You Can and You Did: Encouragement and Feedback in Mathematical Problem Solving

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ABSTRACT. The aim of the present study was to investigate the potential effects of randomly assigned positive feedback and encouragement on mathematical problem solving. Undergraduates (N = 80) first completed the Mathematic Self-Efficacy Scale to measure their trait self-efficacy toward mathematics. Participants then completed a trial of Modular Arithmetic problems to serve as a baseline for performance. After this, participants were randomly assigned to receive positive feedback, being told that they scored in the 90th percentile, or not, prior to completing a second trial of Modular Arithmetic problems. During the second trial, participants were randomly assigned to receive verbal encouragement, or not. There was a small positive correlation between trait self-efficacy and performance (rs = .23, p = .03). More importantly, there was a positive effect of randomly assigned positive feedback on Trial 2 performance (β = .14, t = 2.10, p = .02). This effect was not dependent on self-efficacy levels or baseline performance (ps > .10). Positive encouragement did not have a significant effect on performance (β = .03, t = .48, p = .32). The findings from this study imply that positive feedback can enhance students’ performance. The data provided no evidence for an effect of encouragement.

Perceived self-efficacy in mathematics can be an important component of adolescents’ developing self-concept and can potentially facilitate future performance in math (Pajares & Miller, 1994). This is critical because mathematical literacy is frequently considered one of the most important skills a student can have and is beneficial not only in a work setting, but also in everyday life (Jameson & Fusco, 2014). In general, self-efficacy is an individual’s belief regarding how well-equipped the person is to handle and accomplish a task (Bandura, 1997). The causal relationship between self-efficacy and performance is often difficult to determine. Some have suggested that self-efficacy facilitates goal setting, which in turn facilitates performance, while others have suggested that self-efficacy is a reflection of past performance (see Sitzmann & Yeo, 2013). In a meta-analysis of self-efficacy studies, Sitzmann and Yeo (2013) examined the previous findings concerning the relationship between self-efficacy and performance. Their meta-analysis suggested that a number of other factors such as encouragement and feedback moderated the performance/efficacy relationship. This brought into question what sort of external factors might interact with self-efficacy to affect performance, and whether interventions can be utilized to manipulate perceived self-efficacy if, indeed, self-efficacy can facilitate performance.

Previous research has found a positive relationship between performance and trait self-efficacy (Bouffard-Bouchard, 1990; Sitzmann & Yeo, 2013), and has introduced manipulations aimed at enhancing self-efficacy including feedback (Anand, Oehlberg, Treadway, & Nusslock, 2016) and encouragement (Gambino, 2016; Guéguen, Martin, & Rio Andrea, 2015). The current study utilized these two manipulations in a mathematical problem-solving context while considering trait self-efficacy as an individual differences variable.
Randomly Assigned Positive Feedback

Feedback is arguably one of the strongest influences in obtaining a new skill and continuing to improve because learning is a mutual process in which individuals take in information from others or the environment to perfect their performance. Thus, without direct or indirect (e.g., self-generated) feedback, learning would be difficult (Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Hattie & Timperley, 2007). Feedback is generally provided by an outside source and is based on an individual’s prior performance or an assessment of their conceptual understanding (Hattie & Timperley, 2007).

