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An Investigation in Negative Transfer: Theory of Inhibition

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Abstract

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Campbell and Robert (2012) found that numerical addition practice led to negative transfer on a subsequent test of numerical multiplication. Alternatively, Rickard et al (2011) found negative transfer for numerical addition, when participants where tested on an intermixed set of addition and subtractions problems after first practicing addition, and then practicing subtraction. The present study sought to assess negative transfer by practicing participants with alphabet addition verification problems and testing the performance on alphabet multiplication verification. Ninety-five participants were split into 4 groups and given varying number of days of practice. During the test phase, some multiplication verification problems included the same components as the practiced addition problems (e.g., B+3=E and Bx3=E). The results suggest that participants demonstrated significant learning of alphabet addition as well as negative transfer occurring for the alphabet multiplication problems when looking at an overall analysis. When looking at individual groups negative transfer was not seen.

An Investigation in Negative Transfer: Theory of Inhibition

Negative transfer occurs when a learned activity inhibits or interferes with another related, but newer activity. There are two theories as to what causes negative transfer. Inhibition Theory proposed by Bjork (1989) suggests that when one task or skill is practiced to the point of being completely automatic negative transfer will occur when a new but related task is introduced due to overlearned and overlapping representations that exist with the first task. Alternatively, the Interference Theory proposed by Mensink (1988) suggests that when two tasks are practiced independently, one right after the other, to the point of both skills being completely automatic negative transfer will occur when both tasks are tested simultaneously where order of practice will determine the effect, such that the first learned task will interfere with the second learned task due to the overlearned and overlapping representations of the first task. The interference theory suggests negative transfer occurs because the people are more likely to perform the second learned task incorrectly due to the interference by the first learned task.

Campbell & Robert (2012) tested the inhibition theory giving participants 2 blocks of practice on 36 addition problems (6+8=14), and then testing them on 6 blocks of 12 multiplication problems (6x8=48). Their results suggest that negative transfer occurred for multiplication problems that had the same operands as those used in the addition practice (e.g., 6x8=? And 6+8=?), because of the overlap in the mental representations for each type of problem. In this case, the practiced addition set inhibited the retrieval for the multiplication problem from memory. This is demonstrated by participants answering the multiplication problems incorrectly during test with multiplication problems. For example, after participants had practiced on the addition problems they were more likely to endorse incorrect multiplication problem like 6x8=14. In other words, Campbell & Robert (2012) set up the experimental design as a test of inhibition theory such that participants practiced addition, then were tested on multiplication (no practicing on multiplication).

In contrast, Rickard, Bajic, & Kwak (2011) tested the interference theory using addition and subtraction problems. In this study, participants practiced 96 addition problems (4+5=9) for 16 blocks followed by practice with 96 subtraction problems (9-5=4) for 16 blocks, then were tested on a mix of 96 problems of both types. In this case, negative transfer occurred such that during performance in the mixed problem condition participants made errors on subtraction problems more often than the addition problems, because the initial practice of addition (i.e., practicing addition first) interfered with answering the subtraction problems. Thus, the experimental design used in Rickard et al (2011) was such that participants practiced addition, then subtraction (testing interference).

Building off the work of Campbell and Robert (2012) and Rickard et al (2011) the present study sought to test the inhibition theory with a new skill to replicate Campbell's results. The purpose of this study was to test the inhibition theory by seeing how much practice is necessary for a skill to be overlearned enough for negative transfer to occur. The study involved practice with alphabet addition then testing performance on alphabet multiplication.

Method

Participants

Ninety-five Union College students enrolled in introduction to Psychology courses served in the experiment in exchange for partial course credit. Additionally, 16 participants in group 4 were paid $30 for their 4-day participation in the study. The participants aged from 18 to 22 years old. There were 4 groups in total for the study with each group receiving varying number of days of alphabet addition practice. Group 1 (25 participants, 10 males and 15 females) were given 1 day of addition, group 2 (25 participants, 15 males and 10 females) were given 2 days of addition, group 3 (25 participants, 15 males and 10 females) were given 3 days of addition, and group 4 (20 participants, 16 males and 4 females) were given 4 days of addition.

