Improving Student Achievement in STEM (Science, Technology, Engineering, Mathematics) Disciplines: The Role of Online Interventions

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Abstract

Attributional retraining (AR) is a remedial intervention that targets students' maladaptive causal attributions for poor performance by encouraging controllable attributions that correspond to academic success. The present study investigated how web-based AR impacted achievement (grade point average) in 138 college students enrolled in STEM degree programs (i.e., science, technology, engineering, medicine). Students' GPA was measured longitudinally across four semesters as afforded by objective institutional data. Results revealed that writing-based AR was the most effective version of the intervention for helping students improve their GPA longitudinally. The aptitude test AR format was found to have the greatest initial positive impact on performance, however, this effect dissipated by the third semester. Future directions for web-based AR research are discussed.

Objective

Attributional retraining (AR) is a remedial intervention that targets students' maladaptive causal attributions for poor performance by encouraging controllable attributions that correspond to academic success (Haynes et al., 2009; Perry et al., 1993). AR interventions are derived from Weiner's attribution theory (Weiner, 1985, 2006) that demonstrates how performance and achievement striving are influenced by the attributions individuals make about evaluative outcomes. The present study investigated how web-based AR impacted achievement (grade point average) in college students enrolled in science, technology, engineering, or mathematics (STEM) degree programs.

Background

When faced with unexpected failure events, Weiner's (1985, 2006) attribution theory postulates that individuals make attributions in order to determine the cause(s) behind their failure - especially when the task is perceived as important. Every attribution is linked to a set of behavioural, cognitive, and emotional consequences that impact future motivation levels and achievement striving (Weiner, 1985, 2006). In the academic domain, these attributions can include effort, ability (acquired skills or aptitude), quality of instruction, luck, course difficulty, grading criteria, and help or hindrance from others (Graham & Williams, 2009). Lack of ability, for example, is usually perceived as an innate characteristic that is immutable and beyond the control of the individual. Stable and uncontrollable attributions, such as lack of ability, foster hopelessness and shame. On the other hand, attributing failure to unstable and controllable causes, such as lack of effort or poor study strategy, leads to feelings of hopefulness and guilt that can help promote motivation and achievement striving (Weiner, 1985, 2006). Effort and

ability are the most often cited attributions in achievement contexts and therefore tend to be the focus of many AR programs (Graham & Williams, 2009).

In AR interventions, participants are informed about the benefits of adopting personally controllable, causal attributions as opposed to uncontrollable, maladaptive attributions following poor performance (e.g., low test score). Early studies on college students (e.g., Wilson & Linville, 1982) have shown how AR can help protect motivational resources and encourage persistence and increased effort in the future. Ongoing research has consistently found in-person AR to help students make modest improvements in their academic performance (for reviews see Haynes et al., 2009; Perry et al., 1993). More recently, preliminary findings highlight the beneficial impact of web-based AR programs for improving academic performance among university students in a social science course (Hall et al., 2005). However, a literature search revealed no published studies in which the effects of web-based AR were evaluated for college/university students enrolled in STEM degree programs.

As affordable and accessible motivational interventions administered via the Internet have the potential to be valuable tools for educators and academic administrators for improving students' academic development, empirical research in which the effects of such programs are evaluated is warranted. Recently, organizations and government agencies such as the National Academy of Science, the National Academy of Engineering, and the U.S. Department of Education have stressed the need to strengthen STEM education, increase the number of students entering STEM-related programs, and support students currently enrolled in STEM degrees (National Academy of Science, 2005; U.S. Department of Education, 2006). Thus, there presently exists a considerable focus on re-strengthening STEM education within various federal agencies fueled in part by growing concerns over the United States remaining competitive in the rapidly changing global economy (Chen & Weko, 2009).

The objective of the present study was to determine if web-based AR methods could be used to help college students enrolled in STEM degree programs improve on cumulative achievement measures by encouraging them to adopt controllable attributions for future performance outcomes. Students' grade point average (GPA) was measured longitudinally across four semesters as afforded by objective institutional data. It is anticipated that by adopting controllable attributions encouraged in the AR treatment, students in STEM disciplines will be better equipped to cope with the challenges of demanding STEM programs, and demonstrate greater motivation and achievement throughout their academic career. The AR intervention is thus expected to help protect students' valuable motivational resources and encourage persistence, thereby allowing them to outperform their peers on long-term achievement indicators.

