitive and attitudinal measures of theoretical importance, including mindset, personality, grit, and a variety of other additional measures to gauge students' academic attitudes and sense of belonging in school (see Supplementary Materials S3 for survey details). Next, participants received the mindset manipulation, which involved reading either one prompt claiming that ability is fixed or a separate prompt claiming that ability is malleable, followed by a timed written activity reflecting on the information in the prompt. They then completed a post-manipulation WMC measure on the OSPAN along with a quantitative sub-section of the Graduate Record Exam (GRE). Last, participants completed a battery of post-manipulation surveys including mindset (for manipulation check), and the same attitudinal measures completed at baseline on grit and academic attitudes. Participants also answered questions about anxiety, beliefs about bias in standardized testing, self-reported SAT scores, GPA, and demographic information. At the conclusion of the experiment, participants were debriefed and thanked for their participation. We explained that we were interested in how different beliefs about cognitive ability impact our ability to perform complex cognitive tasks. We also explained that the manipulations were for experimental purposes only and we shared current findings surrounding topics relevant to our experiment, namely mindset, working memory, and stereotype threat. The entire experiment was no longer than 1.5 h and occurred over the course of a single session. This procedure was motivated by previous research [10,13,18] as well as findings that suggest mindset is especially important and effective for underrepresented, marginalized, or at-risk students [21]. Furthermore, these data were used in a secondary and de-identified manner for the purposes of the present study, so we did not require any additional consent.

8.5. Tasks

For brevity, we summarize the measures we focused on in the current study using a secondary data approach. We direct the reader to Supplementary Materials S2 for full original methods and task descriptions in the initial study.

8.6. Baseline Measures

Mindset scale. The mindset scale was used to obtain a sense of how flexible students were in their beliefs about ability at baseline and after the mindset manipulation. The scale is a Likert scale from 1–6 and includes two questions asking subjects about their implicit beliefs about intelligence and ability. The questions were adapted and expanded from [4], and they were designed to determine whether a participant's belief about ability in the domain was more fixed or more malleable.

Pre-manipulation measures. In addition to the mindset manipulation, students completed several attitudinal measures. We focused on those that are theoretically relevant for the current study.

Grit. Students completed a grit scale [61] in order to gauge their levels of enduring effort over time. The scale includes eight items about perseverance and dedication to task completion with few distractions (e.g., "I finish whatever I begin") and are rated on a 5-point scale (1 = Not at all like me to 5 = Very much like me).

Academic Attitudes. To account for a variety of theoretically important individual differences in the original study, students completed survey questions probing several topics, including their interest and identification with various course domains and how much they value their academic performance. We focus on a subset of relevant questions about academic attitudes and students' feelings of belonging at their university. These questions included "Being good at academics is an important part of who I am" and "Doing well on intellectual tasks is very important to me". These questions were rated on a 7-point scale of agreement (1 = strongly disagree to 7 = strongly agree). Items were

motivated by previous work that investigated academic attitudes with a focus on identity and value systems [18]. In addition, students answered questions about how much they feel comfortable expressing their views on important matters, how much they identify or relate with their university, and how much they identify or relate with other students at their university on a 6-point scale of agreement. These items were answered both pre- and post-manipulation.

Reading span. The automated RSPAN was completed pre-manipulation to get a sense of participants' baseline WMC. The RSPAN requires making veridical judgments for sentences while remembering a list of letters. For example, an individual trial in a list would take the following form: "When at last his eyes opened, there was no gleam of triumph, no shade of anger. Yes or No? R". Participants were instructed to read the sentence, answer yes or no, and then remember the letter for later recall. At the end of a list of such trials, participants were asked to recall the letters in serial order, and the total was scored using the partial unit method [62]. Participants received three to seven letters per trial and three sets of each trial length, totaling 15 trials total and yielding a maximum score of 75.

8.7. Mindset Manipulation

Mindset conditions. Participants were randomly assigned to either the fixed or growth manipulation conditions. The fixed mindset manipulation informed subjects that intellectual ability has been shown to be innate and unchangeable, and it used a crafted example of a research article that claims to support this information [12,13]. Participants then completed a 15 min written activity where they detailed an instance in which they worked hard, but their increased effort did not improve their performance. In the growth mindset manipulation, participants read research showing abilities are malleable—that people continue to learn and grow and that intellectual ability can be improved with effort. Participants in the growth mindset condition then completed a short activity where they detailed an instance in which they needed to work hard in order to improve and were successful.