Receiving feedback about successful performance should provide a boost in self-efficacy, given that this information provides direct evidence of competence (Bouffard-Bouchard, 1990). The effect of accurate feedback is hard to differentiate from ability, given that people who receive positive feedback may simply be more competent; thus, research that involves randomly assigned positive or negative feedback may eliminate this problem (Bouffard, Bouchard, Goulet, Denoncourt, & Couture, 2005; Bouffard-Bouchard, 1990). For example, Bouffard-Bouchard (1990) attempted to create a high self-efficacy group and a low self-efficacy group using randomly assigned positive and negative feedback, in between individual trials of a verbal concept-formation task, regardless of participants’ actual performance. This manipulation was not intended to provide informative feedback regarding specific processes or products of learning, but was designed to convince the learners that their efforts were effective at accomplishing the task. Because past performance predicts self-efficacy (Sitzmann & Yeo, 2013), positive feedback should influence self-efficacy, thus creating downstream effects on subsequent performance (Bouffard-Bouchard, 1990). This is indeed what Bouffard-Bouchard (1990) found because students in the positive feedback condition were able to solve more problems and had increased self-efficacy in regard to their abilities to solve the problems correctly. In an extension of this work, Bouffard et al. (2005) examined the participants’ type of goal as a mediating factor and found that individuals who received positive feedback set higher goals for themselves and performed better. Their findings were similar to the original experiment in that there was a significant increase in performance among individuals with positive feedback in comparison to negative feedback; this relationship was mediated by the individual’s goal orientation (Bouffard et al., 2005). It seemed that enhancing self-efficacy through positive feedback encouraged learners to set higher goals for themselves, which facilitated subsequent performance.

In other studies, randomly assigned negative feedback has been shown to hinder performance and lead to less beneficial problem-solving strategies. In one such study, Anand et al. (2016) presented participants with Compound Remote Associates problems, where participants were asked to identify a word that would successfully create compound nouns when paired with a set of target words. Upon completion, participants received randomly assigned false feedback, either negative or positive, regardless of their actual performance. There was no direct effect of feedback on performance, but there was an association between negative feedback and the effort, which suggests that negative feedback led participants to decrease effort, resulting in a worse performance (Anand et al., 2016). One possible explanation for why performance did not decrease false negative feedback was that participants also received targeted feedback on individual items; this might have prevented an effect of the randomly assigned general feedback. Further, it is possible that the effects of randomly assigned feedback may be lessened if the tasks chosen have obvious right or wrong outcomes and thus serve as feedback themselves. In sum, considering previous research, it is reasonable to suggest that randomly assigned feedback should have effects on mathematical problem solving, with positive feedback resulting in more effort and thus increasing performance.

Encouragement

In contrast to the manipulation of feedback—which focuses on past performance—individuals receive encouragement before or during a task, and encouragement is typically general statements based on personal attributes meant to boost motivation and self-efficacy (Guéguen et al., 2015). Previous research has suggested that when individuals become more confident on a task, their performance benefits (Sitzmann & Yeo, 2013), pointing to a potential benefit of encouragement manipulations.

In one demonstration of this effect, Gambino (2016) gave college-aged students positive or negative statements at specific times during the completion of an adult difficulty level maze. The positive statements led to faster completion of the maze and to the students persevering with the maze.
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participants to receive either positive feedback or encouragement. Thus, an interaction was predicted such that individuals with high trait self-efficacy would experience relatively stronger benefits following the administration of positive feedback (Hypothesis 3) or encouragement (Hypothesis 4), compared to high-efficacy participants. The current study addressed this by taking into account individuals’ self-reported trait self-efficacy in mathematics and then assigning participants to receive either positive feedback or encouragement (Hypothesis 2) on performance. These findings suggest that encouragement in the form of process praise, in addition to feedback, could be an effective means of influencing performance in mathematical problem solving.

The Current Study

This study examined the possible influences of randomly assigned positive feedback and encouragement on subsequent mathematical problem-solving performance, while taking into account individual differences in self-efficacy. Based on previous research, we predicted positive effects of both positive feedback (Hypothesis 1) and encouragement (Hypothesis 2) on performance. Individual differences were included to help locate the source of these effects. If these main effects are due to enhancement of self-efficacy, then they should be stronger for individuals with low trait self-efficacy because high-efficacy individuals will already set high goals for their performance without the need for feedback or encouragement. Thus, an interaction was predicted such that individuals with low trait self-efficacy would experience relatively stronger benefits following the administration of positive feedback (Hypothesis 3) or encouragement (Hypothesis 4), compared to high-efficacy participants. The current study addressed this by taking into account individuals’ self-reported trait self-efficacy in mathematics and then assigning participants to receive either positive feedback following a baseline trial, positive encouragement during a subsequent trial, both, or neither. The task used was a set of modular arithmetic problems unfamiliar to college students, which has shown to be sensitive to social manipulations, such as performance pressure (Beilock & Carr, 2005).

