Coulda, Woulda, Will I?: An Experimental Investigation of Counterfactual Thoughts and Intention Generation in Engineering Student Success

Dr. Amy Summerville, Miami University

Dr. Summerville is an Associate Professor in the Department of Psychology at Miami University. She earned her Ph.D. in Psychology from the University of Illinois at Urbana-Champaign. Dr. Summerville is a social psychologist whose research examines how thoughts of "what might have been" affect emotion, motivation, and behavior. She is the PI of a grant from NSF's EEC division investigating new interventions in engineering education that utilize social cognitive psychology.

Dr. Jennifer Blue

Jennifer Blue is an Associate Professor of Physics at Miami University. She works to give more people access to physics. Sometimes that's reforming the curriculum for introductory classes, sometimes it's working with K-12 science teachers, and sometimes it's advocating for traditionally excluded populations, including women in STEM. Her website can be found here: http://www.users.miamioh.edu/bluejm/.

Dr. Brian P Kirkmeyer, Miami University

Brian Kirkmeyer is the Karen Buchwald Wright Senior Assistant Dean for Student Success and Instructor in the College of Engineering and Computing at Miami University in Oxford, Ohio. His background includes BS, MS and PhD degrees in Materials Science and Engineering (specialization in polymers), the former from Purdue University and the latter two from the University of Pennsylvania. He has work experiences in automotive electronics (Delphi Automotive Systems) and consumer products (International Flavors and Fragrances) prior to his current role. He served on the executive committee of the ASEE Women in Engineering division from 2010 to present.

Ms. Brielle Nikole Johnson

Brielle Johnson is a graduate student in the Social Psychology program of the Department of Psychology at Miami University. She earned her B.S. from Grand Valley State University with a double major in Psychology and Sociology. Her research interests include issues related to social class, as well as areas of existential psychology and counterfactual thinking.

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Abstract

Students frequently struggle in first year engineering and cognate classes, posing challenges to timely completion of the degree and potentially contributing to attrition from engineering majors. The goal of our grant (NSF EEC-1530627) is to examine whether helping students reflect on performance early in the course would improve student outcomes. In particular, we examined counterfactual thoughts, thoughts about "what might have been." These thoughts contribute to causal reasoning and play an important role in making plans for the future. Additionally, we examined behavioral intentions, specific plans for future actions in the course, which research has also shown improves student outcomes.

After the first exam in a large-enrollment class taken by first-year engineering majors, 290 students were randomly assigned to either generate counterfactuals about what they personally could have done differently that would have resulting in doing better on the exam (vs. describe their actual performance) and to either generate intentions about what they could personally do to improve their performance for the remainder of the semester (vs. describe their expectations for the remainder of the semester). Students also reported their exam grade. At the end of the semester, instructors provided the final course grade.

We examined the effects of the intervention conditions by regressing final grade onto the counterfactual condition, intention condition, and the standardized value of the exam grade and all possible interaction terms. This revealed no significant effect of either intervention condition, nor any significant interaction involving either intervention condition.

Thus, in the current study, neither reflecting on thoughts about how one could have done something different to improve performance nor generating plans to improve in the future improved student outcomes in the course. Ongoing work is examining whether there are specific subgroups of students who benefitted from the intervention, and whether there are additional circumstances under which these interventions might be beneficial.

Literature review

Students beginning a college career as engineering majors may struggle to adjust to the new challenges and contexts of the university setting. These early challenges can create serious challenges to successful and timely completion of the engineering degree, as students who withdraw from the engineering major are more likely to have failed or withdrawn from first-year classes [1], [2]. Early intervention is thus crucial, as students often develop necessary study skills too late to prevent these early setbacks [3]. Recently, research has begun to focus on developing brief, low-cost interventions informed by research in social-cognitive psychological science [4]. The current research therefore aims to test a novel, brief intervention focused on student thoughts about their performance and behavior.

In particular, the current research is focused on *counterfactual thoughts.* These thoughts about "what might have been" are pervasive in everyday life [5]. Moreover, these thoughts play an important role in causal reasoning [6]–[8]. For instance, if a student thinks "If only I had done more practice problems, I would have gotten a better grade", they have identified a different cause of a poor exam performance than a student who thinks "If only I had taken better notes in class." Given the importance of metacognition in student learning in STEM [9], the process of causal reasoning about failure prompted by counterfactuals may be particularly important to student success.

