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Motivation and memory: An analysis of performance-dependent reward-based motivational effects on encoding and retrieval

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Abstract

Extrinsic reward has been shown to influence memory performance. This study sought to examine the effects of extrinsic reward on the individual processes of encoding/retrieval. Thirty-eight participants were divided into three groups; each underwent a memory task consisting of an encoding phase, filler task, and retrieval phase. The control group did not have an opportunity to receive a reward, unlike the two experimental groups who both had potential to receive a lottery ticket conditional on strong memory performance, although they differed in the times in which they were made aware of the potential reward. An improvement in memory performance primarily attributable to motivated retrieval was expected. There was no significant difference in memory performance or motivation between groups.

Keywords: memory, motivation, reward

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Motivation and memory: An analysis of performance-dependent reward-based motivational effects on encoding and retrieval

Memory is central to overall functioning in daily life. It is used when remembering a phone number, remembering to go to the grocery, or even recognizing family members, yet there are many external factors that affect memory performance. By making use of these external factors, individuals can more effectively learn and remember new information, and memory performance can be bolstered in those who may have additional factors hindering memory processing (Dehn et al., 2020; Landsiedel & Williams, 2019; Rock et al., 2014). For example, individuals with Autism Spectrum Disorder (ASD) are shown to perform significantly worse on time-based prospective memory tasks (memory in which someone has to remember to do something at a future point in time). Landsiedel and Williams (2019) were able to use extrinsic motivation (motivation due to outside influences such as the promise of a reward/punishment) to significantly improve the memory performance of individuals with ASD to near neurotypical levels. Another population with moderately pronounced neuropsychological deficits in memory and attention are patients with Major Depressive Disorder (MDD; Rock et al. 2014). Dehn et al. (2020) were able to demonstrate a significant effect of motivation on memory amongst a group of patients with MDD, suggesting the possible efficacy of a motivationally-based intervention. These findings serve as key examples of just how well research in this area could be put to practical, applied use.

Using the common Information Processing Theory, memory is often broken down into the stages of encoding and retrieval, yet it is unclear how extrinsic motivators affect these processes individually. For example, some existing studies on motivation and memory do not let their participants know ahead of time that there will be a memory test or that they will be

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rewarded for their performance until the time for the test actually comes, meaning that these participants only have the motivator affecting their retrieval ability, rather than also affecting their intentional encoding of stimuli (Dehn et al., 2020; Locke & Braver, 2008; Murayama & Kitagami, 2014; Sharot & Yonelinas, 2008). By breaking the effects of motivation down into these two parts, the interaction between motivation and memory can be better understood and, therefore, theoretically be used more effectively to improve memory and learning on the basis of being able to more finely tune the motivational intervention for memory improvement. This literature review will examine the effects of extrinsic motivation on the individual processes of encoding and retrieval by using evidence from prior research to inform the current study's model of motivation and providing evidence to support the concept of motivation serving to improve memory performance independently of other factors. This paper will discuss prior research on memory improvement, the interaction between motivation and memory, and existing research on extrinsic motivators.

Prior Memory Research

Most models of memorization and information processing are broken down into multiple parts consisting of encoding, consolidation, and retrieval. Goldstein (2018) explains these aspects of memory as follows: Encoding is the process in which information is acquired, then transferred from working memory to long term memory, whereas retrieval is the opposite; information is taken/retrieved from long term memory, back into working memory to be manipulated and used. Consolidation is the process that occurs over a period of time after encoding in which information is changed from its new, fragile state into more permanent, solidified memories (see Figure 1 for an overview).

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There are several existing theories that describe various factors which may improve memory performance that are important to address before motivation as a factor can be isolated. These factors that may influence memory include emotion (Sharot & Yonelinas, 2008; Shigemune et al., 2010), dopamine (Murayama & Kitagami, 2014), and simply individual differences (Locke & Braver, 2008). These need to be taken into account so motivation can be examined in depth and in isolation.