Materials

The study was implemented using E-Prime software, implemented on Lenovo ThinkCentre model number MT-M 3063-B8U desktop computers running Windows 7. On each day of practice, participants were given practice with 30 different problems in a verification format (B+3=E, true or false?). Problems were presented 120 times per block across 4 blocks for a total of 480 problems per day. Within each block of practice problem type (i.e., true and false) was manipulated such that each problem was presented 4 times with two true answers and two different false answers across 4 blocks, for a total of 240 true answers and 240 false answers were shown. Candidate false answers were either near to the correct answer (near distance: numerically 1-3 from the correct answer), or medium distance from the correct answer (numerically 4-6 from the correct answer). Given that there are only 26 letters in the alphabet, no computation could result in a value above 26. The alphabet multiplication verification problem set used during the test phase consisted of 30 problems with two true answers and two different false answers. One false answer was related to the addition problem such that the answer for the multiplication problem was correct for the addition problem as it had been presented earlier (i.e. Ax1=B, false but A+1=B, true). Unrelated false answers were simply incorrect for both the multiplication and addition. The manipulation of answer relatedness allowed for the assessment of negative transfer by assessing errors for related false answers in comparison to errors for unrelated false answers. Specifically, negative transfer would be indicated by more errors for related false answers than for unrelated false answers.

Procedure

After providing an institutionally approved informed consent procedure, all participants were instructed that the study involved learning. The experimenter read instructions on how to perform the alphabet addition task. Specifically, the instructor told participants they would be answering many trials of alphabet addition problems and to determine whether the problem was true or false. The instructor taught participants how to solve problems by going over a practice problem with them. For example, the problem C+3=F, true or false? To solve the problem, start at the first letter in the problem C, convert the letter C to 3 since it is the third letter in the alphabet, then add 3 to 3 to get 6, then convert the 6 to the sixth letter in the alphabet, which is F. It is important to note the two-step conversion process when performing alphabet addition. Participants were asked to work as quickly and accurately as possible. They were further instructed to place one finger on the key labeled true, (number 1 key on the keyboard), and place another finger was on the key labeled false, (number 2 key on the keyboard). Participants were then given 4 blocks of practice with the alphabet addition problems.

After completing the practice sessions, (variable by group number) all participants took the alphabet multiplication test. Similar to the alphabet addition instruction, the instructor told participants they would be answering many trials of alphabet multiplication problems as well as how to place their fingers on the keyboard. The instructor taught participants how to solve problems by going over a practice problem with them. For example, the problem Bx4=H, true or false? To solve the problem, start at the first letter in the problem B, then convert the letter to its corresponding place in the alphabet (i.e. 2). Multiply the letter place, 2, by 4 to get 8. This means the answer is the 8^{th} place in the alphabet, so count up to the 8^{th} letter in the alphabet (i.e. A, B, C, D, E, F, G, H) with the last letter being the answer. Participants were tested on 1 block containing 120 problems for the alphabet multiplication problems. Participants were presented with 30 different problems, 4 times such that each problem was presented twice with true answers and twice with false answers. One false answer was related to an addition answer. For example, B x 4 = F is false, but B + 4 = F is true. The unrelated answer was an answer that had not been seen in the addition practice set. Once the participants finished they were debriefed, and were asked to keep the purpose of the study confidential.

Results

To assess negative transfer of the alphabet addition practice on alphabet multiplication performance, a 3x4 mixed analysis of variance on errors on multiplication problems was performed with problem type as the 3 level within subject factor (true, related, and unrelated) and group as the 4 level between subject variable, this was done by performing a two-way ANOVA. One main effect is the statistically significant difference between true and overall false, $F(1,3) = 152.78$, $p < .001$. The second main effect was the statistically significant difference between related false and unrelated false, $F(1,3) = 6.005$, $p < .05$. Negative transfer would be indicated by a significant difference between false related and false unrelated answers.