Method

Participants

Participants included 80 undergraduate students (44 women, 36 men) from a small private Liberal Arts college, ranging in age from 18 to 25 (M = 19.84, SD = 1.46). Participants were of mixed ethnic backgrounds with the majority being European American (n = 54). In regard to educational experience, 24 were first-year students, 20 were sophomores, 18 were juniors, and 18 were seniors.

Nine participants indicated that they had a medical condition that might have affected their scores (e.g., dyscalculia). However, excluding these individuals did not alter the nature of these results, so their data were retained. For compensation, participants were given the option to receive entry into a drawing for a gift card, extra credit, or course credit where available from professors.

A sensitivity analysis conducted using G*Power (Faul, Erdfelder, Buchner, & Lang, 2009) suggested that this sample size was adequate for detecting effects of one-tailed regression coefficients with an effect size, $f^2$, of .079. This falls between standards for small ($f^2 = .02$) and medium ($f^2 = .15$) effects. In terms of changes to overall model fit, which were used to assess interaction terms, this sample size should be sensitive only to more moderately sized effects ($f^2 = .13$).

Materials

Demographics. The demographic information sheet asked a variety of questions including those pertaining to age, sex, ethnicity, grade level, academic major, and whether participants had a medical condition that may hinder their mathematical abilities.

Mathematics Self-Efficacy Scale. Participants’ trait math self-efficacy was assessed using the Mathematics Self-Efficacy Scale (Nielsen & Moore, 2003). The Mathematics Self-Efficacy Scale is presented in the form of a 5-point Likert scale ranging from 1 (not at all confident) to 5 (very confident). This scale contains nine statements for students to use to judge their abilities in math with various tasks; some of the statements included “work with decimals” and “determine the degrees of a missing angle.”
The purpose of this is to provide a self-reported rating of their perceived self-efficacy for math. The scale has been shown to have strong internal reliability in previous studies (α = .93) and validated by comparing to students’ previous math grades, standardized math test scores, mathematics self-concept, and anticipated math grades (Nielsen & Moore, 2003). This was ideal for assessing trait self-efficacy prior to completing the Modular Arithmetic problems because it focuses specifically on self-efficacy in the mathematics domain. The internal consistency reliability was also adequate (α = .85).

Modular arithmetic problems. The tasks given to participants were modular arithmetic problems originally used by Beilock and Carr (2005). Modular arithmetic problems are unique to other math problems in that they have a novel formula and must be answered in a true or false manner. The uniqueness of the formula is meant to lessen the familiarity advantage for individuals with greater math experience, and the formula involves only simple operations, allowing those who have less math experience to still attempt the problems. The modular arithmetic problems are set up as such: \(53 = 29 \pmod{6}\). To complete a modular arithmetic problem, participants are instructed to subtract the second number, 29, from the first number, 53, and then divide that outcome by the third number, 6, and this should lead to an answer of 4. To complete the problem entirely, the participant must answer whether the final number is a whole number (an answer of “True”) or not (an answer of “False”); in this example, the answer is 4 so the answer is “True.”

In comparison, for the problem 48 = 12 (mod 8), the operations lead to a result of 4.5, which is not a whole number, and thus the correct answer would be “False.”

Two sets of 27 modular arithmetic problems were prepared based on a random selection of items from Beilock and Carr (2005). Sets were administered using a paper-and-pencil format. Pilot data (\(n = 21\)) confirmed that the two sets of problems were not of different difficulty levels, based on a paired-samples t test (Set 1 \(M = 23.62, SD = 3.75\); Set 2 \(M = 24.38, SD = 2.62; t(20) = 1.77, p = .092\)).