The effect emotion has on memory has been well-documented (Sharot & Yonelinas, 2008; Shigemune et al., 2010). Shigemune et al. (2010) examined the effects of motivation and emotion simultaneously as they relate to memory using a 2 (emotional valence: negative, neutral) x 2 (monetary reward: high, low) experimental design. Participants were shown images to memorize and told that they would be tested on them in 24 hours. They found that the memory performance of participants in the negative emotional valence condition was significantly better than the neutral emotional valence condition, and the memory performance of the high monetary reward condition was significantly better than the low monetary reward condition, yet there was no interaction between emotional valence and monetary reward. These two factors operated independently of the other; one did not depend on the other. It's also important to highlight that this experimental design showed an effect of emotion on memory after a 24 hour delay. This is consistent with the findings of Sharot and Yonelinas (2008) where memory improvement for emotional stimuli was shown to occur only after a delay. Emotion does not affect memory when tested immediately, suggesting that its effects of slowed forgetting occur during the consolidation process. With this in mind, it is clear that the effect of emotion can be kept at bay by testing memory immediately rather than after a delay.

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Another theory that has emerged recently is the dopaminergic memory consolidation hypothesis, which states that anticipation of an extrinsic reward may promote memory consolidation by activating the reward system, increasing dopamine in the hippocampus. Murayama and Kitagami (2014) designed an experiment in which participants completed a task where they would encode information to later, unbeknownst to them, be tested on either immediately or after a week delay. Those in the reward condition also received a monetary reward for performance on an unrelated task. This design was intended to produce dopamine from being rewarded, yet controlled for reward motivation by separating the rewarded task from the encoding task. They found improved memory performance in the reward condition only for those who were tested a week later rather than immediately. This, much like the findings for emotion, suggest that while dopamine may affect memory, it occurs during consolidation and requires a delay after encoding.

The final potential confounding factor is individual differences as they relate to motivation. This refers to the fact that the same motivator can have different levels of motivating power for different individuals. Neuroimaging of brain areas related to motivation could theoretically be analyzed to see how objectively motivating something is for an individual based on brain activity in these areas; this is the only potential way to fully regulate individual differences in motivation (Locke & Braver, 2008). There are several brain areas that have been implicated in certain aspects of memory and cognitive control, however, this research is still so young that it is unrealistic to attempt to use the current knowledge of the subject to examine and control for these individual differences in depth or with any degree of certainty (Bowen et al., 2020; Locke & Braver, 2008; Shigemune et al., 2010). It is important to keep this in mind when examining research related to motivation.

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Extrinsic Motivation

Extrinsic motivation can operate independently of the other aforementioned factors, and has its own strong effect on memory that has been measured time and time again. Many studies focus on varying particulars of motivation's effect on memory, yet the overarching finding is that there is a clear, measurable effect (Bowen et al., 2020; Dehn et al., 2020; Landsiedel & Williams, 2019; Millis, 1994; Shigemune et al., 2010).

The effects of motivation on memory are not limited to improved cognitive performance. Millis (1994) examined the role of external, non-neurological factors on Recognition Memory Test (RMT) performance. Three separate groups took the RMT: a severe head trauma (ST) group, a mild head trauma group who returned to work after the trauma (MT-work), and a group with mild head trauma consisting of people seeking financial compensation for the trauma (MT-comp). Findings showed that the MT-comp group received the lowest scores on the RMT, while the MT-work group received the highest scores. Additionally, a significantly higher proportion of the MT-comp group received scores lower than chance when compared to the ST group. This study supports the idea that factors beyond simple memory ability, including external motivating factors, can alter an individual's performance on memory assessments. It is possible that the MT-comp group was simply faking poor memory in order to increase the likelihood of gaining financial compensation for their injuries, but it's also possible that anticipated rewards conditional on poor performance unconsciously changed the effort they put into the RMT, genuinely making it harder for them to remember. This serves as a prime example of how external, motivational factors can affect memory performance.

