

Gates AI Equity Initiative Literature Review

Catherine Good

April 2024

Teacher Feedback: A Brief Literature Review

Overview

Teacher's feedback to students not only conveys information about the disciplinary content being taught, but also conveys cues about a students' belonging in the classroom and underlying capacity to successfully master the content. And as research has shown, students' beliefs about themselves regarding these messages (belonging and underlying intelligence) are powerful predictors of their motivation, learning, and performance. Thus, understanding how explicit feedback affects students' mindsets about themselves as learners is an important factor to consider when designing a tool to support teachers as they provide feedback to their students. Importantly, the broader classroom culture also conveys feedback messages, which although are implicit, are just as important for creating the conditions for either supporting or undermining students' beliefs about themselves and their academic outcomes.

The first group of studies below describes instances of explicit feedback that can facilitate or undermine student learning, motivation, and achievement. The second group turns to studies of implicit feedback embedded within the classroom culture that can facilitate or undermine student learning, motivation, and achievement.

I. Explicit Feedback from Teachers

Rattan, A., Good, C., & Dweck, C. S. (2012). "It's ok—Not everyone can be good at math": Instructors with an entity theory comfort (and demotivate) students. *Journal of experimental social psychology*, 48(3), 731-737.

Abstract: Can comforting struggling students demotivate them and potentially decrease the pool of students pursuing math-related subjects? In Studies 1–3, instructors holding an entity (fixed) theory of math intelligence more readily judged students to have low ability than those holding an incremental (malleable) theory. Studies 2–3 further revealed that those holding an entity (versus incremental) theory were more likely to both comfort students for low math ability and use “kind” strategies unlikely to promote engagement with the field (e.g., assigning less homework). Next, we explored what this comfort-oriented feedback communicated to students, compared with strategy-oriented and control feedback (Study 4). Students responding to comfort-oriented feedback not only perceived the instructor's entity theory and low expectations, but also reported lowered motivation and lower expectations for their own performance. This research has implications for understanding how pedagogical practices can lock students into low achievement and deplete the math pipeline.

Summary

Across three studies, the researchers showed that a teachers' own theory of math intelligence (as either a fixed trait or a malleable quality) predicted the type of attributions they made for a student's poor math performance and the feedback that they gave in response to that low performance. Specifically, the researchers found:

1. Teachers who hold a fixed theory of math ability are more likely to attribute low innate ability simply from one poor test score.
2. In an experimental design, teachers who were manipulated to hold a fixed theory of math ability were more likely to provide comfort-oriented feedback to students (e.g., explain that not everyone has math talent—some people are ‘math people’ and some people aren't”) than those who were manipulated to view math intelligence as a malleable quality.
3. The fixed theory of math ability also led teachers to endorse practices that could undermine learning opportunities and engagement (e.g., provide less math homework or

lower expectations by providing easier math problems to solve). Alternatively, those who were manipulated to view math intelligence as a malleable quality were more likely to provide strategy-oriented feedback (e.g., suggest that the student change their study strategies).

A fourth study combined these endorsed strategies to create two categories of feedback: Comfort Feedback and Strategy Feedback (and a control condition). Students were then presented with a description of a teacher who provided this type of feedback and were asked to report their perceptions of the teachers' theory of math intelligence (fixed or malleable) and expectations for their future performance, their own investment in the class, and their own motivation. Receiving comfort feedback led students to a) perceive their teachers' fixed theory of math intelligence and lower expectations for them as a student; b) report lower investment in the class; b) report lower motivation than those who received the strategy feedback.

Comfort Feedback "I want to assure you that I know you are a talented student in general — it's just not the case that everyone is a "math person." I want you to remember how great you do in other subjects. I want you to know what I'm going to do too — I'm going to make a point not to call on you as much in class because I don't want you to have the added pressure of putting you on the spot and I'm going to give you some easier math tasks to work on so you can get more comfortable with those skills. I want to assure you that I really care, so let's stay in contact about how you're doing in the class."