Counterfactual thoughts thus have the potential to benefit both reasoning and performance [10]. In particular, counterfactuals may increase both the amount of control that an individual feels they have over an outcome [11] and their optimism about the outcome [12]. Furthermore, because of their links to causal reasoning, counterfactuals can facilitate the formation of behavioral intentions [13], [14]. As a result, counterfactuals can increase motivation and persistence [15] and lead to improved outcomes [11], [16]. However, counterfactuals are also implicated in the experience of regret [17], and may be linked to negative mental health outcomes such as anxiety and depression [18], [19].

Counterfactual thoughts are linked to behavioral intentions, specific plans about how a goal will be pursued in the future. (For instance "improve health" is not a behavioral intention; "go to the gym before class" or "eat at least 2 servings of vegetables with dinner every night" are.) However, behavioral intentions have clear benefits independent of counterfactual thought. Behavioral intentions are particularly helpful in situations involving complex tasks that have many component steps, which is characteristic of academic success in most college-level engineering classes. Generating behavioral intentions may thus improve student course outcomes even in the absence of counterfactual thoughts [20], [21].

The current research thus experimentally tested an intervention using a factorial design. Participants were randomly assigned to generate counterfactuals about their performance on the first exam (versus engage in non-counterfactual reflection), and to generate intentions about their plans for the remainder of the course (versus engage in general reflection about "how the course might go" in the future.) We were interested in whether either of these interventions, alone or in concert, would improve students' course grades in courses taken by first-year majors. We targeted two courses taken by large numbers of undergraduate engineering majors, and which both have high rates of students earning low grades (D or F) or withdrawing with a transcript notation.

Method

Participants

Participants were recruited from students at a mid-sized Midwestern university enrolled in either of two courses commonly taken by first-year engineering majors: a calculus-based physics course, which serves as a prerequisite for introductory engineering courses, and an introductory programming course. 375 students completed an initial intake survey, of which 290 completed the experimental session in this study (160 male, 129 female; M_{age} = 18.65; 246 white, 34 Asian or Asian-American, 10 Black, 4 Native American, 11 Hispanic). Of this sample, 178 identified as currently declared or intended engineering majors.

Intake Survey

All students enrolled in the target courses received an email invitation to participate in a paid study. Upon clicking the link in the invitation survey, participants were asked to provide informed consent. Additionally, participants completed a FERPA release authorizing the release of their academic record to the research team. Participants then completed demographic measures. All recruitment materials, consent documents, and measures for all sessions were approved by the university Institutional Review Board.

Experimental session

Participants who completed the intake survey were contacted via email approximately one week after the first exam in the course. Participants were asked to provide their grade on the first exam as a percentage from 0-100; this value was standardized. The critical manipulation in the study involved two writing tasks. For each task, participants were randomly assigned to one of two conditions.

In the first writing task, participants were asked to reflect on the exam they had just taken. In the counterfactual (CF) condition, participants were instructed:

*After an exam, students have many kinds of thoughts—what went well, what went poorly, what they did to prepare, what they might have done differently. Right now, we would like you to think about **how the exam could have gone better if you had done something differently**. Think about if there are things you might have done, but didn't, or things you might not have done, that would have made the exam turn out better than it did. You may need to take a moment to think about this. If you can think of more than one such thing, try to pick the thing that you think would have made the biggest difference in how the exam turned out for you.*

In the space below, explain how you would complete the sentence "If only I _____, the exam would have gone better." Please include enough detail so that someone else could understand the situation, but leave out any details like names that would allow someone to identify you or others.

In the control condition, participants were instructed:

After an exam, students have many kinds of thoughts about a course. What are your thoughts and feelings about this course so far? Please include enough detail so that someone who is unfamiliar with you and the course would understand your thoughts, but omit any details like names, section numbers, etc. that might allow someone to specifically identify you or others.