Research on extrinsic motivational factors has shown motivational effects not only handicapping memory performance (Millis, 1994), but also improving memory performance

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(Bowen et al., 2020; Dehn et al., 2020; Landsiedel & Williams, 2019; Millis, 1994; Shigemune et al., 2010). These studies include Landsiedel and Williams (2019), demonstrating improved time-based prospective memory performance in individuals with ASD when there is an added motivational component; Dehn et al. (2020), which showed a memory improvement in individuals with MDD if their motivation was increased; Shigemune et al. (2010), which showed improved recognition memory performance for highly rewarded learning; and Bowen et al. (2020), which demonstrated improved recognition memory performance for rewarded learning in both young and old adults. In addition to these, a study by Saucet and Villeval (2019) demonstrated improved accuracy in memory when remembering an altruistic act done by the rememberer. In this experiment, participants played a game in which they acted as dictators, deciding how many resources to allocate to receivers. When the dictator allocated resources more altruistically rather than selfishly, they better remembered the exact amount given, suggesting a motivational, selective factor that is capable of improving memory performance.

These findings are by no means new, as even the classic Tolman (1948) experiment points to motivational factors affecting memory. In this experiment, rats were put into a maze with food at the end and their average errors were tracked throughout the trials. Some rats were rewarded with food all throughout the trials and they slowly but surely improved in their maze running abilities (made fewer and fewer errors) before bottoming out. Some rats did not receive any reward at any point and as such, did not improve. Finally, some rats began without receiving any reward, and during this time did not improve at all, but towards the end of the trial began receiving a reward. These rats improved significantly more rapidly than the rats who received food from the beginning, and even reached the point of making fewer errors than the first group,

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suggesting that these rats encoded the maze to some degree, but were not effectively retrieving it. The presence of the reward/motivator improved their retrieval of the information.

Although still young, emerging neuroscientific research offers a new perspective and some intriguing findings regarding motivation and memory. There are several brain regions that neurological scanning (PET and fMRI) has implicated in reward-based conditions. Shigemune et al. (2010) found increased activity in the left orbitofrontal cortex when encoding pictures in the highly rewarding condition compared to the low reward condition. Locke and Braver (2008) found several brain areas with increased activity in the reward block, which were implicated in cognitive control, working memory, and sustained attention. These areas included the right lateral prefrontal cortex, dorsal medial frontal cortex, right parietal cortex, and left cerebellum. These emerging findings, showing increased activation of brain areas involved in memory-related tasks in highly rewarding conditions, serve as preliminary evidence to objectively observe and measure the covert construct of motivation and its effect on memory performance.

There are several particular nuances when choosing a reward and reward schedule that can be utilized to effectively use extrinsic motivation to improve memory performance. Two important factors to look at are the amount or extremity of reward being used, as well as how predictable the delivery of the reward is. First, it is important to realize that not all rewards are equal, so how does the difference in highly rewarding reinforcers vary from lowly rewarding reinforcers? In Shigemune and colleagues' (2010) experiment, which examined the effects of both motivation and emotion on memory, participants in the highly rewarding condition (100 yen per correct answer) performed significantly better on the memory test when compared to the low reward condition (1 yen per correct answer), suggesting that the magnitude of memory improvement scales with the amount of reinforcement that any motivator provides.

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Second, there is possible variation in how rewards are actually delivered, so how does the ability of participants to predict the delivery of the reward alter the effects of the reward?

Bialleck et al. (2011) examined the role of predictability of rewards on reaction time, accuracy, and recognition memory performance. Participants were presented with objects from varying categories that either signaled a predictable reward or unpredictable reward on the subsequent number comparison task (reward conditional on successful completion of this task). Following this, participants were asked to complete a surprise recognition memory test in which they had to identify old objects that were shown alongside new distractor objects. The experiment showed a significant improvement in both reaction time and recognition memory performance for objects previously presented with a predictable reward. There was also a significant interaction between predictability and reward: Objects in the predictable, rewarded trials were successfully remembered in a significantly shorter period of time. This interaction was also seen when examining accuracy, as well as a significant main effect of reward. This supports the idea that more predictable rewards have a stronger positive effect on cognitive factors such as memory and reaction time when compared to unpredictable rewards.