Strategy Feedback "I want to assure you that I know that you are a talented student in general. I want you to change your study strategies and consider working with a tutor. I want you to know what I'm going to do too — I'm going to make a point to call on you more in class and I'm going to give you more challenging math tasks. I want to assure you that I really care, so let's stay in contact about how you're doing in the class."

Control Feedback "I want to assure you that I know you are a talented student in general, and I want to assure you that I really care, so let's stay in contact about how you're doing in the class."

Mueller, C. M., & Dweck, C. S. (1998). Praise for intelligence can undermine children's motivation and performance. *Journal of personality and social psychology*, 75(1), 33.

Abstract: Praise for ability is commonly considered to have beneficial effects on motivation. Contrary to this popular belief, six studies demonstrated that praise for intelligence had more negative consequences for students' achievement motivation than praise for effort. Fifth graders praised for intelligence were found to care more about performance goals relative to learning goals than children praised for effort. After failure, they also displayed less task persistence, less task enjoyment, more low-ability

attributions, and worse task performance than children praised for effort. Finally, children praised for intelligence described it as a fixed trait more than children praised for hard work, who believed it to be subject to improvement. These findings have important implications for how achievement is best encouraged, as well as for more theoretical issues, such as the potential cost of performance goals and the socialization of contingent self-worth.

Summary

Across six studies, children completed tasks that were designed to either elicit success or failure, and were then either praised for their intelligence (e.g., “wow, you must be smart at these problems”) or their efforts (“you must have worked hard at these problems”).

1. After success, receiving intelligence praise leads children to choose easy problems that were likely to ensure continued good performance (representing a performance goal) yet provided no opportunity to learn new information.
2. After success, receiving effort praise led children to choose problems that promised increased learning, even if it risked showing lower performance.
3. Intelligence praise led children to prefer information about how others had performed, whereas effort praise led children to seek information about problem-solving strategies that could improve their future learning and performance.
4. After failure, ability feedback led students to attribute their poor performance to low intelligence rather than ineffective effort; alternatively, effort-feedback led students to attribute their poor performance to low effort.

Thus, ability-feedback (either for success or failure) leads students to embrace maladaptive approaches to learning; whereas effort-feedback orients students mastery-approaches to learning.

Cohen, G. L., Steele, C. M., & Ross, L. D. (1999). The mentor's dilemma: Providing critical feedback across the racial divide. *Personality and social psychology bulletin*, 25(10), 1302-1318.

Abstract: Two studies examined the response of Black and White students to critical feedback presented either alone or buffered with additional information to ameliorate its negative effects. Black students who received unbuffered critical feedback responded less favorably than White students both in ratings of the evaluator's bias and in measures of task motivation. By contrast, when the feedback was accompanied both by an invocation of high standards and by an assurance of the student's capacity to reach those standards,

Black students responded as positively as White students and both groups reported enhanced identification with relevant skills and careers. This “wise,” two-faceted intervention proved more effective than buffering criticism either with performance praise (Study 1) or with an invocation of high standards alone (Study 2). The role of stigma in mediating responses to critical feedback, and the implications of our results for mentoring and other teacher-student interactions, are explored.

Summary

In two studies, Black and White students wrote a letter of commendation for their favorite teacher. They then received critical feedback from a reviewer portrayed to be white regarding strengths, weaknesses, and specific strategies for improvement. The feedback was provided under one of three experimental conditions: 1) the students received this critical feedback with no further comment (unbuffered feedback); 2) students received the same critical feedback buffered with an explicit invocation of high standards and an assurance of the particular student’s capacity to reach those standards (wise feedback); 3) students received the critical feedback buffered only by general praise of their performance (positive buffer).

Wise Feedback: It’s obvious to me that you’ve taken your task seriously and I’m going to do likewise by giving you some straight-forward, honest feedback. The letter itself is okay as far as it goes—you’ve followed the instructions, listed your teacher’s merits, given evidence in support of them, and importantly, produced an articulate letter. On the other hand, judged by a higher standard, the one that really counts, that is, whether your letter will be publishable in our journal, I have serious reservations. The comments I provide in the following pages are quite critical but I hope helpful. Remember, I wouldn’t go to the trouble of giving you this feedback if I didn’t think, based on what I’ve read in your letter, that you are capable of meeting the higher standard I mentioned.