Participants were then asked to rate to what extent different statements described their thoughts using 7 point scales labelled from "Strongly Disagree" to "Strongly Agree" (e.g. "Right now, I am thinking about the things I did well.") The statement "Right now, I am thinking about how things might have been better if I had done something differently" was used as a manipulation check of self-focused counterfactual thought. Participants then completed a measure of their current feelings of regret, the Regret Elements Scale (RES) [22]. The RES measures a cognitive component of regret (e.g. "I should have behaved differently") and an affective component of regret (e.g. "I feel like kicking myself). We wished to ensure that the manipulation did not increase affective regret; given that the cognitive subscale is a measure of self-focused counterfactual thought, we used this as an additional manipulation check.

Following this, participants completed the second writing task, in which they were asked to reflect on the upcoming portion of the course. Participants randomly assigned to the intention generation condition were told:

We'd now like you to think about the rest of the semester in this course. What things can you do (or do differently, or stop doing) that will help you be more successful in the course going forward? What steps do you need to take to actually do these things? (For instance, if you want to spend more time studying for the course, you might need to schedule time on your weekly calendar; if you want to go to office hours, you might need to look up the time and location, etc.) Please include enough detail so that someone else could understand your plans, but leave out any details like names that would allow someone to identify you or others.

Participants assigned to the control condition were instructed:

We are also interested in your thoughts and feelings about this course in the remainder of the semester. In the space below, please describe your thoughts and feelings about the remaining weeks in the course. Please include enough detail so that someone who is unfamiliar with you and the course would understand your thoughts, but omit any details like names, section numbers, etc. that might allow someone to specifically identify you or others.

Course Grades

Instructors of the target courses were contacted after the end of the semester and asked to report course grades for participants. Letter grades were converted to a 4-point GPA scale using the university's GPA point system.

Results

We first analyzed data from the manipulation check measures. Surprisingly, the manipulation check in the counterfactual condition did not differ from the control condition (Ms = 5.252 vs. 5.250, $t(283.92) = 0.01$, $p = .99$). However, participants in the counterfactual condition reported more cognitive regret (Ms = 4.79 vs. 4.44, $t(284.73) = 2.17$, $p = .03$), indicating that they were in fact engaged in more counterfactual thought about their own actions. However, the two conditions did not differ in affective regret (Ms = 3.78 vs. 3.59, $t(285) = 0.99$, $p = .32$), indicating that the manipulation was successful at changing students' thoughts without increasing emotional distress.

The main question in this study was whether the intervention conditions (counterfactual and/or intentions) improved student outcomes. To test this, we regressed the course grade onto the interaction of the counterfactual condition (coded as 0 = control, 1 = counterfactual), intention condition (0 = control, 1 = intention), and the standardized value for the exam grade. This revealed only a significant main effect of exam grade (B = 0.76, $t(253) = 6.69$, $p < .001$). Neither main effect of condition was significant (CF: B = -0.17, $t(253) = 1.20$, $p = .23$; Intention:

B = 0.02, t(253) = 0.16, p = .87), nor were any 2-way interactions (all t < 1.50, all p > .15). See Figure 1.