Due to the individual nature of motivation, it is important to make sure extrinsic motivational manipulation is working as intended. This research informs how an extrinsic motivator should be delivered to ensure that it is as motivating as possible.

There is evidence supporting the idea that extrinsic motivation plays a key role in memory performance, however, it is unclear how exactly the timing of the reward interacts with the encoding and retrieval processes when it comes to assessing memory performance. Some studies involve introducing the motivator to the participants from the very start, in which it would affect the encoding process as well as the retrieval process (Bialleck et al., 2011; Bowen

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et al., 2020; Shigemune et al., 2010). Other studies, however, involve a design in which the participants are not told about the motivator, or perhaps even the memory test at all, until it is time to retrieve the information they encoded previously (Dehn et al., 2020; Locke & Braver, 2008; Murayama & Kitagami, 2014; Sharot & Yonelinas, 2008). In these designs, the effects of motivation are seen only on retrieval. There has not been a study that examined how this key difference in motivation's effect on encoding and retrieval affects memory performance.

This study will seek to answer the question: does reward motivation influence memory performance primarily because of effects on the encoding process or the retrieval process? An improvement in memory purely due to the presence of an extrinsic reward is expected (Bialleck et al., 2011; Bowen et al., 2020; Dehn et al., 2020; Locke & Braver, 2008; Murayama & Kitagami, 2014; Sharot & Yonelinas, 2008; Shigemune et al., 2010). It is unclear whether there is an isolated motivational effect on encoding, as participants cannot be made aware of a reward during encoding then subsequently made unaware of the reward for retrieval, requiring a creative experimental design. This experiment seeks to isolate those effects and compare the magnitude of memory improvement attributable to motivated encoding versus motivated retrieval. Due to the prevalence of literature supporting the strong positive effect of extrinsic reward on retrieval alone, it is expected that the primary motivational boost in memory performance is because of motivated retrieval more so than motivated encoding (Dehn et al., 2020; Locke & Braver, 2008; Murayama & Kitagami, 2014; Sharot & Yonelinas, 2008). Some level of memory improvement purely on the basis of motivational factors improving encoding is expected, although is predicted to be weaker than the improvement from motivated retrieval.

Methods

Participants

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Thirty-eight participants (27 female, 11 male) were recruited from undergraduate general psychology and developmental psychology classes from a small university in the eastern United States. Participants were required by their instructor to participate in an experimental study, and received credit in their general/developmental psychology class for their participation.

Convenience sampling was used to recruit participants ages 18+ without any targeting of race or gender. The median age was 19 ($M = 20.68$, $SD = 7.23$) and the population was predominantly white (58%). Participants were screened for brain or head trauma within the past six months, as well as current medical conditions that may impair memory. These were used as exclusionary criteria. All research protocol was approved by the university IRB.

Measures

Memory Test. The measure of memory performance was a recognition memory test. Participants underwent a learning/encoding phase, in which 30 words such as ball, mountain, spoon, etc., were flashed one at a time on a computer screen for 1.5 seconds each in random order. Following this was a letter-number sequencing filler task in which participants needed to recite back letters and numbers in the appropriate sequence. Following the filler task was a memory assessment (retrieval phase), in which 60 words were shown on screen one at a time, and the participant pressed a button on the keyboard to identify the word as either old (part of the previous learning phase) or new (not part of the previous learning phase). The word order was randomized. Thirty of the words were previously learned words, and the other 30 were new distractor words such as dinner, star, child, etc. A measure of the percent of words correctly identified was the data point taken from this. A correctly identified word could be an old word correctly identified as old, or a distractor word correctly identified as new. Additionally, the

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percentage of old words correctly remembered without taking the distractor words into account was examined.

