Play for Performance:
Using Computer Word Games to Improve Test-Taking Performance

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Abstract
The prevalence of high-stakes testing has increased substantially over the past decade. These tests, such as the SAT, ACT, GRE, and GMAT strive to measure an individual’s cognitive ability. Building off of the “serious gaming” literature, we developed a Web-based computer word game designed to “prime” individuals for high achievement on a cognitive ability test. Priming is the use of stimuli to activate internal representations in an attempt to influence subsequent behavior. Our results show that individuals who were administered cognitive ability tests immediately after playing an achievement-oriented computer game significantly outperformed individuals who played a neutral computer game designed to have no effect. The effect size was moderate (0.63) or visible to the naked eye.

1. Introduction
Computers are ubiquitous in today’s learning environments [38]. Research continues to examine the most prudent ways to incorporate computers into comprehensive learning [20]. Much of this research has focused on using computer games as a way to engage students in learning [41]. Current research has highlighted cognitive benefits from playing computer games, including an increased ability to mentally rotate objects and improved spatial reasoning [12, 40].

Increasingly, serious games are being used as a conduit for learning [41]. Serious games are games used for purposes other than pure entertainment [41]. Among other benefits, these games enable educators to provide a learning environment wherein students are able to experience situations that were previously impractical due to cost, time, or safety. However, much of the research on serious games has focused on facilitating learning outcomes [2, 22], not enhancing test-taking performance. With the increased use of high-stakes testing in academia [26], it is as important as ever to investigate ways of improving cognition so that each student can perform at his or her best.

Our study used a serious computer word game designed to “prime” the individual with the concept of achievement in order to improve test-taking performance. Individual test-taking behavior is affected by motivation [15]. Motivational theories contend that motivation is a function of the importance of a goal and the expectation of attaining it [15]. Priming involves the activation of mental representations to affect an individual’s subsequent mood, attitudes, or behavior [5]. In this study, we focus on priming the concept of “achievement,” which has been hypothesized to improve the performance of individuals by increasing an individual’s, nonconscious expectation of success thereby increasing motivation [6]. Though there is evidence that priming can influence individual behavior, we are aware of no studies that delivered priming via a computer game in an attempt to improve test-taking performance.

In this study, we hypothesize that achievement oriented priming delivered through a computer game will enhance test-taking performance. A key point that differentiates this study from previous studies related to use of serious games in education is the purpose for which the computer game is used. The achievement priming based computer game nonconsciously increases an individual’s motivation to “achieve,” which drives individual performance on subsequent tests. While the subject is aware of the game, he or she is unaware of the activation of a goal to “achieve.”

The results of our study show that individuals playing an computer word game that delivered achievement priming performed significantly better on a cognitive ability test than individuals playing a a version of the computer game designed to have no effect. The Cohen’s $d$ effect size was 0.63, indicating a “moderate” effect that Cohen describes as non-trivial [14]. This effect would translate to a 50 to 60 point improvement on composite SAT score [1].
2. Prior theory

2.1. Test-taking

Individual performance on aptitude tests has been a topic of interest for many researchers in the education and psychology domain, especially following the implementation of No Child Left Behind and increased use of high-stakes testing [26]. Test-taking performance has been widely accepted as a joint function of motivation and cognitive ability [10]. Previous research has identified various factors that affect performance on cognitive ability tests like the SAT [10, 31]. Factors such as coaching for the test, motivation prior to the test, and positive perceptions about the test have all been found to have a positive influence on student performance on the SAT [10, 31]. Researchers have also focused on understanding the motivational factors that lead to students performing better in cognitive ability tests [3, 33]. Motivation and attitude of test-takers has been found to greatly influence test-taking performance. This makes understanding the factors that stimulate these dispositions crucial to improving subsequent performance [3].

Individual motivation towards an activity is a function of the individual’s perception of the importance of that activity and the expectancy of success [43]. If one can positively influence either the perception of importance or expectancy of success, motivation will increase [43]. In many cases, students understand the importance of high stakes testing. What is less uniform is students’ expectancy of success. Not every student expects to do well. Our goal is to influence students’ mindsets so that they have a greater expectancy of success.

Research has also focused on understanding post-hoc reactions of test-takers to aptitude tests, measuring perceptions about the ease of the test, their motivation level during the test, and the degree of concentration while taking it [3, 9]. While these are examples of research focused on understanding the post-test perceptions and their influence on test scores, there is limited research on understanding if performing various activities or tasks immediately prior to taking a test can influence perceptions or performance on that test.

2.2. Computer games

Recent research has identified computer-based serious gaming as an enhancer of educational learning, motivation level, knowledge retention, and performance on cognitive ability tests [18, 19, 32, 33]. The term ‘serious games’ became popular in 2002 when it was first used by the Serious Games Initiative to establish a connection between the computer gaming industry and the educational gaming community [41]. Since then, serious computer gaming has been incorporated in various areas such as public policy, health sciences, education, and strategic communication [41].

Computer-based gaming has been defined as a “rule-governed, goal-focused, microcomputer driven activity incorporating principles of gaming and computer assisted instruction” [16]. Such games have also been found to improve collaboration, problem solving and decision-making skills of people. While these games have been known to enhance knowledge acquisition and retention, a major focus of recent research has been on the motivational influence of computer games [19]. Three key attributes of the computer games have been found to be directly related to the motivational appeal of the game: novelty, competition, and dynamic interaction [30, 31]. These three attributes can not only enhance the learning and learning attitude of the participants, but can also improve their attention towards the test [31].

