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The Effect of Positive and Negative Reinforcement on Sixth Graders' Mental Math Performance

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Summary

We examined the relationship between different forms of reinforcement and subjects' mathematical performance. Thirty sixth-grade students were asked to mentally calculate answers to fraction problems, while holding a heart rate monitor, after receiving a positive, negative, or neutral form of reinforcement. While the results suggest that any motivation, positive or negative, may result in higher grades, the positive reinforcement group displayed the largest gain. However, the results were not statistically significant, though the trend was consistent with prior research. The heart rates of the positively-reinforced group were significantly lower than those of the negatively-reinforced and control groups. These results suggest that motivation through reward, rather than punishment, has a greater effect on the performance of students academically and may increase their grades, as well as lower heart rates during assessments.

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Introduction

The effects of positive and negative reinforcement on different forms of performance have been studied and debated for years. Positive reinforcement is generally defined as reinforcing a specific behavior by providing a positive reward for that behavior (1). Negative reinforcement is generally defined as removing a negative experience that causes discomfort or harm by performing a specific behavior (1). Negative reinforcement could be argued as a serious instigating factor, but also as a discouraging factor, while views on positive reinforcement could vary from seeing it as a natural aspect of human decency to unnecessary coddling.

Reward versus punishment as a means of motivation is both a psychological and biological question and has had varying results, depending on the subject and situation. In one study, reactions and performances were different, even between very close age groups. Researchers studied 'social comparison,' a process where a person finds where they stand compared to those around them. Positive social comparison led to greater success than negative social comparison, and the study reported higher self-reinforcement after positive comparisons, no matter the age, sex, or reward (2). These positive influences could support the idea that optimism, where through compliments or the desire for candy with no consequences, benefits performance. In one experiment testing substance-dependent individuals (SDI), negative reinforcement motivated subjects during a decision-making task, and it was found that SDI were more sensitive to the frequency, rather than the magnitude, of loss while control subjects responded to both (3). Another study found that subjects had better academic success after seeing their previous work in prosperous projects, which could serve as positive reinforcement (4). However, in another study, neural activity in three sections of the brain in subjects in the case of reward or loss was very similar. Additionally, this neural activity did not change with the magnitude of the reinforcement (5). This is a surprising discovery, given the repeated findings that positive and negative reinforcements seem to have at least marginally different effects on performance. Unfortunately, with conflicting data, a solid conclusion has yet to be reached. These previous studies have suggested that while positive reinforcement in groups does have a positive effect on the subjects, brain activity, as monitored by fMRI, displays little difference (5). Negative reinforcement also may have a positive effect on subjects compared to the control treatment, but it is not fully understood why it may be less successful than reward tactics. As a result, researchers remain in search for a more definitive, comprehensive understanding of how different forms of reinforcement affect performance, and why each form does so.

This study attempted to find if and how positive and negative reinforcement affected the mental performance of sixth graders on a math test. This could aid teachers in planning their class style and motivation techniques, as well as how they handle student achievement or failure. How students learn is a major component of the learning process, and finding ways to increase

A

Oral Test Questions

Question Number	Question	Correct Answer
1	1/4 + 1/2	3/4
2	5/6 - 5/12	5/12
3	7/8 × 1/3	7/24
4	1/3 ÷ 1/2	2/3
5	12/15 - 2/3	2/15
6	4/9 + 15/18	1 + 5/18
7	2/7 × 9/3	18/21 or 6/7
8	3/5 ÷ 1/4	2.4 or 12/5
9	5/8 + 5/24	20/24 or 5/6
10	6/7 - 4/14	8/14 or 4/7
11	3/8 × 4/5	12/40 or 3/10
12	3/4 ÷ 2/5	15/8
13	5/4 - 3/12	12/12 or 1
14	9/10 + 4/5	17/10 or 1 + 7/10
15	1/9 ÷ 5/10	2/9
16	5/7 × 4/12	20/84 or 5/21
17	6/7 - 15/21	3/21 or 1/7
18	2/6 + 5/18	11/18
19	4/5 × 6/7	24/35
20	11/15 ÷ 2/3	33/30 or 11/10 or 1.1