Demographics Questionnaire. After the memory test, participants completed a questionnaire in order to acquire demographic information. This questionnaire included age, gender, race/ethnicity, mother's level of education used as a measure of socioeconomic status (socioeconomic status is shown to be linked to cognitive performance; Greenfield & Moorman, 2019), first generation college status, and current college GPA.

Manipulation Check. At the end of the demographic questionnaire there was a single question manipulation check. It asked the participants to rate how motivated they felt to perform well on the memory test on a scale from 1 (not motivated) to 7 (extremely motivated).

Procedures

This study used a between-subjects design with three experimental conditions (control [C], reward before encoding [RBE], and reward before retrieval [RBR]). Participants signed up for one experimental time slot which took approximately 20 minutes. Each time slot had a randomly predetermined experimental condition which the participants did not know about when signing up. Participants were tested at the university's psychology research lab, a small room with four computers, in groups of one to two participants.

Encoding. Upon entry to the lab, participants filled out an informed consent form and a brain/head trauma screening form. Following completion of these forms they moved to the computer to begin the testing. Participants saw a message instructing them that they would be shown words to memorize and that they would be tested on them later. Participants in the RBE condition saw an additional message on the computer and had a lottery ticket placed directly in front of them. The additional message told them that if they answered 60% of the questions

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correctly on the subsequent memory test, then they would receive the lottery ticket. This was intended to add an extrinsic motivational component to both the learning/encoding process, as well as the testing/retrieval process in the RBE group. Participants completed the encoding phase as described in the measures section. Thirty words were flashed on screen one at a time in random order for 1.5 seconds each.

Retrieval. Following the encoding phase, participants received another on-screen message telling them to raise their hand and wait for the experimenter. This message also informed them that they would complete a letter-number sequencing task administered by the experimenter, followed by a memory test. Those in the RBR condition also received an additional message exactly like the one received by the RBE condition before encoding, and had a lottery ticket placed in front of each of them after the filler task. This was intended to add an extrinsic motivational component to only the testing/retrieval process for the RBR group. Participants completed the letter-number sequencing task administered by the experimenter, then followed the on-screen instructions to complete the testing/retrieval phase as described in the measures section. Sixty words, 30 old and 30 new, were displayed on-screen in random order one at a time, and the participants used the keyboard to identify each word as either old or new. After the testing phase, participants saw a message with their score in the form of a percentage correct. They were then given the lottery ticket if they were in either the RBE or RBR conditions and scored high enough. Following this, participants completed a pencil and paper demographics questionnaire with the added manipulation check described above.

Results

Data Analysis

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First, a chi-square analysis was used to identify any differences in group demographics. Afterwards, several one-way ANOVAs were run to examine group differences in GPA, motivation, and memory performance. Furthermore, independent samples *t*-tests were used to compare motivation levels in the control group to the two reward groups, as well as assess any differences in motivation between genders. Finally, a Pearson correlation was used to examine any possible relationship between motivation levels and memory performance.

Demographics

A chi-square analysis revealed no significant difference in race, $\chi^2(12, N = 38) = 12.01, p = 0.45$, gender, $\chi^2(2, N = 38) = 3.35, p = 0.19$, age, $\chi^2(12, N = 38) = 13.68, p = 0.32$, first-generation college status, $\chi^2(2, N = 38) = 0.11, p = 0.95$, or mother's level of education used as a measure of socioeconomic status, $\chi^2(14, N = 38) = 6.11, p = 0.96$, between the experimental conditions. Additionally, a one-way ANOVA revealed no significant difference in GPA between experimental conditions, $F(2, 35) = 0.45, p = 0.64$. See Table 1 for a summary of descriptive statistics broken down by condition.