Method

Participants and Procedure

The study sample consisted of 138 college students (mean age = 20.33, *SD* = 2.63, 60% male) from the University of California, Irvine. All participants were enrolled in one of six STEM-related programs including physical sciences, biological sciences, health sciences,

computer/information sciences, engineering, and medicine. In exchange for participating in the study, participants were provided either extra course credit or were entered into a raffle for an Ipod. In the Winter '07 semester, all participants completed a web-based questionnaire that included a battery of motivation-related measures as well as demographic items (20-30 minutes). Participants were automatically assigned to the AR treatment or No AR control group based on the order at which they arrived at the preceding questionnaire (i.e., even numbers = AR, odd numbers = No AR). Participants in the AR treatment were randomly assigned to one of two conditions (an aptitude test or writing assignment AR format) and were then immediately presented with the intervention (20 minutes). Sessional GPAs were obtained from the university registrar's office for all study participants.

Study Measures

Attributional retraining. Participants in the AR treatment first reviewed a brief, web-based reading (i.e., an informational schematic) based on an AR handout used in previous in-person AR studies (e.g., Perry & Struthers, 1994). The reading consisted of a variety of statements informing them of the benefits of personally controllable causal attributions (e.g., effort: "I didn't study hard enough") as opposed to uncontrollable attributions (e.g., ability: "I'm not smart enough to succeed in this course") following poor performance. The reading thus suggested a number of adaptive attributions that the participants could adopt following poor performance.

In the second phase, participants completed a timed aptitude test or writing assignment. The aptitude test (Hall et al., 2004; Perry & Dickens, 1984) consisted of two sections including verbal analogy and mathematics questions (five minutes per section). The test was intentionally difficult in order to elicit reactance and promote the usage of the adaptive failure attributions. The writing assignment (cf., deep learning; Entwistle, 2000) required students to think about the AR information in the first phase by having them summarize it, list potential reasons for poor performance, and provide examples of how they can incorporate the AR information into their studies (15 minutes). This was followed by a debriefing page notifying participants of the study purpose along with a final presentation of the AR reading.

Sessional GPA. Academic achievement was assessed by obtaining students' end-of-semester sessional GPAs from institutional records for the Fall '06, Winter '07, Spring '07, Fall '07, and Winter '08 semesters.

Analysis

The analysis consisted of a repeated-measures ANCOVA (treatment condition as IV: Aptitude Test AR, Writing AR, No AR) on four post-AR GPAs. To control for potential confounds involving the degree to which the participants were engaged in the experimental protocol, covariates included the time elapsed during the pre-AR survey and the order in which the participants began the questionnaire (see Hall et al., 2005). Based on a one-way ANOVA revealing a significant AR initial difference on Fall '06 GPA, this variable was also included as a covariate. Additionally, course load and level of study were included as covariates to eliminate potential confounds due to students' enrollment status. Participants' final high-school grade was

also included as a covariate as a proxy for aptitude differences. Finally, gender was controlled for due to unequal male-to-female ratios in STEM disciplines (Chen & Weko, 2009).

Results

The repeated-measures ANCOVA revealed a significant within-subjects interaction between time and AR on GPA, $F(5.75, 367.66) = 2.49$, $p = .025$. This was accompanied by a significant within-subjects linear contrast, $F(2, 128) = 4.32$, $p = .015$.

As presented in Figure 1, the results indicated that writing-based AR was the most effective form of the intervention for aiding students' academic performance. At the end of the semester in which the intervention was administered (Winter '07), and in the semester immediately following (Spring '07), students in the writing-based AR version performed slightly better (Winter '07: $M = 3.08$, $SD = .08$; Spring '07: $M = 3.09$, $SD = .08$) than the control group (Winter '07: $M = 2.99$, $SD = .08$; Spring '07: $M = 3.04$, $SD = .08$). However, in the following semester (Fall '07), students in the writing-based AR group made significant improvements in their GPA ($M = 3.12$, $SD = .09$) relative to the control group who exhibited a decline in performance ($M = 2.92$, $SD = .09$). Despite improvements in the control group's performance in the fourth and final semester (Winter '08: $M = 3.07$, $SD = .10$), students in the writing version of the intervention continued to significantly outperform the controls ($M = 3.22$, $SD = .10$).

For students in the aptitude test AR group, the results were mixed. Initially, students who had undergone the aptitude test AR (Winter '07: $M = 3.12$, $SD = .09$; Spring '07: $M = 3.15$, $SD = .09$) outperformed students in both the writing AR (Winter '07: $M = 3.08$, $SD = .08$; Spring '07: $M = 3.09$, $SD = .08$) and control groups (Winter '07: $M = 2.99$, $SD = .08$; Spring '07: $M = 3.04$, $SD = .08$; see Figure 1). In the Fall '07 semester, however, the beneficial effects of the intervention were less evident with students in the aptitude test AR group ($M = 2.86$, $SD = .11$) performing similarly to controls ($M = 2.92$, $SD = .09$). A full year after the intervention had been administered (Winter '08), the treatment effects for the aptitude test AR were reversed, with students in the control group demonstrating higher achievement levels ($M = 3.07$, $SD = .10$) relative to students in the aptitude test AR group ($M = 2.83$, $SD = .12$).