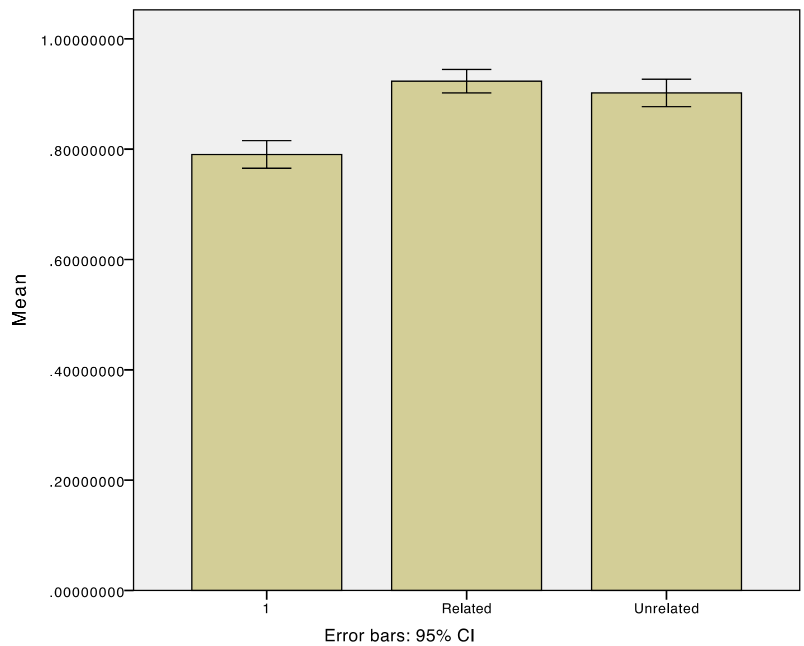


Figure 1. Mean Accuracy by Problem Type for Total Group ANOVA.

Learning of the alphabet addition problems was assessed through analysis of participants' accuracy and reaction times (RTs). Liner regression was used to assess changes in mean accuracy across practice blocks. Mean accuracy for group 1, 2 and 4 did not significantly increase across practice block $R^2 = 0.221$, $p > 0.05$ for group 1, $R^2 = 0.297$, $p > 0.05$ for group 2, $R^2 = 0.336$, $p < 0.05$ for group 4. Mean accuracy did significantly increase across practice block for group 3 $R^2 = 0.704$, $p < 0.05$.

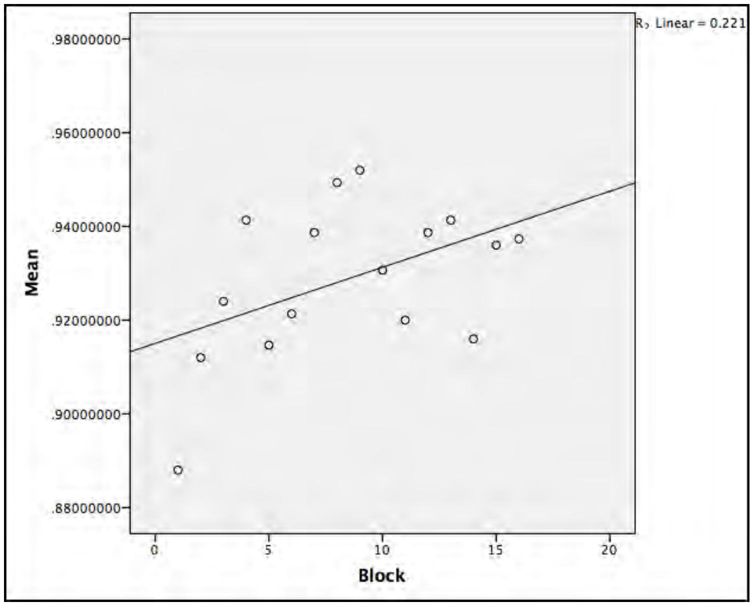


Figure 2. Mean Accuracy by Block for Group 1, 1 day of practice.

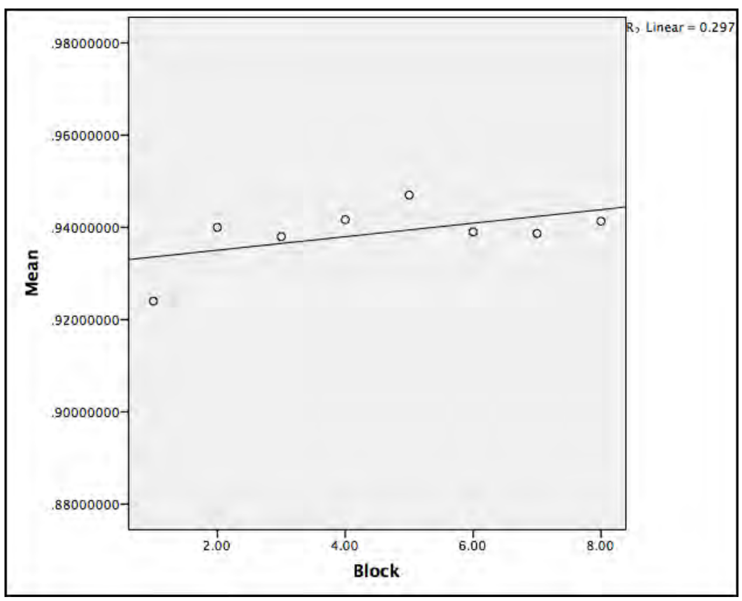


Figure 3. Mean Accuracy by Block for Group 2, 2 days practice.