This mathematical task was chosen due to several considerations. First, we wanted to focus on mathematical problem solving due to its important role in work settings and in everyday life (Jameson & Fusco, 2014). Additionally, all students were taught basic mathematic manipulations including addition, subtraction, multiplication, and division, making these specific problems easy to explain with participants in a short experimental session. Finally, modular arithmetic problems, and typically mathematic problems in general, have either a right or wrong answer with no ambiguity for scoring.

Feedback manipulation. The feedback manipulation followed the completion of an initial baseline trial of modular arithmetic problems and focused on participants’ superior performance to their peers (Bouffard-Bouchard, 1990). This manipulation involved two levels: false positive feedback or no feedback. Individuals receiving the positive feedback were informed verbally that they scored in the top 90th percentile in comparison to their peers, regardless of their actual performance. A relative performance score was chosen rather than an absolute (e.g., that they answered 90% of the items correctly) in order to be believable even for participants who were aware that they made a mistake, or for those that did not finish all 27 items. This feedback was general and did not involve any feedback regarding the accuracy of individual responses.

Encouragement manipulation. The encouragement manipulation occurred during completion of the second trial of modular arithmetic problems. This included statements from the experimenter including “you’re doing well on time,” “keep up the good work,” and “you’ve got this” modified from Gambino (2016). These statements were identical for all participants who received the encouragement condition, were announced at the same times across participants, and always occurred in the same order.

Performance. Performance was evaluated by the number of questions each individual answered correctly, minus the number of incorrect responses. This was done to account for any accurate responses that may be due to guessing. Performance was measured both before and after the manipulations.

Procedure
This project was approved by the university’s Institutional Review Board prior to all data collection. All participants first read and signed an informed consent document and then completed the Mathematics Self-Efficacy Scale (Nielsen & Moore, 2003). Then, participants were informed about the modular arithmetic problems, received the instructions, and were given an opportunity to ask questions. This was followed by a sample problem for which they could request help to ensure that they understood the problem structure for the proceeding problems. All participants then completed the first trial of 27 modular arithmetic problems.
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Across participants, as trait self-efficacy increased, so did their subsequent performance, although this relationship was not particularly strong.

Major Analyses

A hierarchical multiple linear regression analysis was conducted with Trial 2 performance as the dependent variable.1 In Step 1, Trial 1 performance was included to control for any baseline performance differences, along with the independent variables (feedback and encouragement) and the self-efficacy moderator. The model was significant overall, $R^2 = .69, F(4, 75) = 41.36, p < .001$. This was due in large part to the strong relationship with Trial 1 performance ($r = .82, p = .04$, one-tailed). Participants who received positive feedback performed better on trial 2 ($M = 20.85, SD = 6.00$) compared to participants who received no feedback ($M = 18.83, SD = 7.21$). Inconsistent with Hypothesis 2, there was no significant effect of encouragement ($\beta = .03, t = .48, p = .32$, one-tailed). Participants who received encouragement ($M = 20.10, SD = 5.81$) performed

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1Our first approach to data analysis involved an Analysis of Covariance (ANCOVA). After peer-review, we repeated the analysis using multiple regression to avoid issues related to using a median split for the self-efficacy measure. The conclusions based on the two analyses did not differ.
similarly to participants who did not (M = 19.58, SD = 7.50). There was no effect of self-efficacy, likely because any variance due to this variable was already accounted for by Trial 1 performance.