Figure 1: Effect of intervention conditions on final grades
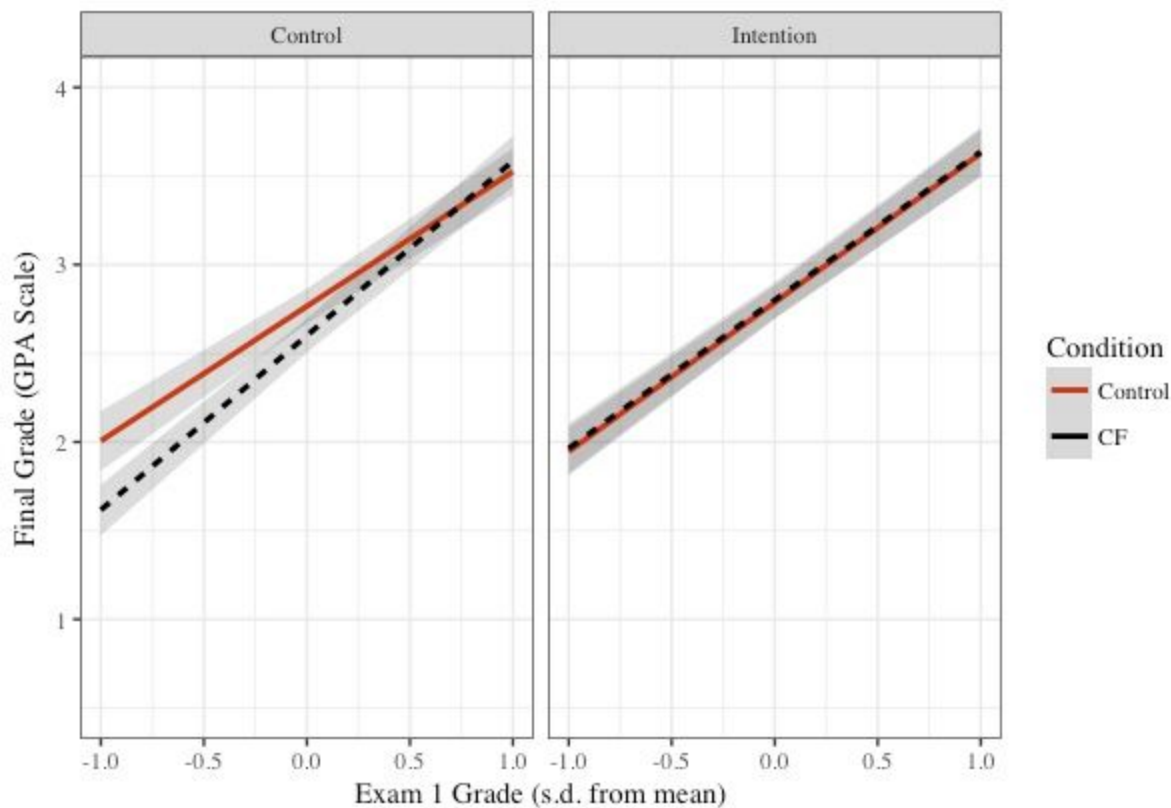
Discussion

The current research was intended to test a potential set of interventions focused on changing students' thoughts about their academic performance as a way to improve performance. It used an experimental approach to test whether generating counterfactuals about initial performance, intentions for the future, or both in combination, would lead to higher course grades. Contrary to our hopes and expectations, this study indicated that neither intervention was not successful at improving course grades.

One potential issue with the current research is whether the intervention effectively manipulated student thoughts as intended. In particular, there was no difference in the rating of the extent to which participants in the counterfactual versus control conditions were focused on thoughts of how the exam might have gone better as a result of their own actions, though there were differences in cognitive regret, another measure of this same pattern of thinking. Moreover, there was no manipulation check in the intention condition. Even if these instructions were effective

at instilling the kinds of thoughts intended, it is possible that the thoughts students generated were ineffective. Past research indicates that both counterfactuals and intentions must be focused on specific and controllable actions to have an impact on behavior [20], [23]. If students instead generated general counterfactuals or intentions (e.g. "study harder"), these would be less likely to improve outcomes. Moreover, students may focus on less effective study strategies (e.g., re-reading the textbook versus rewriting notes), which would further limit the potential effectiveness of these thoughts. Counterfactuals that focus on less relevant factors may produce biases in reasoning and worse outcomes [24]. Thus, a more in-depth intervention that includes some training on effective versus ineffective study strategies may be more effective than the relatively self-generated approach in the current research. For instance, it may be more beneficial to train faculty and academic advisors in the process of generating counterfactuals and intentions as a strategy to use in conversations with struggling students.

Although the current results make clear that the interventions in the present study were not uniformly effective, it is possible that there are subgroups for whom these interventions may have been useful. Given the benefits of counterfactuals for motivation and optimism, it may be the case that students with lower efficacy or more fixed mindsets would benefit more from these interventions. Additionally, if these interventions are effective among student populations with higher attrition risk, they might be more selectively deployed as an intervention with these students.

Despite the promise and appeal of brief and low-cost interventions based on psychological science, the current research makes clear that these approaches are not a "magic bullet" [25]. Instead, further research is necessary to refine the current intervention or better specify the contexts under which it may be effective.

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