Dependent variables included attribution of bias by the reviewer, motivation for the task, belief in one’s ability to improve with further work, and interest in revising and resubmitting the letter. The Wise Feedback eliminated the race gaps in all dependent variables.

This study highlights the importance of not only conveying high standards for students when giving feedback, but also of assuring them of your confidence that they have the ability to meet those standards.

Vial, A. C., & Cimpian, A. (2020). Evaluative feedback expresses and reinforces cultural stereotypes. In *Psychological perspectives on praise* (pp. 119-128). Routledge.

Abstract: Evaluative feedback (praise and criticism) has a powerful influence on behavior, in part because it communicates what society values in and expects of an

individual. Importantly, feedback often reflects values and expectations that are informed by the social group of the individual receiving feedback, and the stereotypes attached to it, rather than being based just on information specific to the individual. In this chapter, we first detail how group stereotypes affect the evaluative feedback given to stereotyped individuals. We then review the effects of stereotyped feedback, highlighting the role that such feedback plays in maintaining group disparities.

Summary

This chapter reviews literature on the intersection of stereotypes and feedback. The authors highlight the following key points:

1. **Stereotype Effects on the Intensity of Feedback.** Variations in feedback intensity are predicted by the stereotypes of the group to which the student receiving the feedback belongs. For example, high achieving females in math may receive effusive praise, suggesting that they are an anomaly. Similarly, low achieving females in math may receive milder feedback than low-achieving males, suggesting that standards for females' performance are lower than males'.
2. **Stereotype Effects on the Type of Feedback.** Similarly, praise versus criticism for performance often follows ability-based stereotypes. For example, work produced by white students is likely to receive higher praise than the same quality of work produced by black students.
3. **Stereotype Effects on Causal Attributions.** The attributions made for students' performance are affected by the stereotypes associated with that student's group membership. For example, women's high math achievement is often attributed to luck, whereas men's high math achievement is often attributed to innate ability.
4. **Stereotype Effects on Global Impressions of the Person.** People who violate the prescriptive stereotypes about their group (i.e., the expectations of how a person should perform or behave) are often judged negatively on more global traits. For example, women who are competent in male-dominated domains are often judged as unlikeable.
5. **Stereotype Effects on Frequency of Feedback.** People who conform (or fail to conform) to prescriptive stereotypes are more likely to be praised or criticized (respectively) for those behaviors. For example, women are more likely to be praised for their appearance, whereas men are more likely to be praised for their intelligence.

It is important to attend to the intersection between stereotypes and feedback; stereotype-influenced evaluative feedback contributes to the maintenance of the societal status quo and produces and maintains inequalities.

Anderman, E. M., Eccles, J. S., Yoon, K. S., Roeser, R., Wigfield, A., & Blumenfeld, P. (2001). Learning to value mathematics and reading: Relations to mastery and performance-oriented instructional practices. *Contemporary educational psychology*, 26(1), 76-95.

Abstract: Changes in students' achievement values in mathematics and reading were examined in a sample of children and early adolescents. Hierarchical linear modeling techniques were used to account for both classroom- and student-level effects. At the student level, positive changes in students' achievement values were associated positively with self-concept of ability and the previous year's achievement values in both reading and math. Measures of teachers' mastery- and performance-oriented instructional practices were included in the full HLM model. Students experienced decrements in achievement values, after controlling for other student and classroom-level variables, in classrooms where performance-oriented instructional practices were used. In the full model, self-concept of ability was related positively to increases in achievement values, whereas gender was unrelated to changes in achievement values.

Summary

Students and teachers in classrooms were studied to determine the effect of teachers' instructional practices on students' achievement values. Specifically, the extent to which teachers emphasized mastery- and performance-oriented instructional practices were measured.

Performance oriented practices: working for the top grades in class, knowing who is doing the best, knowing who is striving to do the best, and achieving higher test scores than others.

Mastery-oriented practices: paying attention to one's own improvement, choosing or initiating independent projects, and attempting challenging assignments or projects even when faced with difficulty.