8.8. Post Manipulation Measures

Operation span. The automated OSPAN was completed post-manipulation to obtain a sense of students' state of WMC. The OSPAN task requires completing a series of arithmetic problems while remembering a list of letters. For example, an individual trial in a list would take the following form: " $[5 \times 9] + 5 = 45$? Yes or No? P". Participants were instructed to solve the equation, answer yes or no, and then remember the letter for later recall. At the end of a list of such trials, participants were asked to recall the letters in serial order, and the total score was calculated using the partial unit method [62]. Participants received three to seven letters per trial and three sets of each trial length, totaling 15 trials total and yielding a maximum score of 75.

GRE—math. The GRE mathematics subsection consisted of 25 multiple-choice or short-answer questions, each requiring mathematical reasoning and quantitative comparison skills (e.g., Solve the equation $5 = 4x + 3$ for x . Is x greater than, less than, or equal to 1?). Participants were given 20 min to complete the subsection. The material was taken from free online practice materials provided by the Educational Testing Service. The final score was the proportion of questions correct out of 25 possible questions.

Manipulation check. Students were asked again about their implicit beliefs about ability on the mindset scale in order to assess whether the manipulation was effective in attitude change from baseline.

8.9. Post-Manipulation Attitudinal Measures

Anxiety. Participants completed the Spielberger State–Trait Anxiety Inventory (STAI) [63] in order to observe state anxiety. The inventory consisted of 6 questions where participants were asked to indicate the most appropriate answer to each statement based on their present feelings. The inventory contained a 4-point Likert scale (e.g., "I feel calm?"

on a scale of 1 = not at all and 4 = very much). Questions associated with low levels of anxiety (e.g., “I am relaxed”) were reverse scored. For scoring purposes, the values for each question were summed—the scores ranged from 6 to 24.

Academic Attitudes. These questions are detailed in the pre-manipulation section. They were also administered post-manipulation.

Experiment survey. All participants completed an experiment survey. The survey included demographic information, and participants also reported their GPA and SAT scores in verbal and quantitative domains.

9. Results

9.1. Summary Statistics and Correlations

Descriptive statistics and correlations are presented in Table 1 and Figure 1 below. We found that participants scored above the middle of the scale (from 1–6) on mindset prior to the manipulation ($M = 4.41$, $SD = 1.22$), indicating that participants were reporting more of a malleable than a fixed mindset even before the intervention. There was a statistically significant negative correlation between mindset and grit at baseline ($r = -0.27$, $p = 0.014$), signifying that higher grit was correlated with less of a growth mindset, contrary to what we expected. Most of the relations with the mindset and other attitudinal measures were not statistically significant and in the opposite direction as predicted (see Figure 1).

Table 1. Summary statistics.

Measure	M	SD	Min	Max
1. GPA	3.53	0.33	2.7	4
2. OSPAN	65.95	6.96	42	75
3. RSPAN	60.09	10.21	30	75
4. Math GRE proportion correct	0.54	0.19	0.16	0.96
5. Math GRE proportion attempted	0.78	0.15	0.36	1
6. Mindset pre-manipulation	4.41	1.22	1	6
7. Mindset post-manipulation	4.3	1.26	1	6
8. Comfort expressing views pre-manipulation	4.37	1.15	1	6
9. Relating to university pre-manipulation	4.12	1.23	1	6
10. Relating to other students pre-manipulation	4.14	1.16	1	6
11. Grit pre-manipulation	3.27	0.62	1.625	4.625
12. Grit post-manipulation	3.43	0.62	1.75	4.75
13. Anxiety	12.67	3.27	6	21
14. Comfort expressing views post-manipulation	4.38	0.93	3	6
15. Relating to university post-manipulation	4.04	1.31	1	6
16. Relating to other students post-manipulation	4.13	1.22	1	6
17. Verbal SAT	749.8	45.72	620	800
18. Math SAT	734.42	55.5	600	800
19. Being good at academics is important	5.54	1.24	1	7
20. Doing well on intellectual tasks is important	5.75	1.08	3	7
21. Doing well on math tasks is important	4.59	1.47	1	7
22. Academic success is not important	1.97	1.17	1	6
23. Standardized tests are biased against me	3.05	1.57	1	7