Motivation

A one-way ANOVA revealed no significant difference in motivation between the control group ($M = 4.73, SD = 1.56$), RBE group ($M = 5.54, SD = 1.39$), and RBR group ($M = 5.21, SD = 1.05$), $F(2, 35) = 1.12, p = 0.34$ (see Figure 2). Additionally, an independent samples *t*-test revealed no significant difference in motivation between the control group ($M = 4.73, SD = 1.56$) and rewarded groups ($M = 5.37, SD = 1.21$), $t(36) = 1.37, p = 0.18$. Finally, an independent samples *t*-test revealed no significant difference in motivation between females ($M = 5.33, SD = 1.11$) and males ($M = 4.82, SD = 1.78$), $t(36) = 1.08, p = 0.27$.

Memory Scores

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A one-way ANOVA revealed no significant difference in overall memory score between experimental conditions, $F(2,35) = 1.53, p = 0.23$. Additionally, a one-way ANOVA revealed no significant difference in the percentage of old words successfully remembered between experimental conditions, $F(2,35) = 0.01, p = 0.99$ (see Figure 3). A Pearson's Correlation also revealed no relationship between motivation and overall memory score, $r(36) = 0.16, p = 0.34$, or between motivation and the percentage of old words correctly remembered, $r(36) = 0.11, p = 0.52$.

Discussion

The lack of a significant difference in memory scores between experimental conditions made it impossible to run the intended calculations to isolate the effects of motivation on encoding and retrieval. The lack of significance was surprising and inconsistent with prior literature (Bowen et al., 2020; Dehn et al., 2020; Landsiedel & Williams, 2019; Locke & Braver, 2008; Millis, 1994; Murayama & Kitagami, 2014; Saucet & Villeval, 2019; Tolman, 1948). The failed manipulation check seems to highlight the most likely reason for this. While the mean levels of motivation were consistent with predictions, the lack of significance makes it difficult to claim that the reward conditions were sufficiently motivated. It is possible that the measure of motivation was simply underpowered due to the small sample size, however, even if more participants were run and the manipulation check reached a level of significance, it is still possible that no effect on memory would be witnessed. The reason for this is because, as Shigemune et al. (2010) demonstrated, the improvement in memory scales with how rewarding the extrinsic motivator is, and the lottery ticket was likely not motivating enough. This study provides strong further support for Shigemune et al. (2010), highlighting the necessity of properly motivating rewards to actually witness an effect on memory performance.

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There is also a possibility that the placement of the lottery ticket directly in front of the participant served to sabotage the rewarding effects of it. The salience of the reward throughout the memory test portion could have triggered test anxiety due to it causing more of a hot, emotion-filled cognitive response. In other words, the presence of the reward may have made it difficult to focus and think logically due to the emotional charge behind the possibility of receiving a reward.

One final possible confound within the demographics of the participants could be GPA. There was not a significant difference between groups, however, the mean GPA of the control group was higher than the other two experimental groups. It is possible that this measure was underpowered and may be the primary reason for the higher-than-expected control group memory performance.

Future Research and Limitations

This study offers an experimental design that should be replicated. The results were not significant, yet were far from conclusive due to the failed manipulation check. It is still unclear how motivation interacts with encoding and retrieval individually. This study serves to highlight the importance of reward choice in motivation studies; subsequent studies should carefully consider their choice of reward. It can be difficult to predict what will be most motivating for participants due to individual differences in motivation, so anything that can be done to maximize the rewarding value of the motivator should be used. This study was limited by funding but, if available, future researchers should use more highly rewarding monetary motivators such as cash for every single question answered correctly. Additionally, a larger sample size would strengthen the study as there would be no question of underpowered

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measures. Further, a more diverse sample with an even balance of gender and a wider age range would be beneficial.

Future research exploring the relationship between memory performance and GPA as a measure of school performance could also be instructive. Additionally, research into how motivation interacts with these two factors could yield potential applications for motivational strategies to boost memory.