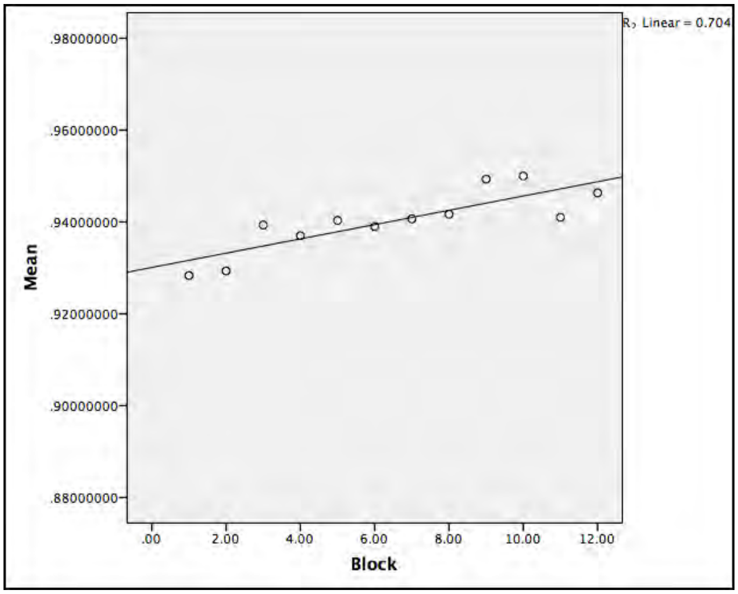


Figure 4. Mean Accuracy by Block for Group 3, 3 days practice.

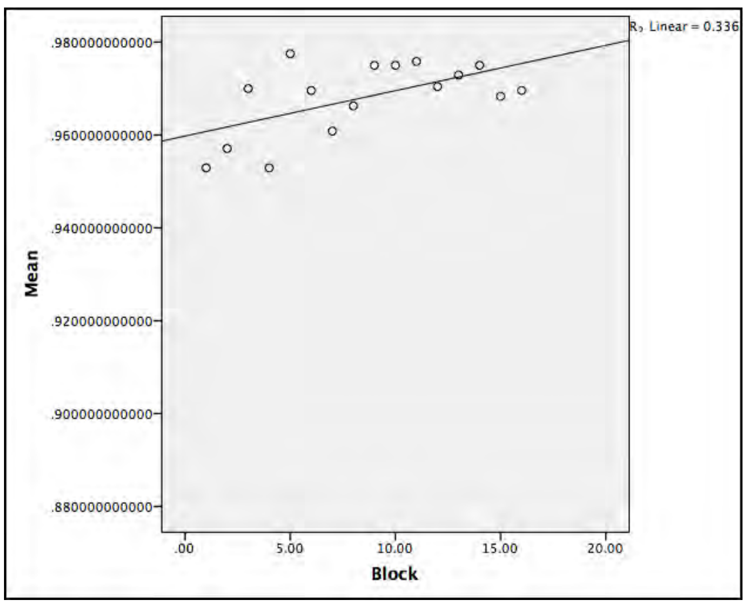


Figure 5. Mean Accuracy by Block for Group 4, 4 days practice.

Learning was also assessed through speed up of log reaction time across log block. Liner regression was used to assess changes in mean reaction time across practice blocks. Mean reaction time for group 1, 2, 3, and 4 did significantly increase across practice block for all groups, $R^2 = 0.572$, $p < 0.05$ for group 1, $R^2 = 0.951$, $p < 0.05$ for group 2, $R^2 = 0.985$, $p < 0.05$ for group 3, and $R^2 = 0.989$, $p < 0.05$ for group 4.