In terms of the cognitive measures, participants scored higher overall on the post-manipulation measure of WMC on the OSPAN than on the baseline measure of WMC on the RSPAN, and this difference was statistically significant, $t(76) = 5.41$, $p < 0.001$, $d = 0.62$. We also found that while participants scored an average of about 54% correct answers on the math GRE, students attempted an average of about 78% of the test items. In terms of the relations among measures, we found that the WMC tasks were moderately correlated ($r = 0.44$, $p < 0.001$), but only OSPAN was statistically significant and weakly correlated with the proportion of correct answers on the math GRE ($r = 0.29$, $p = 0.011$). Interestingly, we also found that for the attitudinal measure of students’ beliefs that standardized tests are biased against them that there were weak-to-moderate negative relations with several measures,

including state WMC on the OSPAN ($r = -0.24, p = 0.041$), self-reported GPA ($r = -0.32, p = 0.013$), as well as for reported verbal ($r = -0.41, p = 0.003$) and math ($r = -0.33, p = 0.017$) SAT scores (see Figure 1).

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1. GPA	—																						
2. OSPAN	0.14	—																					
3. RSPAN	0.18	0.44**	—																				
4. Math GRE proportion correct	0.34**	0.29*	0.14	—																			
5. Math GRE proportion attempted	0.35**	0.21	0.08	0.72**	—																		
6. Mindset pre-manipulation	-0.13	-0.19	-0.22	-0.16	0.03	—																	
7. Mindset post-manipulation	-0.12	-0.14	-0.19	-0.03	0.19	0.82**	—																
8. Comfort expressing views pre-manipulation	0.13	-0.02	0.09	0.01	0.05	-0.04	-0.01	—															
9. Relating to university pre-manipulation	0.38**	-0.1	0	0.13	0.18	-0.05	0.02	0.2	—														
10. Relating to other students pre-manipulation	0.30*	0.13	0.1	0.17	0.14	-0.01	0.02	0.07	0.57**	—													
11. Grit pre-manipulation	0.25	0.15	0.12	0.01	0.07	-0.27*	-0.13	0.39**	0.29**	0.11	—												
12. Grit post-manipulation	0.18	0.21	0.21	-0.01	0.08	-0.26*	-0.14	0.24*	0.23*	0.19	0.83**	—											
13. Anxiety	0.11	-0.18	-0.07	-0.11	-0.13	0.12	0.05	0.06	0.09	0.06	-0.03	-0.09	—										
14. Comfort expressing views post-manipulation	0.14	-0.02	0.16	-0.01	0.13	0.08	0.13	0.72**	0.42**	0.21	0.36**	0.35**	-0.01	—									
15. Relating to university post-manipulation	0.39**	-0.09	-0.03	0.03	0.08	-0.05	-0.1	0.18	0.83**	0.63**	0.24*	0.31**	0	0.40**	—								
16. Relating to other students post-manipulation	0.19	0.08	-0.03	0.1	0.07	0.08	0.06	0.02	0.49**	0.85**	0.01	0.15	0.03	0.14	0.67**	—							
17. Verbal SAT	0.52**	0.03	0.09	0.59**	0.35*	-0.21	-0.11	0.31*	0.25	0	0.17	0.06	0.14	0.2	0.1	-0.07	—						
18. Math SAT	0.45**	0.21	0.12	0.65**	0.38**	-0.12	-0.06	-0.04	0.07	-0.04	0	-0.02	0.01	0	-0.02	-0.1	0.58**	—					
19. Being good at academics is important	0.22	0.02	0.03	0.15	0.14	-0.05	-0.12	0.19	0.28*	0.39**	0.15	0.20	-0.17	0.31**	0.37**	0.32**	0.08	0.11	—				
20. Doing well on intellectual tasks is important	0.26*	0.06	0.1	0.05	0.16	-0.08	-0.05	0.15	0.16	0.29*	0.23*	0.24*	-0.01	0.19	0.24*	0.25*	-0.01	-0.06	0.58**	—			
21. Doing well on math tasks is important	0.09	-0.03	-0.04	0.26*	0.20	-0.20	-0.17	-0.03	-0.02	0.27*	0.09	0.18	-0.16	-0.05	0.11	0.18	0.09	0.16	0.44**	0.50**	—		
22. Academic success is not important	-0.22	0.08	-0.01	-0.1	-0.05	-0.07	-0.2	-0.26*	-0.14	-0.19	-0.15	-0.06	-0.19	-0.29*	-0.08	-0.18	-0.14	-0.56**	-0.42**	-0.16	—		
23. Standardized tests are biased against me	-0.32*	-0.24*	-0.16	-0.37**	-0.16	0.06	0	-0.08	-0.31**	-0.42**	-0.13	-0.19	0.09	-0.25*	-0.26*	-0.33**	-0.41**	-0.33*	-0.24*	-0.07	-0.16	0.09	—

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

Figure 1. Correlations of variables.