Hypotheses 3 and 4 stated that individuals with low self-efficacy would be more greatly affected by the presence of positive feedback and encouragement, respectively. To test this, interaction terms were calculated based on the product of standardized results from the Mathematics Self-Efficacy Scores and each of the independent variables (Feedback × Self-Efficacy; Encouragement × Self-Efficacy). These two interaction terms were included in Step 2 of the regression analysis. Contrary to both hypotheses, including the interaction terms did not contribute significantly to the model, ΔR² = .01, F(2, 73) = .63, p = .53. The interaction between feedback and self-efficacy was not significant, β = .04, t = .30, p = .76. Similarly, the interaction between encouragement and self-efficacy was not significant, β = .07, t = .58, p = .56. Thus, there was no obvious difference in the effects of the manipulations based on mathematics self-efficacy.

Exploratory Analyses
In an attempt to identify why the feedback positively affected performance, we considered whether there may be an interaction between Trial 1 performance and positive feedback. If the positive feedback was only effective for individuals who performed well, then it may indicate that the feedback is only useful when it is informative regarding true performance levels. That is, although high performers might not truly have scored in the 90th percentile, this feedback would accurately inform the student of their relatively strong performance.

To test this, we conducted another multiple regression analysis with Trial 2 performance as the dependent variable. We first entered Trial 1 performance and feedback in Step 1, which was redundant with the major analysis above. In Step 2, we entered an interaction term based on the product of Trial 1 performance and feedback. The interaction term did not account for significant variance in Trial 2 performance, ΔR² = .01, F(1, 76) = 2.03, p = .16. Thus, the main effect of feedback was not obviously dependent on baseline performance levels.

Discussion
The current study examined the potential influences of encouragement and randomly assigned positive feedback on performance for individuals varying in math self-efficacy. As predicted, the individuals who received randomly assigned positive feedback following the first set of problems did significantly better on the second set of problems compared to those who did not receive positive feedback. However, encouragement had no such effect on performance, and the results were not significantly moderated by self-efficacy, or by initial performance levels.

There are at least two possible explanations for the effectiveness of the current feedback manipulation. First, the manipulation might have provided useful information to the learners regarding their overall performance. Hattie and Timperley (2007) classified four types of feedback based on what the feedback addresses: the task, the process, self-regulation, or the person. In the present study, the feedback focused on the task. This is also referred to as knowledge of results and is characterized by informing how well a task is being completed (Hattie & Timperley, 2007). In this context, the weakness of the current feedback was that it was general and focused on performance relative to peers without providing any specific information regarding individual errors or process-related information. Although the feedback was randomly assigned to participants and was not based on their actual performance, it is possible that if the participants understood how to complete the problems on the first trial, then this feedback would have a fair representation, or exaggeration, of their actual understanding. This could explain why it was still beneficial. If this is true, though, we would expect a stronger feedback effect for individuals who performed well on Trial 1 compared to individuals who performed poorly, an interaction between Trial 1 performance and feedback. This was not observed, calling into question the idea that the manipulation provided useful knowledge of results feedback.

The second possible explanation is that the positive feedback manipulation provided a boost to self-efficacy on the task, which influenced effortful behavior, goal-setting, and performance on the second trial. Self-efficacy is strongly influenced by past performance (Sitzmann & Yeo, 2013), and participants were randomly assigned to positive feedback regarding past performance (Bouffard et al., 2005). However, if self-efficacy was the locus of the feedback effect, we would expect the manipulation to be more effective for individuals with relatively low trait self-efficacy because high-efficacy learners would not need positive feedback to set relatively high goals. This was not observed,
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however, with feedback effects unmoderated by self-efficacy. Additional research would be necessary to assess whether the feedback influenced or was moderated by other relevant variables such as self-concept, goal orientation, or goal setting (see Bouffard et al., 2005).

Regardless of the specific mechanism, the present study suggests that exclusively positive feedback, even when randomly assigned, can have positive effects on performance even without corrective or formative information (see also Bouffard-Bouchard, 1990). We note that this manipulation has somewhat limited external validity because it would not often be appropriate to give students false positive feedback on their performance in an academic setting. However, one could easily imagine situations where well-meaning instructors or parents could provide exclusively positive or “optimistic” feedback. The current study supports previous findings that this type of positive feedback has some benefits for performance.