Results showed that teachers who emphasized mastery (versus performance) practices were more likely to have students who experienced increases in achievement values and higher self-concept of ability.

Summary

Students and teachers in classrooms were studied to determine the effect of teachers' instructional practices on students' achievement values. Specifically, the extent to which teachers emphasized mastery- and performance-oriented instructional practices were measured.

Performance oriented practices: working for the top grades in class, knowing who is doing the best, knowing who is striving to do the best, and achieving higher test scores than others.

Mastery-oriented practices: paying attention to one's own improvement, choosing or initiating independent projects, and attempting challenging assignments or projects even when faced with difficulty.

Results showed that teachers who emphasized mastery (versus performance) practices were more likely to have students who experienced increases in achievement values and higher self-concept of ability.

Butler, R. (1987). Task-involving and ego-involving properties of evaluation: Effects of different feedback conditions on motivational perceptions, interest, and performance. *Journal of educational psychology*, 79(4), 474.

Abstract: I designed this study to test, the hypothesis that the impact of information about performance on subsequent intrinsic motivation depends significantly on the degree to which this information promotes a task-involved or an ego-involved motivational orientation. A total of 200 fifth- and sixth-grade students with high or low school achievement were given interesting divergent thinking tasks in each of three sessions. Individual comments, numerical grades, standardized praise, or no feedback were received after Sessions 1 and 2. Results confirmed that at Session 3 (posttest), interest, performance, and attributions of effort, outcome, and the impact of evaluation to task-involved causes were highest at both levels of achievement after receipt of comments. Ego- involved attributions were highest after receipt of grades and praise. These findings support the conceptualization of the feedback conditions as task involving (comments), ego involving (grades and praise), or neither (no feedback). The similar impact of grades and praise would not be predicted by cognitive evaluation theory. I discuss the importance of distinguishing between task- and ego-involved orientations in the study of continuing motivation.

II. Implicit Feedback: Teacher Mindsets and Classroom Cultures

Good, C., Rattan, A., & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of personality and social psychology*, 102(4), 700.

Abstract: Sense of belonging to math—one's feelings of membership and acceptance in the math domain—was established as a new and an important factor in the representation gap between males and females in math. First, a new scale of sense of belonging to math was created and validated, and was found to predict unique variance in college students' intent to pursue math in the future (Studies 1–2). Second, in a longitudinal study of calculus students (Study 3), students' perceptions of 2 factors in their math environment—the message that math ability is a fixed trait and the stereotype that women have less of this ability than men—worked together to erode women's, but not men's, sense of belonging in math. Their lowered sense of belonging, in turn, mediated women's desire to pursue math in the future and their math grades. Interestingly, the message that math ability could be acquired protected women from negative stereotypes, allowing them to maintain a high sense of belonging in math and the intention to pursue math in the future.

Summary

In two studies, a measure of academic sense of belonging to math was validated and shown to have unique power to predict math-related outcomes. Specifically, college students who reported higher sense of belonging to math (i.e., feeling like accepted members of the math community whose presence and participation was valued) reported lower math anxiety, greater usefulness of math, higher math self-confidence, and greater intrinsic motivation to pursue math in the future. A third study examined the ways that classroom culture can undermine women's sense of belonging, math performance, and intrinsic motivation in math. Calculus students' perceptions of a culture of talent and negative stereotypes of women's math abilities in their math classroom were measured. Students also completed the new Sense of Belonging to Math scale as well as their intentions to pursue math in the future. Their final course grades were collected at the end of the semester. The results highlight the importance of creating classroom cultures free of stereotypes and that reject talent-based views of math. Specifically, women's (but not men's) perceptions of a culture of talent and ability-impugning stereotypes about women predicted lower sense of belonging, lower math grades, and lower intentions to remain in math. Sense of belonging fully mediated the effects of the classroom culture on grades and intrinsic motivation. Unfortunately, stereotypes are inherently difficult to eradicate and thus, are unlikely to be productive candidates for classroom interventions. However, shifting people's perceptions of

innate talent as a necessary condition for achievement in math is much more promising approach. Indeed, this research showed that women who perceived a culture of growth (rather than talent) maintained a high sense of belonging, high grades, and high intrinsic motivation, even when their learning environment conveyed negative stereotypes about women's math abilities.