9.2. Mindset Manipulation Effects

Manipulation check. To examine the degree to which the manipulations caused participants to endorse more fixed or growth mindsets, we conducted paired t -tests to investigate the change in students' mindset scale scores by condition from pre- to post-intervention. We found that people in the growth condition became more malleable, $t(36) = 2.12, p = 0.041, d = 0.35$, and that people in the fixed condition became more fixed, $t(38) = -3.10, p = 0.004, d = 0.50$, indicating that the manipulation was effective in promoting attitudinal change in the hypothesized directions.

Effect of manipulations on cognitive measures. In testing the hypothesis that growth mindsets are better for cognitive performance than fixed mindsets, we conducted independent t -tests to investigate these effects on cognitive performance measures of WMC and standardized test performance on the math GRE. First, we found that there were no statistically significant differences in baseline WMC on the RPSAN in the fixed- and growth mindset conditions, $t(75) = 1.06, p = 0.293, d = 0.24$.

Next, we looked at the effect of the mindset intervention on state WMC on the OPSAN; this difference was also not statistically significant, $t(75) = -0.55, p = 0.583, d = 0.13$ (see Figure 2).

Subsequently, we investigated whether the mindset intervention would have an impact on standardized test performance. We conducted an independent t -test and found no statistically significant difference in performance on the math GRE between the fixed and growth mindset conditions, $t(78) = -0.26, p = 0.796, d = 0.058$.

Effect of mindset manipulations on attitudinal measures. When examining overall change in grit scores ignoring mindset conditions, we found a statistically significant difference, $t(77) = 3.79, p < 0.001, d = 0.43$, indicating that overall, people reported higher grit scores after the manipulation ($M = 3.42, SD = 0.62$) than at baseline ($M = 3.27, SD = 0.62$). Next, we tested whether the fixed condition caused people to be less gritty from baseline than the growth condition as we hypothesized. We tested this by creating a gain score, taking the difference between post- and pre-manipulation grit scores. When we looked at change in grit by mindset condition, we found there was not a statistically significant difference, $t(76) = 1.9274, p = 0.058, d = 0.44$. Contrary to our hypothesis, we found that both fixed and growth conditions caused an increase in grit from baseline, but the fixed condition was not statistically significantly higher than the growth condition.

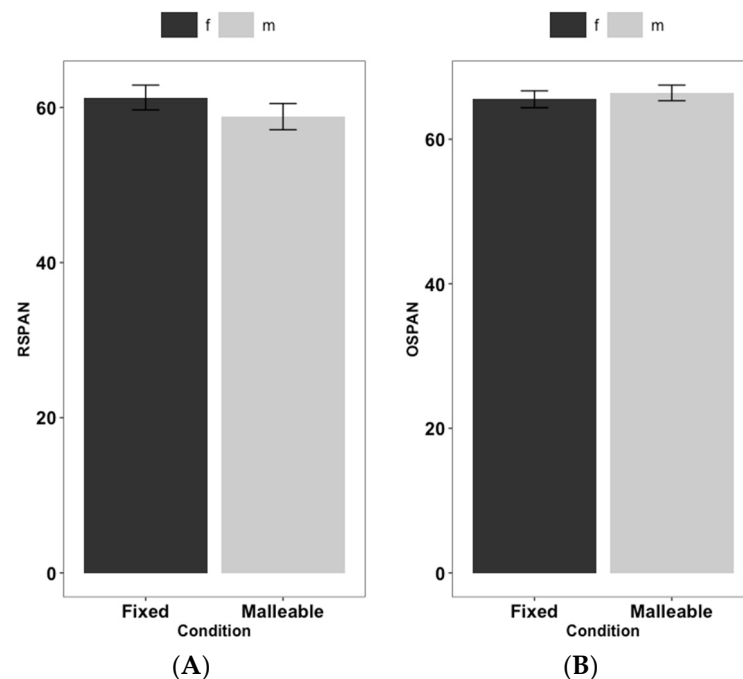


Figure 2. Effect of mindset intervention on trait WMC on the RSPAN (A) and state WMC on the OSPAN (B).