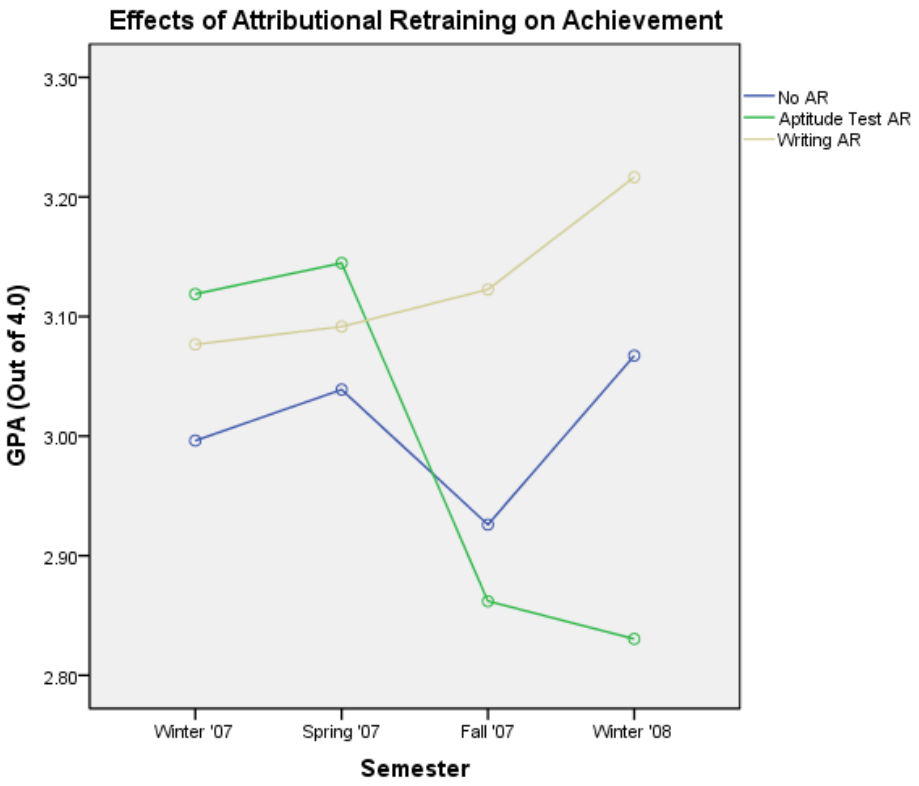

Figure 1. Differential effects of attributional retraining on GPA.

Discussion and Implications

The present findings revealed that writing-based AR was the most beneficial version of the intervention for helping students in STEM degree programs to improve their GPA. Students who received writing-based AR at the beginning of the Winter ’07 semester were able to consistently improve their sessional GPA across four semesters and were still benefitting from the intervention in the Winter ’08 semester, *one full year* after the intervention was administered. These results therefore replicate the findings of Hall et al. (2005) in which web-based AR was found to help improve academic performance for students in the social sciences, by showing these effects to also occur for students in natural science disciplines.

STEM students who had undergone the aptitude test AR showed the greatest initial improvements in GPA. In the Winter ’07 and Spring ’07 semesters, the aptitude test AR group recorded higher GPAs than the controls and writing-based AR group. However, this effect had dissipated by the Fall ’07 semester and by the Winter ’08 semester was slightly reversed. Having been able to measure performance longitudinally, the results revealed that this initial improvement in GPA was unfortunately followed by a noted decline similar to that observed for control participants.

The present findings are encouraging in demonstrating the potential longitudinal achievement benefits of a brief, one-time, web-based intervention for improving academic performance in STEM students. These findings are also valuable in highlighting the differential effectiveness of

AR methods, with reflective writing exercises proving more effective long-term than mock failure exercises. Future research is needed to investigate the underlying causes for these differences, for example, to analyze potential moderating and mediating variables known to impact the effects of AR such as over-optimism (Haynes et al., 2006; Ruthig et al., 2004), self-esteem (Hall et al., 2010, 2011), and motivational strategy use (Hall et al., 2006). By investigating how these variables impact performance in STEM students, researchers can gain a more comprehensive understanding of how online AR helps (or hinders) academic performance, and bring us one step closer to the large-scale implementation of effective web-based motivational interventions, such as attributional retraining, for struggling students in social science as well as STEM degree programs.

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