Canning, E. A., Muenks, K., Green, D. J., & Murphy, M. C. (2019). STEM faculty who believe ability is fixed have larger racial achievement gaps and inspire less student motivation in their classes. *Science advances*, 5(2), eaau4734.

Abstract: An important goal of the scientific community is broadening the achievement and participation of racial minorities in STEM fields. Yet, professors' beliefs about the fixedness of ability may be an unwitting and overlooked barrier for stigmatized students. Results from a longitudinal university-wide sample (150 STEM professors and more than 15,000 students) revealed that the racial achievement gaps in courses taught by more fixed mindset faculty were twice as large as the achievement gaps in courses taught by more growth mindset faculty. Course evaluations revealed that students were demotivated and had more negative experiences in classes taught by fixed (versus growth) mindset faculty. Faculty mindset beliefs predicted student achievement and motivation above and beyond any other faculty characteristic, including their gender, race/ethnicity, age, teaching experience, or tenure status. These findings suggest that faculty mindset beliefs have important implications for the classroom experiences and achievement of underrepresented minority students in STEM.

Summary

This study directly measured STEM faculty's endorsement of fixed (versus growth) mindsets about STEM abilities. The researchers then used these differential faculty mindsets to predict students' motivation and negative experiences in class (as indicated by course evaluations), and grades. Faculty fixed mindsets not only predicted less motivation, more negative experiences, and worse grades, but also led to a race gap in achievement that was twice as large as the race gap in classes taught by faculty with growth mindsets.

Good, C., Godbole, M., Milless, K., Rattan, A., & Aronson, J. (Under Review). More than mindsets: Creating learning contexts to combat stereotype threat. *Journal of Applied Developmental Psychology*.

Abstract: Many theories have been put forward to address the lack of representation of women at the highest levels of mathematics. Some explanations favor stereotype-based arguments, while others point to a "culture of talent" in math. The effect of these

forces may take root in childhood. Across three studies, we experimentally test that a) stereotype threat emerges as a critical factor for girls' math achievement in middle school; b) students can accurately surmise a teachers' underlying theory of intelligence from their pedagogical practices and c) a culture of talent in a mathematics classroom environment exacerbates the impact of stereotype threat on girls' mathematics performance, while a learning culture focused on effort and engagement reduces the impact of stereotype threat. Results supported our predictions. We found stereotype threat to undermine girls' math performance in 6th grade, but not before. We then showed that students who learned math from a fixed-mindset perspective accurately predicted their instructor to also hold a fixed mindset. Finally, we showed that a combination of stereotype threat and learning within a culture of talent undermined girls' math performance. But when they learned math from a growth perspective, the effects of stereotype threat were eliminated. We also discuss an intersectional analysis by race indicating that these effects do not hold for black girls.

Summary

Whereas the previous two studies showed the correlation between instructors' fixed mindsets (or a perceived culture of talent) and students' academic outcomes, this paper experimentally tests those hypotheses. In the first study, the researchers establish that stereotype threat can undermine girls' math performance as early as 6th grade.

In the second study, middle school students watched an instructional video that taught a novel math concept (spherical geometry). The culture of this "micro-classroom" learning environment was experimentally manipulated to either convey a culture of talent or a culture of growth and development. A culture of talent was created by infusing messages about the brilliance of the mathematician who discovered spherical geometry and the ease at which math came to him at an early age. A culture of growth was created by infusing messages about the hard work and effort that the mathematician who discovered spherical geometry put into his studies, and that he was not always a good math student—rather, he committed himself to improving. Results showed students who learned math in the culture of talent predicted that the instructor believed that math ability was a fixed trait; those who learned math in the culture of growth predicted that the instructor believed that math ability was a malleable quality.

In study 3, after watching the videos described in study 2, students took a math test under conditions of stereotype threat (evaluative) or non-threat (not-evaluative). Results showed that when learning math in a culture of talent, stereotype threat undermined girls' math performance (but not boys'). But when students learned math from a growth perspective, the effects of stereotype threat were eliminated.