B

Student Demographics

Student Number	Reinforcement Type	Gender	Ethnicity	Current Math Class Grade (%)	Oral Exam Performance
1	Positive	M	Hispanic	100	same
2	Control	M	Middle-Eastern	100	same
3	Positive	M	White	100	worse
4	Negative	M	White	100	worse
5	Negative	M	White	100	worse
6	Positive	F	White	100	worse
7	Negative	M	White	100	worse
8	Control	F	White	100	worse
9	Control	F	White	100	worse
10	Positive	F	Indian	96.77	worse
11	Negative	F	White	96.77	worse
12	Control	M	White	96.77	worse
13	Positive	F	White	93.55	worse
14	Negative	M	White	93.55	worse
15	Control	M	African-American	93.23	worse
16	Positive	F	White	91.94	worse
17	Negative	M	White	90.32	worse
18	Control	F	African-American	90.32	worse
19	Negative	M	White	90.32	worse
20	Control	M	White	90.32	better
21	Positive	M	Chinese	88.71	better
22	Positive	F	White	85.48	worse
23	Control	F	White	85.48	worse
24	Negative	M	African-American	83.87	worse
25	Positive	F	White	75.81	worse
26	Negative	M	White	69.35	worse
27	Control	M	White	67.74	worse
28	Control	M	White	66.94	worse
29	Negative	M	White	64.52	worse
30	Positive	M	African-American	62.90	worse

Table 1: Oral Test Questions and Student Demographics. A) Oral test questions given to students and the correct answers. B) Student Demographics. Students listed by number, displaying reinforcement type (green = positive, pink = negative, yellow = control), gender, ethnicity, in-class math class grade (percent), and oral exam performance compared to current math class grade.

student success is an investment in the next generation. Given that previous studies found positively-reinforced subjects had higher performance (2, 4) and that negative reinforcement did have a smaller but noticeable positive effect (3), we hypothesized that students given positive reinforcement would have the highest average score and negatively-reinforced students would do better on average than the control group. Although the data of this study are consistent with the hypothesis, the increases were not statistically significant. These results suggest that motivation through reward, rather than punishment, has a greater effect on the academic performance of students and may increase their grades.

Results

Since the impact of positive and negative reinforcement on students has not yet been established, this study attempted to determine how reinforcement type affected the mental math performances of sixth grade students at a Midwest suburban STEM (science, technology, engineering, and mathematics) school. The students were each given a twenty-question fraction test (**Table 1A**). During the test, the students held a heart rate monitor with their hands and answered the math questions orally. Prior to the test, the thirty students were divided into three groups: control (no reinforcement), positive (positive reinforcement), and negative (negative reinforcement). Prior to test administration, students in the positive-reinforcement group were told that if they earned an “A” on the test, they would receive candy; students in the negative-reinforcement group were told that if they did not meet their teacher’s expectations, they would come in at recess and after school to study fractions; students in the control group were told that their results were anonymous and would not affect their academic career. Each group represented a mix of ethnicities, genders, backgrounds, and academic performances (**Table 1B**). To ensure similar ability levels between groups, each group had a similar (within 0.36%) average on their current math class grade (**Figure 1**). We hypothesized that students given positive reinforcement would have the highest average score, followed by negatively-reinforced students and then the control group.

The average score of the control group on the oral math exam was 56.5% correct (**Figure 1**). For the negative-reinforcement group, the average score was 61.5% correct (**Figure 1**); the average score of the positive-reinforcement group was 71.5% correct (**Figure 1**). The positive-reinforcement group had the highest average score, followed by the negative-reinforcement group. Both reinforcement groups had a higher score than the control group, which received no type of reinforcement. These findings are consistent with our hypothesis that students given positive reinforcement would have the highest average score, followed by negatively reinforced