Next, we looked at the effect of mindset on academic attitudinal measures. For the item “Being good at academics is an important part of who I am”, we found no statistically significant difference, $t(72) = 0.92$, $p = 0.360$, $d = 0.22$.

Looking at the effect of mindset on the item “Doing well on intellectual tasks is very important to me”, we also found no statistically significant difference, $t(70) = 0.76$, $p = 0.510$, $d = 0.16$.

For the effect of mindset on the item “Doing well on intellectual tasks in the quantitative/mathematics domain is very important to me”, we found no statistically significant difference, $t(72) = 0.92$, $p = 0.361$, $d = 0.21$.

For the effect of mindset on the item “Academic success is not very valuable to me”, we ran a Welch t -test due to violation of Levene’s test and we found no statistically significant difference, $t(55.33) = -0.57$, $p = 0.571$, $d = 0.13$.

For the effect of mindset on the item “I feel that standardized achievement tests are definitely biased against me”, we found no statistically significant difference, $t(72) = 1.02$, $p = 0.310$, $d = 0.24$.

Finally, we investigated the effect of mindset on students’ reported anxiety. We found no statistically significant difference, $t(77) = -1.26$, $p = 0.213$, $d = 0.28$.

Overall, the results of these post-survey items indicate that the mindset manipulation did not have statistically significant differential effects on many of these attitudinal variables.

Next, we explored whether the mindset conditions differed in their effect on the change in several attitudinal survey items. These items probed how much participants feel comfortable expressing their views on important matters, how much they identify or relate with their university, and how much they identify or relate with other students at their university. Based on our detailing of mindset theory above, it is reasonable to expect that people primed with fixed mindsets might be less comfortable with expressing their views on important matters and may even feel less connected with those around them. We tested these hypotheses by creating gain scores for the survey items listed above.

Turning to the effect of mindset on the change in beliefs regarding how comfortable students feel expressing their views on important matters, we found no significant difference, $t(72) = 1.14$, $p = 0.256$, $d = 0.26$.

Examining the effect of mindset on the change in beliefs regarding how much students identified or related with their university, we found a statistically significant difference, $t(75) = 2.04$, $p = 0.044$, $d = 0.47$, which was not in line with our hypothesis, as the fixed condition believed this more after the manipulation (Figure 3; $M = 0.077$, $SD = 0.81$) and the growth condition believed this less after the manipulation ($M = -0.26$, $SD = 0.64$).

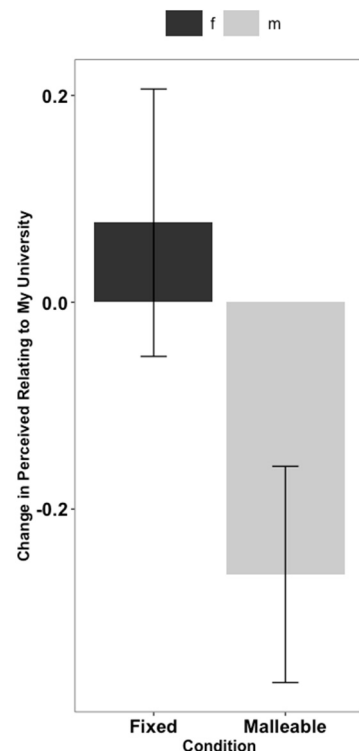


Figure 3. Change in student beliefs about relating to their university by mindset condition.

Finally, we investigated the effect of mindset on changes in beliefs regarding how much students identified or related with other students at their university, and found that this difference was not significant, $t(75) = 1.79$, $p = 0.078$, $d = 0.41$.

Taken together, the effect of the mindset intervention on the change in students' attitudes generally did not provide evidence supporting our hypotheses based on mindset theory.

10. Discussion

The purpose of this study was to explore the effects of a mindset intervention on WMC and standardized test performance measures for women while also considering the role of attitudinal variables. The study's methodology was motivated by the need for a more nuanced understanding of mindset intervention effects. We expected that the mindset intervention would make participants show more growth or more fixed mindsets based on the experimental conditions and that the participants with more growth mindsets would perform better on WMC and standardized test performance measures. Additionally, we predicted that in the growth mindset condition, participants would have higher grit and more positive academic attitudes and lower anxiety compared to the fixed condition.