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Appendix

Figure 1

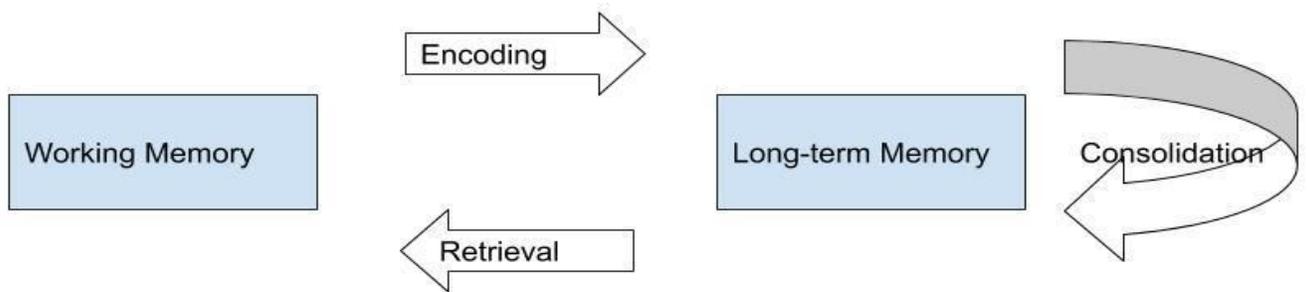
Model of Information Processing

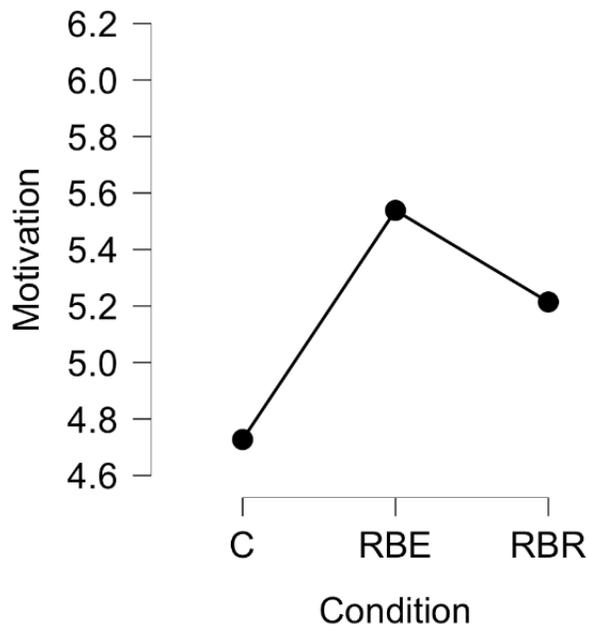
Table 1

Descriptive Statistics

	Age			GPA			Motivation			PercentCorrectOld(z)			OverallPercentCorrect		
	C	RBE	RBR	C	RBE	RBR	C	RBE	RBR	C	RBE	RBR	C	RBE	RBR
Valid	11	13	14	10	13	13	11	13	14	11	13	14	11	13	14
Missing	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
Mean	20.455	22.692	19.000	3.713	3.543	3.678	4.727	5.538	5.214	0.742	0.738	0.736	0.795	0.765	0.717
Std. Deviation	2.505	12.134	1.038	0.330	0.588	0.413	1.555	1.391	1.051	0.170	0.143	0.148	0.120	0.120	0.105
Minimum	18.000	18.000	18.000	3.110	2.000	2.500	2.000	3.000	3.000	0.367	0.433	0.433	0.600	0.550	0.550
Maximum	27.000	63.000	22.000	4.000	4.000	4.000	6.000	7.000	7.000	0.933	0.967	0.933	0.917	0.933	0.900

Note. Descriptive statistics separated by the three experimental conditions: control (C), reward before encoding (RBE), and reward before retrieval (RBR)

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Figure 2*Motivation by Condition***Figure 3***Percentage of Old Words Correctly Remembered by Condition*