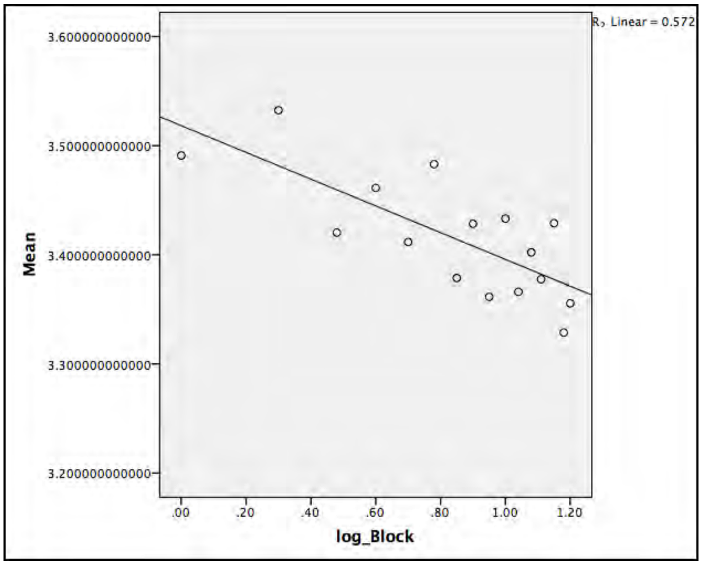


Figure 6. Log Mean Reaction Time by Log Block for Group 1, 1 day practice.

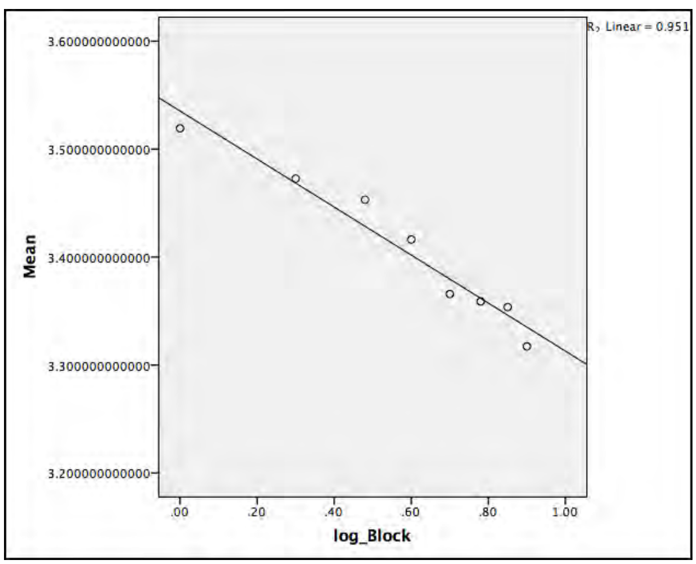


Figure 7. Log Mean Reaction Time by Log Block for Group 2, 2 days practice.

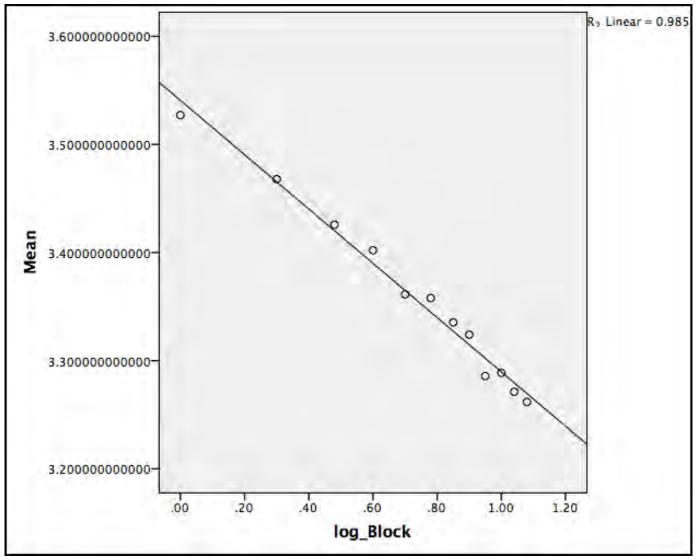


Figure 8. Log Mean Reaction Time by Log Block for Group 3, 3 days practice.