Our results do not support these hypotheses en masse. First, a manipulation check indicated that the mindset intervention was successful in shifting participants' mindsets, but this effect did not lead to significantly higher post-manipulation WMC in the growth condition compared to the fixed condition. The results also indicate that standardized test performance was slightly higher in the growth mindset condition as expected, but this effect was small and not significant. Further, grit increased from baseline overall but was not significantly higher in the growth condition, which was contrary to our hypothesis. The majority of the attitudinal measures revealed no significant relations with mindset, no

significant differences in student attitudes between conditions, and no significant attitudinal change in the predicted directions.

These results do not provide strong evidence to support the claim that mindset interventions are generally or immediately beneficial for measures of cognitive ability, such as WMC and standardized test performance. This falls in line with the mindset intervention literature that demonstrates concerns regarding effectiveness, replicability, and generalizability [21,22,25–27]. Moreover, our finding that both growth and fixed conditions increased in grit from baseline supports the recent literature that suggests that the premises surrounding mindset theory are more nuanced and complicated than the original theory purports [25]. Specifically, mindset theory proposes that a fixed mindset is associated with aversion to challenge and persistence [4], yet we found that both growth and fixed conditions increased persistence through grit scores.

Nevertheless, we believe that our non-significant results, within the scope of mindset theory and intervention, provide a more comprehensive understanding of the conditions for a successful mindset intervention. A deeper look into the study's limitations and methodology might provide insight into the processes underlying mindset interventions, ultimately clarifying when, how, and most importantly for whom they are effective. This knowledge may contribute to a framework for precise and targeted interventions that more effectively meet the needs of students [3].

11. Limitations

We recognize some limitations of this research. First, we ended up with a relatively small final sample size. This limitation could contribute to the lack of statistical significance in our study, specifically regarding the higher scores on post-manipulation WMC and standardized math test performance for participants in the growth mindset condition. The small sample size could have tempered the significance of the small increase that we observed by weakening the power of this boost in performance. Our observed effect sizes were $d = 0.13$ for post-manipulation WMC on the OSPAN, which were small to moderate, whereas the observed effect size for performance on the math standardized test was $d = 0.058$, which was very small and more in line with the meta-analytic average standardized mean difference reported in [21] of $d = 0.08$. However, this meta-analysis was published after the present experiment was conducted, so it could not have been considered for this experiment's methods. Rather, our sample size was motivated by [10,13,18]. Each of these studies contained samples with around 40 participants per condition and found significant differences between mindset conditions of interest. Nevertheless, employing a larger sample size allows for greater statistical power and may help resolve the extent to which these results were driven by low statistical power. Furthermore, due to the relatively small sample size and the exploratory nature of our measures, we performed quite a few statistical tests without correcting for multiple comparisons. The results here should be seen as trends and replicated with direct and targeted tests that make these corrections. Finally, we acknowledge that while our deliberate focus on an all-female sample for testing our hypotheses regarding mindset intervention in math was purposeful, this does slightly limit the potential generalizability of our findings for the mindset intervention literature more broadly.

12. Additional Explanations

Beyond the aforementioned limitations, other conceptual factors could have played a role in the outcome of our study. These factors may also offer a more in-depth understanding of mindset theory and social-psychological mindset interventions by elucidating the elements that influence an intervention's efficacy.

The length of our study may have played a role in our findings. We did not explore the effect of our mindset intervention longitudinally. Our entire study was only 1.5 h max and did not entail follow-up measures after the study. Our study's design and the lack of significant transfer to measures of cognitive ability may offer support for the

notion that one-off social–psychological interventions are less effective. Some research suggests that mindset interventions work by changing the way in which students approach challenges, bolstering students’ resilience or tapping into recursive processes [12,63]. Yeager and Walton [12] propose that these recursive processes engage motivational cycles and behaviors, which could take more time to effect positive change. These ideas, juxtaposed with our null findings, could suggest that mindset interventions may operate in a more longitudinal and contextual system and that these attributes may be necessary for their influence over measures of cognitive ability. As such, one perspective might be that our study was not long enough to see the intended effects. However, we should also note that several of the aforementioned studies in the mindset literature, including those that motivated our design, were able to show significant correlational and experimental effects of mindset for performance measures assessed in both the shorter (e.g., immediate post-intervention performance [10,32]) and longer term (e.g., performance over the course of the semester or over the course of several years [13,18,24,64]). In addition, the length of time between intervention and final test in some studies [10] was similar to ours, suggesting that longer retention intervals may not necessarily be required in order to see significant mindset intervention effects.