These results provide evidence not only that stereotype threat can undermine female's math performance at an early age, but that actively creating a culture of talent can eliminate the negative effects of ability-impugning stereotypes and reduce gaps in achievement.

Aronson, J., & Inzlicht, M. (2004). The ups and downs of attributional ambiguity: Stereotype vulnerability and the academic self-knowledge of African American college students. *Psychological science*, 15(12), 829-836.

Abstract: This research examined whether stereotype vulnerability—the tendency to expect, perceive, and be influenced by negative stereotypes about one's social category—is associated with uncertainty about one's academic self-knowledge in two important ways. We predicted that stereotype-vulnerable African American students would (a) know less about how much they know than less vulnerable students do and (b) have unstable academic efficacy. In Study 1, Black and White participants took a verbal test and indicated the probability that each of their answers was correct. As expected, stereotype-vulnerable Black participants were more miscalibrated than other participants. In Study 2, participants completed measures of self-efficacy twice daily for 8 days. Also as expected, the academic efficacy of stereotype-vulnerable Blacks fluctuated more—and more extremely—than that of other participants. The results suggest that, in addition to undermining intellectual performance, stigma interferes with academic self-knowledge.

Summary

Across two studies, the researchers highlighted a new predicament that students who are targets of ability-impugning stereotypes face: uncertainty of their performance on a given task and instability of their self-efficacy over time. Specifically, Black students were worse at predicting their performance on a verbal task. Furthermore, Black students' self-efficacy fluctuated more and more extremely than did white students'. The implications of this study suggest that teachers should take more care in bolstering minoritized students' academic self-knowledge through careful (and wise) feedback.

Milless, K., Godbole, M., Donaldson, B., Treisman, P. U., & Good, C. (Under Review). Bridging the gap between research-based and school-based approaches to academic disciplines: The effects on mindsets and pedagogical practices. *Journal of Educational Psychology*.

Abstract: We conducted a field study to develop a new measure of teachers' conceptions of the nature of math and to test its effect on teachers' mindsets and pedagogical practices. We conducted the work in the context of Math Teachers' Circles (MTCs), with a sample of K-12 math teachers across the US (n = 249). MTCs are local professional

communities of math teachers and mathematicians who meet regularly to engage in rich, authentic problem solving. Specifically, we (a) develop and validate the Nature of Mathematics as a Discipline scale (Active vs Static View of math) and (b) test the relationships among participation in MTC and teachers' views of math, mathematical mindsets, and endorsement of adaptive pedagogical practices. More frequent participation in MTC predicted greater endorsement of an "Active View" of math, which in turn predicted various adaptive mindsets, including stronger sense of belonging to mathematics, stronger math identity, and more malleable views of intelligence. These adaptive teacher mindsets in turn predicted increased endorsement of adaptive pedagogical practices, such as normalizing mistake-making and mastery goals. The results highlight the benefit of an "Active View" of math and demonstrate how authentic math experiences, like MTCs, can help teachers to adopt this view, and as a result, endorse adaptive mindsets and pedagogical strategies. These findings expand the psychological theory of mindsets to teachers and highlight the importance of reforming teacher education programs to include authentic mathematics experiences that more closely resemble mathematics as practiced by professional mathematicians.

This study suggests that K-12 math professional development programs that provide high-level mathematics experiences led by practicing mathematicians can lead teachers to endorse a conception of math as a creative process of understanding relationships and patterns rather than a formulaic process with clear steps to be followed. Fostering this "Active View" of math has the potential to strengthen teachers' beliefs that math intelligence is a malleable quality and their endorsement of adaptive pedagogical strategies that have been associated with improved student outcomes.