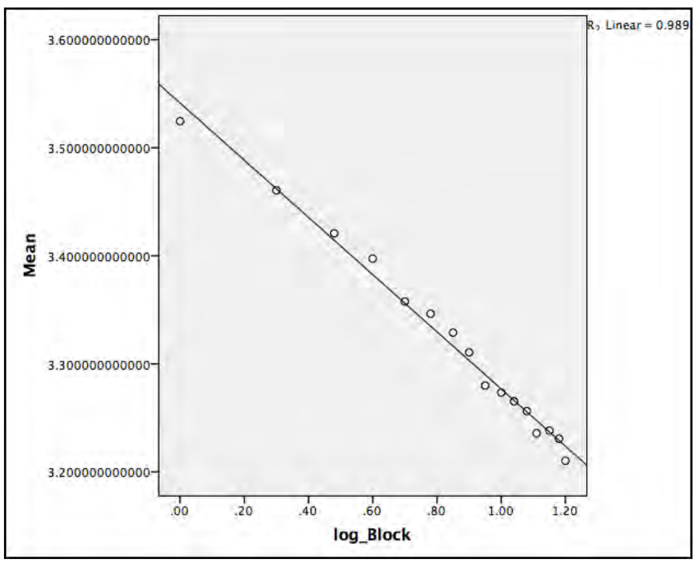


Figure 9. Log Mean Reaction Time by Log Block for Group 4, 4 days practice.

One way ANOVA was also performed per group with Mean Accuracy by Problem Type to determine where negative transfer occurred. For groups 1, 2, 3, and 4 the results were significant when looking at a main effect of problem type $F(2,48) = 16.99$, $p < .001$ for group 1, $F(2,48) = 26.08$, $p < .001$ for group 2, $F(2,48) = 38.14$, $p < .001$ for group 3, and $F(2,38) = 28.79$, $p < .001$ for group 4. Further examination of this finding showed that True and Overall False were statistically different $F(1,24) = 16.34$, p

$< .001$ for group 1, $F(1,24) = 22.29$, $p < .001$ for group 2, $F(1,24) = 50.70$, $p < .001$ for group 3, different $F(1,24) = 61.28$, $p < .001$ for group 4. In groups 1, 2, 3, and 4 the results were not significant when comparing Related False and Unrelated False, $t(24) = 1.014$, $p > .05$ for group 1, $t(24) = 1.593$, $p > .05$ for group 2, $t(24) = 1.690$, $p > .05$ for group 3, and $t(19) = .879$, $p > .05$ for group 4.

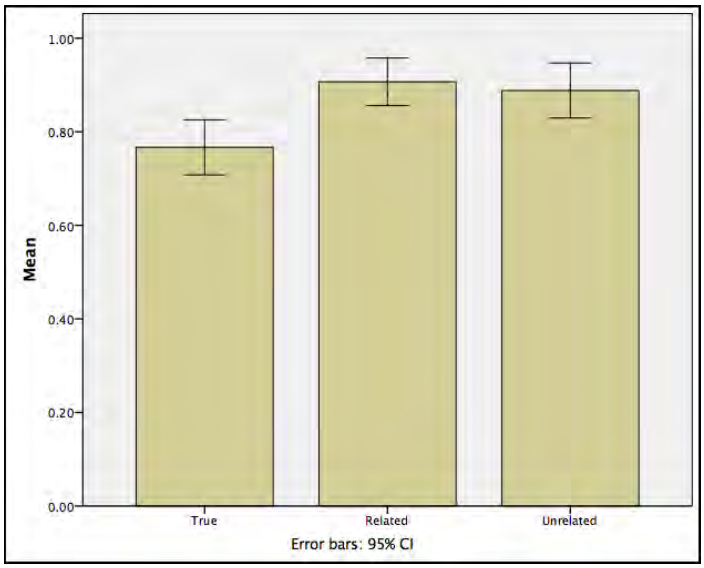


Figure 10. Mean Accuracy by Problem Type Group 1 ANOVA.