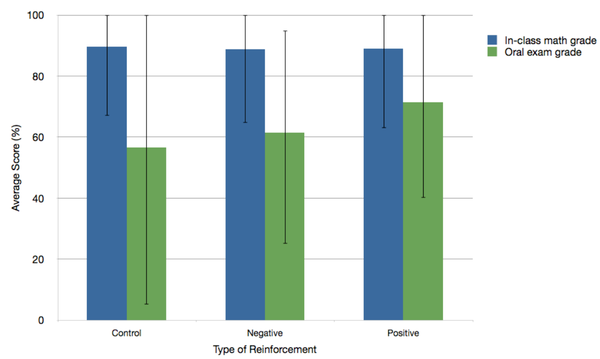

Figure 1: Type of Reinforcement Versus Average Score of Subject Groups. Student scores for in-class math grades (blue) and oral exam grades (green) were averaged for each group. Error bars represent range of scores for group.

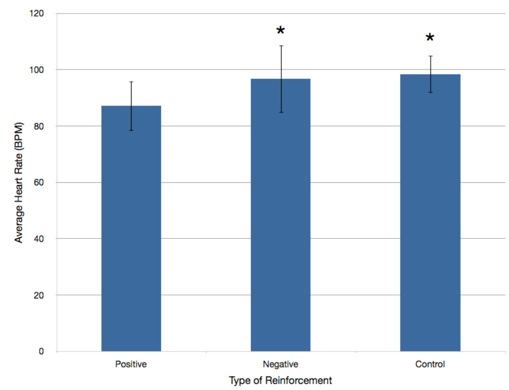

Figure 2: Type of Reinforcement Versus Average Heart Rate of Subject Groups. The mean heart rates of students were averaged by group. Error bars represent standard deviation. * denotes a significant difference from the positively-reinforced group.

students, and then the control group.

While a trend consistent with the hypothesis was found in the data, there was no significant difference between the performance of the groups (ANOVA, F = 0.89, p = 0.422), perhaps due to the small sample size (n = 30) and high variability in the groups, as shown by the large range of the oral exam scores (**Figure 1**). The control group's scores ranged from 100% correct to 5% correct; the negative-reinforcement group's scores ranged from 80% to 25% correct; the positive-reinforcement group's scores ranged from 100% to 40% correct. The high variability in each of the groups, combined with the small number of test subjects, could have resulted in the statistical insignificance, despite the trend being consistent with the hypothesis.

Looking at individual student performance, only four students of the thirty performed at the same level or better on the oral math exam as in their current math class (**Table 1B**). Two students who performed at the same level both had a class grade of 100% and received 100% on their oral exam (**Table 1B**, students 1, 2). Two students had oral exam scores that were higher than their class grade (current class grades of 88.71% and 90.32%; their oral math exam scores were 90% and 95%, respectively) (**Table 1B**, students 21, 20). All four of these students were in either the positive-reinforcement group or the control group (one same, one better in each group). All other students, including all the students in the negative reinforcement group, had oral exam scores that were lower than their current math class grade (**Table 1B**).

Students' heart rates during the oral exam were also recorded. The average heart rate of the control group while taking the oral exam was 98.28 BPM (beats per minute); the average heart rate of the negative-reinforcement group was 96.72 BPM; the average heart rate of the positive-reinforcement group was 87.17 BPM (**Figure 2**). The positive reinforcement group had the lowest average heart rate, followed by the negative reinforcement group. Both groups had a lower average heart rate than did the control group (**Figure 2**). Average heart rates for the groups were found to be statistically significantly different (ANOVA, F = 4.05, p = 0.029). The positive reinforcement group had a significantly lower average heart rate than did the control (t-test, p = 0.005) and the negative-reinforcement groups (t-test, p = 0.042). Due to students completing the oral exam at different speeds, heart rates for specific questions could not be compared across the groups.

Discussion

While not statistically significant (ANOVA, F = 0.89, p = 0.422), the trend in the data suggests that with both positive and negative reinforcement, students are more likely to perform better on an oral math exam than controls, potentially with positively-reinforced individuals having the greatest performance. This indicates that these students may have responded with more drive to succeed when there was a reward given for reaching a certain mark. These results matched the expected results: that students given positive reinforcement would have the highest average score and negatively-reinforced students would still do better on average than the control group.