The hypothesis that encouragement would have a beneficial effect on performance was not supported by the data. Benefits of encouragement have been supported in previous research (Gambino, 2016; Guéguen et al., 2015). Further, the current encouragement manipulation could be considered similar to “process praise” (see Lessard et al., 2015) because it focused on participants’ performance on the task, rather than their value as people. Research has shown that process praise has positive benefits for performance. Thus, the null effect found here is inconsistent with some previous findings. One potential limitation of the encouragement manipulation is that the encouragement was a much more noticeable manipulation than was feedback. Because participants completed the baseline trial with just verbal time cues and then the second trial added encouragement, it was a noticeable change. Several participants commented after completing the study that they were trying to determine the purpose of the study while others mentioned that they could tell that encouragement was part of it. Therefore, a response bias due to demand characteristics is very possible. Finally, it is possible that the encouragement could have been distracting for participants because it occurred multiple times during a time-limited task that required attentional control to complete (Beilock & Carr, 2005). Originally modified from the Gambino (2016) study, there was a substantial difference between the two tasks in question in that Gambino (2016) used a spatial task that might not have been influenced as strongly by the distracting verbal encouragement manipulation. Thus, one possible implication of these findings is that encouragement may have benefits for some types of outcomes, but not for this type of mathematical problem solving. Future studies may be required to determine the conditions under which encouragement does, and does not, boost performance.

The most pressing question at this point is why the feedback was beneficial even though it did not reflect actual performance or offer any formative information on how to improve. In the future, this experiment could be altered by removing the presence of encouragement and looking at various levels of feedback such as negative, neutral, and positive while also having questionnaires to account for some of the other possible factors, such as how participants reacted to the feedback. Without information on participants’ individual reactions, there is no way to be sure if the feedback was motivating, increased self-efficacy, had no conscious effect, or was disappointing. Although the effects of feedback were not moderated by self-efficacy or Trial 1 performance, it should be noted that subtle interactions with these or other moderators might be observed in a more powerful study. For example, the effects of feedback could be moderated by motivational variables such as mindset (Dweck, 2008), regulatory focus (Van-Dijk & Kluger, 2004), or by cultural differences (Bailey, Chen, & Dou, 1997). Additionally, it would be interesting to incorporate this manipulation into a classroom setting because Hattie and Timperley (2007) pointed out that students are typically more likely to benefit from positive feedback, whereas if the individual had no real commitment to the goal of completion, then they learn better from negative feedback. Having this take place in a classroom setting adds the goal of learning the material in order to receive a good grade in the course.

Another direction would be to analyze this type of feedback in relation to other, potentially more beneficial forms of feedback to see how they compare. This could be as simple as genuine feedback for which questions they got right or wrong and percentage-based feedback, or more complex addressing the four types of feedback mentioned by Hattie and Timperley (2007). These manipulations may show differential effects depending on trait self-efficacy that were not demonstrated here. It would also be interesting to try this study with different domains such as a motor task, memory task, or creativity based task.
Self-efficacy is a major factor in educational achievement, and so it is important to understand how controllable factors such as positive feedback and encouragement interact with this trait to influence performance. This study has shown that feedback, but not encouragement, from others can affect performance at least at a basic level, but this could be applicable to almost every school setting. Students often must complete tasks in a timed manner and, upon completion, receive feedback on their performance. As Bangert-Drowns and colleagues (1991) pointed out, learning is a mutual effort in that what students learn and how they become proficient in a skill is not solely based on the individuals but on those around them. Delving deeper into how peers or professors may influence an individual’s performance and to what extent, could have major implications in the classroom. Knowing what types of feedback and encouragement are beneficial, for which students, and when, could have a major effect on whether that manipulation is beneficial or harmful to a student’s learning.

References

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