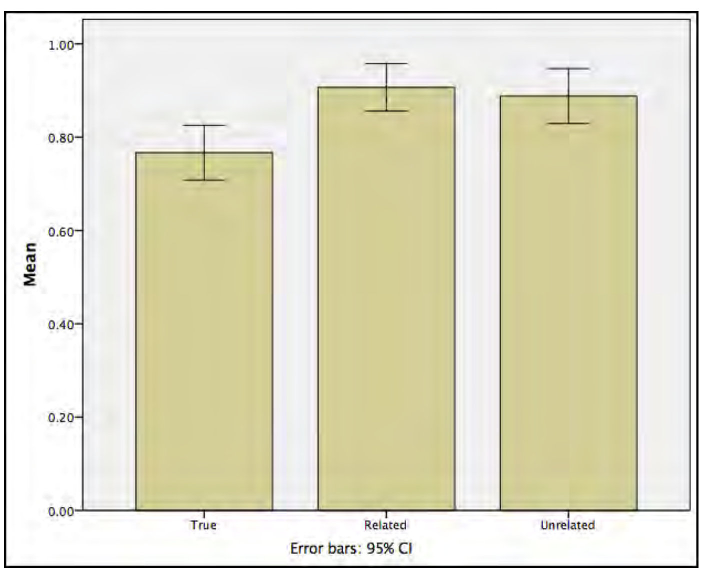


Figure 11. Mean Accuracy by Problem Type Group 2 ANOVA.

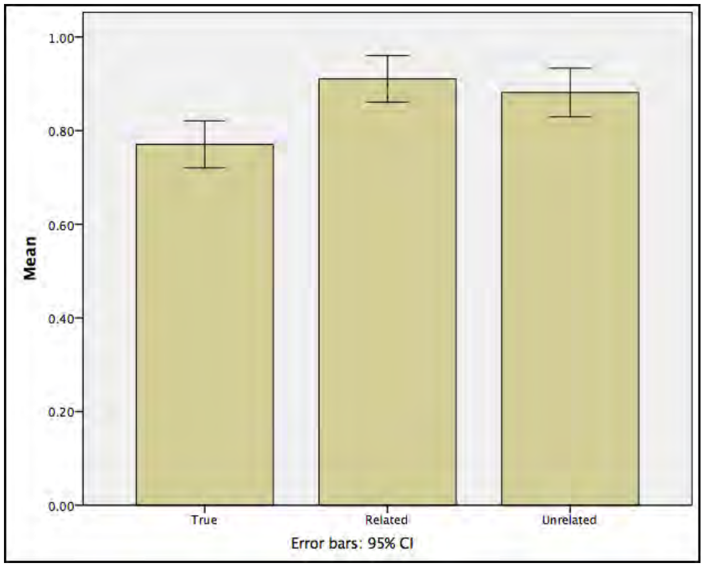
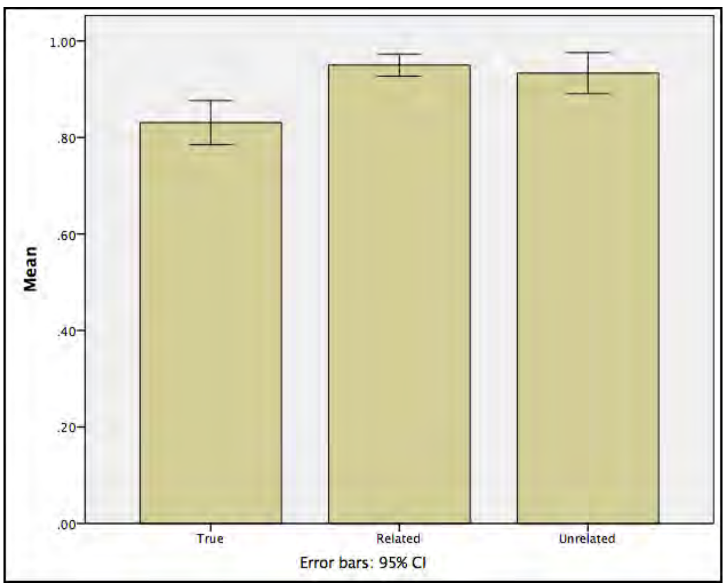


Figure 12.



Mean Accuracy by Problem Type Group 3 ANOVA.

Figure 13. Mean Accuracy by Problem Type Group 4 ANOVA.

Discussion

Although there was no significant increase in accuracy across blocks for groups 1, 2 and 4, these findings may be due to ceiling effects. Looking at the accuracy graphs, across blocks participants the lowest average accuracy during the first block was 88% for group 1. All other groups demonstrated higher accuracy on the first block, and by block 4 average accuracy in all groups increased to 95% or higher.