Surprisingly, many of the students who had the highest scores in class were not the top scorers in the experiment. Two subjects in the control group, whose scores placed them at the top of their class, had experimental scores 40% and 45% less than their class grade. One negatively-reinforced subject, who possessed a perfect score in class, actually had a lower score in the experiment than did a student whose class score was nearly failing. In the positively-reinforced and control groups, only two subjects scored higher than or equal to their class score (**Table 1B**) and none in the negatively-reinforced group did (**Table 1B**). These radically different scores could be due to the different motivations, or the different form the test was taken in: orally versus written. These findings may indicate students find oral math exams more difficult than written work.

Oral testing could also have affected students' heart rates. While the heart rates of the positively-reinforced subjects were significantly lower than those of the other groups (**Figure 2**), the difference between them (or the similarity of the negatively-reinforced and control subjects) may be due to the fact that the students had not been tested this way before. Nervousness may have arisen in all groups and shifted the rates, not because of the actual questions, but by the way they were given. However, considering the large difference between the positively-reinforced subjects and the two other groups, it is possible that the possibility of reward, as well as having nothing to lose, kept those subjects more calm than their counterparts. Students being encouraged through fear of punishment may exhibit nervousness or be distracted by their worries, while students who are being rewarded for success may feel that they have less to lose and may be able to focus more easily. However, students not given any reason, punishment or reward, to perform to the best of their abilities may do worse because they do not feel any motivation to succeed. This data could potentially be used by teachers to show why positive reinforcement has a greater effect on students' success and used by child psychologists to describe how children are motivated.

In future studies, a larger sample size would aid in counteracting statistical insignificance. Students could be tested multiple times, to assess different reactions pertaining to the situation. Heart rates could also be carefully monitored to correspond with individual questions (allowing heart rates to return to resting between questions), in order to determine if certain questions make students' heart rates increase. Depending on the subjects, different rewards and punishments may also be issued. Candy may not be the healthiest reward, but our results indicate that it may have been an incentive for children, and while extra studying may not be an incredibly joyful experience, it be may be able to help students succeed academically.

In conclusion, this study's findings on mental math performance were not statistically significant, and thus, cannot be the basis of massive educational reform. However, the trend found matches previous experiments and may indicate how different forms of motivation affect students' mental math performance. Findings did indicate that students in the positively-reinforced group had significantly decreased heart rates while taking the oral exam and that most students (26/30 or 86.7%) performed worse on the oral exam than their current in-class math grade. These results could be used by teachers or administrators in lesson and assessment planning to possibly increase students' motivation and reduce heart rate in class or on standardized tests.

Methods

Sixth grade students at a Midwest suburban STEM school were chosen as test subjects. A twenty-question test involving adding, subtracting, multiplying, and dividing fractions was written for the study (**Table 1A**). The test contained varying levels of difficulty and was checked by a sixth-grade math teacher for accuracy and relevance. Fractions were chosen as the topic because the students had recently completed a unit on fractions, so the content would be familiar to them. Consent forms were dispersed amongst the entire sixth grade class at the Midwest suburban STEM school. Thirty students who returned the consent forms were chosen for the study. These students represented a mix of ethnicities, genders, backgrounds, and academic performances (**Table 1B**). The thirty subjects were divided into three groups of ten students based on their math class grades shortly after their final fractions test, which was provided by the sixth grade math teacher (**Table 1B**). The groups were divided to have the closest average grade in their math class, and the group's averages were all within .36% of each other (**Figure 1**). Each group was classified as control, positive, or negative reinforcement.

Every student was brought to a small office to take the test during their study hall period. Fraction problems were shown on index cards to the students. A Vernier heart-rate monitor was held by each student as they mentally calculated their answers. Percent correct was recorded in a spreadsheet that calculated individual and group scores. Students in the control group were told that the scores were completely anonymous and would have no effect on them or their academic career. Students in the negative-reinforcement group were told that their teacher would see their scores, and should they not meet their teacher's standards, they would be asked to come in during recess and after school to study fractions. Students in the positive reinforcement group were told that if they scored an A, they would receive candy after all of the scores were collected. These reinforcements were chosen due to their possible immediate effect and how much they would motivate students.

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