Summary

The researchers developed a new measure of The Nature of Math as a Discipline to distinguish between perceiving math as a static subject (as it is often taught in math classrooms, with rules and procedures to follow) versus as an active field (as it is perceived by professional mathematicians, with open questions and knowledge to discover). They then used this new scale to study the Math Teachers Circles (MTC). Results showed that the more teachers participated in MTCs, the more likely they were to view math as professional mathematicians do (that is, as an active field). This active view of math in turn predicted a stronger identification with mathematics, stronger growth mindset in math, and stronger sense of belonging to math. These variables, in turn, predicted teachers' endorsement of mastery approaches in their pedagogical practices, greater acceptance of mistake-making in their students, and higher math confidence. These outcomes are important because as described above, teacher mindsets and mastery-approaches in classrooms are in turn predictive of positive psycho-social, learning, and

achievement outcomes for students. Thus, teacher feedback to students should reflect an Active versus a Static view of math.

Mangels, J. A., Butterfield, B., Lamb, J., Good, C., & Dweck, C. S. (2006). Why do beliefs about intelligence influence learning success? A social cognitive neuroscience model. *Social cognitive and affective neuroscience*, 1(2), 75-86.

Abstract: Students' beliefs and goals can powerfully influence their learning success. Those who believe intelligence is a fixed entity (entity theorists) tend to emphasize 'performance goals,' leaving them vulnerable to negative feedback and likely to disengage from challenging learning opportunities. In contrast, students who believe intelligence is malleable (incremental theorists) tend to emphasize 'learning goals' and rebound better from occasional failures. Guided by cognitive neuroscience models of top-down, goal-directed behavior, we use event-related potentials (ERPs) to understand how these beliefs influence attention to information associated with successful error correction. Focusing on waveforms associated with conflict detection and error correction in a test of general knowledge, we found evidence indicating that entity theorists oriented differently toward negative performance feedback, as indicated by an enhanced anterior frontal P3 that was also positively correlated with concerns about proving ability relative to others. Yet, following negative feedback, entity theorists demonstrated less sustained memory-related activity (left temporal negativity) to corrective information, suggesting reduced effortful conceptual encoding of this material—a strategic approach that may have contributed to their reduced error correction on a subsequent surprise retest. These results suggest that beliefs can influence learning success through top-down biasing of attention and conceptual processing toward goal-congruent information.

Summary

In this study, the researchers investigated the neural-correlates of attention to performance-related feedback. Specifically, students' mindsets about intelligence were measured to identify either those holding a fixed mindset or those holding a growth mindset about general intelligence. They were then given a general knowledge test. After each question was presented, students indicated their answer, were given performance feedback (was the answer correct or incorrect) and learning feedback (what was the correct answer). They then took a retest of these same items to measure learning. During the task, event-related potentials were measured and time-locked to the presentation of the performance feedback. Results showed that students with a fixed mindset were more focused on negative performance feedback than were their growth-mindset peers. Despite this increased attention to the negative feedback, they also showed less sustained memory-related activity when presented with the learning feedback.

These results suggest that students with a fixed-mindset are less able to benefit from feedback that can increase their future knowledge, perhaps because of their biased attention to the negative performance feedback. Ultimately, these attentional biases (more attention to performance feedback; less attention to learning feedback) manifested in poorer learning—they corrected less of their mistakes on a surprise retest than did their growth-mindset peers.

These findings suggest that teachers should be mindful of students' underlying mindsets when giving feedback. Negative performance feedback may be so distracting (because of the implications it holds for their self concept, self-esteem, confidence, etc) that it blocks their ability to take in the crucial learning moments that follow.

Beilock, S. L., Gunderson, E. A., Ramirez, G., & Levine, S. C. (2010). Female teachers' math anxiety affects girls' math achievement. *Proceedings of the National Academy of Sciences*, 107(5), 1860-1863.

Abstract: People's fear and anxiety about doing math—over and above actual math ability—can be an impediment to their math achievement. We show that when the math-anxious individuals are female elementary school teachers, their math anxiety carries negative consequences for the math achievement of their female students. Early elementary school teachers in the United States are almost exclusively female (>90%), and we provide evidence that these female teachers' anxieties relate to girls' math achievement via girls' beliefs about who is good at math. First- and second-grade female teachers completed measures of math anxiety. The math achievement of the students in these teachers' classrooms was also assessed. There was no relation between a teacher's math anxiety and her students' math achievement at the beginning of the school year. By the school year's end, however, the more anxious teachers were about math, the more likely girls (but not boys) were to endorse the commonly held stereotype that “boys are good at math, and girls are good at reading” and the lower these girls' math achievement. Indeed, by the end of the school year, girls who endorsed this stereotype had significantly worse math achievement than girls who did not and than boys overall. In early elementary school, where the teachers are almost all female, teachers' math anxiety carries consequences for girls' math achievement by influencing girls' beliefs about who is good at math.