On the other hand, learning was demonstrated in significant RT speed-up across blocks for every group, which enabled the further analysis of errors for the alphabet multiplication problems to assess negative transfer. It was predicted that negative transfer would be reflected by more errors on related false problems than for the true and unrelated false problems. As seen in Figure 1, negative transfer occurred when examining Mean Accuracy by Problem Type for all of the groups, but not when examining each of the groups individually. This may have occurred because there was not enough statistical power in the individual groups, but when combining the subjects for an overall analysis, there was enough statistical power to support negative transfer. Although negative transfer occurred, it is not possible to pinpoint where negative transfer occurred. While there was an overall significant effect while investigating negative transfer, there was not when looking at individual groups as presented by the individual graphs for mean accuracy by groups. When looking at individual groups, there was not enough participants, but when combining the data to find an overall affect the greater number of participants increased the statistical power.

Future studies will need to be done to determine at what point is a skill learned enough for negative transfer to occur. One possible study would be to increase the number of participants per group to have enough statistical power to show negative transfer in the data. Future studies are also planned to test the interference theory. These studies will be similar to those of the inhibition theory in that they will contain 3 groups, each with 2 subgroups. The difference in subgroups will be the first subgroup will practice alphabet addition first, while the second subgroup will practice alphabet multiplication first. The first group will practice alphabet addition and alphabet multiplication for a day and be tested on an intermixed set of problems. The second group will practice alphabet addition and alphabet multiplication for two days and be tested on the intermixed set of problems on the second day. The third group will practice alphabet addition and alphabet multiplication for three days and be tested on the intermixed set of problems on the third day. Evidence for the interference theory would be found if negative transfer occurs to the same extent in all three groups regardless of the amount of practice.

References

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Appendix

Addition Instructions

Welcome and thank you for participating. I am going to read you the instructions at the start of every session. This way I am sure to tell everyone the same things.

Please listen carefully to the instructions I am about to read to you. The task you are about to participate in is not a measure of intelligence; we do ask, however, that you respond quickly and accurately as possible. When I start the computer program you will be asked to do many trials of an alphabet addition task. Problems in this task contain both letters and numbers. These problems are just like regular addition with numbers except alphabet addition is based on the alphabet and not on the number line. For example, the problem C+3=F. You can easily reach this answer by starting at the first letter in the problem—C in this case and then convert the letter C to 3 since it is the third letter in the alphabet, then add 3 to 3 to get 6, then convert the 6 to the 6th letter in the alphabet which is F. In this experiment the problems will be presented with a candidate answer and your job is to decide if this answer is true or false and then press the "true" or "false," button to indicate your decision. Examples of other problems would be B+4=F and C+5=H.

You will probably make a few mistakes in this task, as everyone does. Don't worry about these just continue to work as quickly and as accurately as possible.

At the start of the first block your hand should be placed on the keyboard so that one finger is consistently on the "true" key and the next finger is on the "false" key, and keep them there until while you are doing the task. After each block there will be a "pause." During this time, only, you can move your hand from its position on the true and false keys. During the "pause," you will be allowed to move your hand and stretch, if necessary. Once again it is important to work as quickly and as accurately as possible. Please follow any other instructions presented on the screen.

Thank you for participating and please press the spacebar to begin.

Multiplication Instructions

Welcome and thank you for participating. I am going to read you the instructions at the start of every session. This way I am sure to tell everyone the same things.

Please listen carefully to the instructions I am about to read to you. The task you are about to participate in is not a measure of intelligence; we do ask, however, that you respond quickly and accurately as possible. When I start the computer program you will be asked to do many trials of an alphabet multiplication task. Problems in this task contain both letters and numbers. These problems are just like regular multiplication with numbers except alphabet multiplication is based on the alphabet and not on the number line. For example the problem Bx4=H You can easily reach this answer by starting at the first letter in the problem – B in this case and then convert it to its corresponding place in the alphabet (i.e. 2) then multiply by 4 to get 8. This means the answer is the 8^{th} letter in the alphabet then you can count up (i.e. A, B, C, D, E, F, G, H) and the last letter is the correct answer. In this experiment the problems with a candidate answer and your job is to decide if this answer is true or false and then press the "true" or "false," button to indicate you decision. Examples of other problems would be Dx4=P and Ex5=Y.

You will probably make a few mistakes in this task, as everyone does. Don't worry about these just continue to work as quickly and as accurately as possible. At the start of the first block your hand should be placed on the keyboard so that one finger is consistently on the “true” key and the next finger is on the “false” key, and keep them there until while you are doing the task. Please follow the instructions presented on the screen.

Thank you for participating and please press the spacebar to begin.