Additionally, our manipulations targeted general intelligence rather than domain-specific intelligence in math. Many mindset interventions target general intelligence, so we had participants read prompts and write about the innate or malleable nature of their intellectual ability. We believe that this paradigm is appropriate when translated to the domain of math due to the common perception that math ability is not only innate but also highly indicative of one’s general intelligence, and seminal works show that mindset interventions targeting general intelligence have direct effects on performance in the math domain [13,15]. Nevertheless, we cannot rule out the possibility that our lack of domain specificity in the manipulations did not contribute to our non-significant results. A math-oriented mindset intervention may have been more effective in improving performance on the OSPAN and math standardized test.

Another possible explanation for our findings involves the age of the participants. While some studies examine mindset interventions in college students [18], most target a younger demographic [12]. It is possible that younger students may be more receptive to social–psychological interventions and that one’s mindset may more easily transfer to measures of cognitive ability in younger students. Given this framework, our study’s focus on women college students may have influenced the findings. This provides further support for the importance of strategically targeted and timed interventions in order to achieve an optimal outcome [20], suggesting that older students may not be the most appropriate or practical targets for these kinds of social–psychological interventions.

Finally, the high-achieving nature of our student sample may also help explain the findings. Our sample population consisted mostly of undergraduate students from a private university. We recognize that private university students are diverse and come from different backgrounds, but entry into these universities can be competitive and requires high performance on measures of cognitive ability, like standardized testing and WMC. This high achieving sample could have attenuated the effect of the intervention on measures of cognitive ability since they may not have as much to improve regarding standardized test performance as other populations. Furthermore, we also saw increases in WMC for the fixed mindset condition and the growth mindset condition, which may be explained by the participants presumably having enough WMC at baseline to use the fixed intervention as motivation as well, which follows studies that consider how fixed mindsets may even be beneficial for people in favorable circumstances [66]. These findings offer insight into the individual differences that impact the efficacy of mindset interventions. The absence of a significant transfer between growth mindsets and WMC or standardized test performance measures suggests that mindset interventions may not be as effective in high-achieving samples. These findings also support the notion that the beneficial effects of mindset may be overstated in generalized populations [25] and may have greatest effects

in certain minority student groups, more disadvantaged and/or at-risk students, or lower SES populations [9,17,21]. Our findings fall in line, ultimately suggesting that some sample populations, such as high achievers and successful students, may not have as much to gain from academic mindset interventions.

13. Conclusions

Though this study did not see the intended effects of significantly increased WMC and standardized test performance following a mindset intervention for women, it provides important insight into mindset theory and the factors that may influence an interventions' efficacy. It is worthwhile to continue probing the relationship between mindset and measures of cognitive ability, and there is value in revealing when, how, and for whom mindset interventions do not improve these measures.

Given the inconsistency of social-psychological mindset interventions, the resource demands and opportunity costs associated with implementing them, and the urgency to mend pervasive and consequential academic achievement gaps, it is imperative that we know what makes these interventions effective. Our findings can help inform where limited resources are best allocated by encouraging caution for mindset interventions that have a one-off design, concern an older student demographic, or sample more high-achieving populations. Ultimately, this study strengthens our understanding of mindset theory and its effects on measures of cognitive ability and academic attitudes, equipping us with tools to make more informed decisions about future research and practical applications of mindset interventions.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/educsci14030227/s1>, Supplementary Material S1: Original Stereotype Threat Study Methods and Results; Supplementary Material S2: Manipulation Materials; Supplementary Material S3: Survey Materials.

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Institutional Review Board Statement: The original study was conducted in accordance with the Declaration of Helsinki, and approved by Princeton Institutional Review Board for Human Participants (protocol code 10037 and Approval Date: November 2017).

Informed Consent Statement: The current data do not require IRB or additional informed consent as they are secondary de-identified data. The original data were collected under a doctoral dissertation project at a private research university in the northeast of the United States which concluded in 2018. Presently, as the first author collected this data as part of doctoral research these de-identified secondary data analyses do not require additional consent of any kind.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

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