Good, C., Aronson, J., & Inzlicht, M. (2003). Improving adolescents' standardized test performance: An intervention to reduce the effects of stereotype threat. *Journal of Applied Developmental Psychology*, 24(6), 645-662.

Abstract: Standardized tests continue to generate gender and race gaps in achievement despite decades of national attention. Research on “stereotype threat” (Steele & Aronson,

1995) suggests that these gaps may be partly due to stereotypes that impugn the math abilities of females and the intellectual abilities of Black, Hispanic, and low-income students. A field experiment was performed to test methods of helping female, minority, and low-income adolescents overcome the anxiety-inducing effects of stereotype threat and, consequently, improve their standardized test scores. Specifically, seventh-grade students in the experimental conditions were mentored by college students who encouraged them either to view intelligence as malleable or to attribute academic difficulties in the seventh grade to the novelty of the educational setting. Results showed that females in both experimental conditions earned significantly higher math standardized test scores than females in the control condition. Similarly, the students—who were largely minority and low-income adolescents—in the experimental conditions earned significantly higher reading standardized test scores than students in the control condition.

Aronson, J., Fried, C. B., & Good, C. (2002). Reducing the effects of stereotype threat on African American college students by shaping theories of intelligence. *Journal of experimental social psychology*, 38(2), 113-125.

Abstract: African American college students tend to obtain lower grades than their White counterparts, even when they enter college with equivalent test scores. Past research suggests that negative stereotypes impugning Black students' intellectual abilities play a role in this underperformance. Awareness of these stereotypes can psychologically threaten African Americans, a phenomenon known as “stereotype threat” (Steele & Aronson, 1995), which can in turn provoke responses that impair both academic performance and psychological engagement with academics. An experiment was performed to test a method of helping students resist these responses to stereotype threat. Specifically, students in the experimental condition of the experiment were encouraged to see intelligence—the object of the stereotype—as a malleable rather than fixed capacity. This mind-set was predicted to make students' performances less vulnerable to stereotype threat and help them maintain their psychological engagement with academics, both of which could help boost their college grades. Results were consistent with predictions. The African American students (and, to some degree, the White students) encouraged to view intelligence as malleable reported greater enjoyment of the academic process, greater academic engagement, and obtained higher grade point averages than their counterparts in two control groups.

Mangels, J. A., Good, C., Whiteman, R. C., Maniscalco, B., & Dweck, C. S. (2012). Emotion blocks the path to learning under stereotype threat. *Social cognitive and affective neuroscience*, 7(2), 230-241.

Abstract: Gender-based stereotypes undermine females' performance on challenging math tests, but how do they influence their ability to learn from the errors they make? Females under stereotype threat or non-threat were presented with accuracy feedback after each problem on a GRE-like math test, followed by an optional interactive tutorial that provided step-wise problem-solving instruction. Event-related potentials tracked the initial detection of the negative feedback following errors [feedback related negativity (FRN), P3a], as well as any subsequent sustained attention/arousal to that information [late positive potential (LPP)]. Learning was defined as success in applying tutorial information to correction of initial test errors on a surprise retest 24-h later. Under non-threat conditions, emotional responses to negative feedback did not curtail exploration of the tutor, and the amount of tutor exploration predicted learning success. In the stereotype threat condition, however, greater initial salience of the failure (FRN) predicted less exploration of the tutor, and sustained attention to the negative feedback (LPP) predicted poor learning from what was explored. Thus, under stereotype threat, emotional responses to negative feedback predicted both disengagement from learning and interference with learning attempts. We discuss the importance of emotion regulation in successful rebound from failure for stigmatized groups in stereotype-salient environments.