Research in cognitive psychology suggests that if these computer games are based on learning and instructional theories, they can improve the test-taking performance [30]. Such serious games can not only improve the motivation levels of students for taking a test but can also improve their cognitive abilities, which result in better test performance [12, 40]. In this paper, we implement a serious computer game that incorporates features capable of stimulating the cognitive abilities of those playing it. The next few paragraphs describe the theoretical background for priming, which is the underlying psychological mechanism utilized in the computer game in this study.

2.3. Priming and individual cognition

Priming is the activation of internal mental representations in order to influence subsequent behavior [5]. Research in psychology has documented the ability to influence individual behavior through priming [4, 5]. The priming literature has consistently shown that influencing human behavior, attitudes, or beliefs is possible by activating the mental representations underlying the desired behavior, attitudes or beliefs [7, 17, 36]. Once an individual’s mental representations have been activated, the subsequent behavior of the individual is affected. Much of the research on cognitive ability testing has focused on the activation of mental representations of stereotypes or anxiety that serve to encumber test-taking performance of individuals [39]. However, no
research has examined if test-taking performance can be positively influenced by activating mental representations related to achievement.

Initially referred to as “perceptual readiness,” the term priming was later coined by Segal and Cofer (1960) in reference to a phenomenon where participants exposed to words in one task were more likely to use those words in subsequent tasks [13]. In other studies, priming was used to activate mental representations in attempts to influence future individual behavior [5].

Researchers generally deliver primes in one of two ways: subliminal (“below threshold”) and supraliminal (“above threshold”). Subliminal priming involves brief presentation of a stimulus followed by a perceptual mask [5]. In subliminal priming the stimulus is presented quickly and the participant is not consciously aware of that stimulus. In contrast, in supraliminal priming, the participant is consciously aware of the stimulus, but the participant is not aware of the intent behind it. Subliminal and supraliminal priming share a common theme: the participant is unaware that the stimulus is activating internal mental representations [5]. In this study, we use a computer word game to deliver a supraliminal prime to participants.

Semantic priming, priming delivered using words, is one of the many ways individuals can be primed. It is believed to work by activating semantic networks within the brain [34]. The brain is organized into networks based on the associations one makes during prior experiences [28]. These experiences begin to form semantic networks, which develop as we begin to interact with the world and form a basis of memory that is interconnected with our previous associations of core objects, concepts, or beliefs [29]. Previous research established differential neural activation between semantically associated and semantically unrelated stimuli [24]. Later research found that the association between words was more important in activating mental representations than the word itself [27]. The use of priming consequently spread into social psychology when researchers illustrated the ability to prime concepts and categories, not just individual words [21]. In addition, research illustrated that it is possible to influence motivation associated with individual performance on a task [4, 6].

In recent experiments, researchers have found that goals can be triggered outside of awareness and run to completion [6]. In one such experiment, researchers used a word search puzzle to prime the concept of achievement [6]. In this study, individuals received either priming semantically related to achievement (i.e. – compete, win, succeed) or neutral words (i.e. – ranch, carpet, shampoo). Investigators found that the individuals primed with “achievement” performed better in subsequent tasks than individuals exposed to the neutral prime [6]. The investigators believed that the prime activated an automatic goal pursuit of achievement, which led to high performance on the subsequent tasks [6].

The longevity of the priming effect has been shown to be influenced by the length of time a participant is exposed to the priming stimuli [5]. Early work on priming showed that the longer a person was exposed to a prime, the longer the priming effect would last [5]. One study varied the number of primes participants were exposed to in a Scrambled Sentence Task [37]. The research found that the more total primes an individual is exposed to resulted in a greater observed priming effect [37]. In goal activation priming, an individual’s goal activation can decay if goal pursuit is not activated shortly after the prime [5]. However, studies have shown that individuals pursuing goals following exposure to a prime often will pursue the goals to completion [6]. Typical priming experiments prime for 5 minutes which produces a priming effect that lasts approximately 30 minutes [6].

We believe that it is possible to use achievement priming to change a student’s mindset prior to taking a test. By subconsciously inducing an achievement mindset, students will have a greater subconscious expectancy of success and therefore greater motivation to perform [4, 6, 39]. This increased motivation will lead to better performance on the test [3, 30], even if students are not consciously aware of the effect.

2.4. Our game

Our computer game utilized an achievement prime designed to improve performance on subsequent tasks [6]. We used a Scrambled Sentence Test, in which participants develop a four word newspaper headline from a set of five words [37]. The Scrambled Sentence Test is a priming technique that has been used extensively over the last decade to deliver semantic priming [4, 11, 35]. This approach to priming is believed to work by activating semantic networks within the brain that are related to the concept being primed [34]. Specifically, the prime is believed to activate motivation towards individual performance in pursuit of achievement [6]. However, no study has examined whether priming can be used to improve performance in cognitive ability testing.

A screenshot of the computer word game is provided in Figure 1. The computer game presented a set of five words, from which a participant could choose four words to create a newspaper headline. As seen in the screenshot, each of the five words presented on the screen had a “Select” button to the left. The “Select” buttons were oriented next to the words, in
order to create engagement between the participant and the list of words. After thinking about the formation of a four word sentence from the list of five words, the participant selected four words using the select button. If the participant was not satisfied with the selection, he or she could cancel the selection using the “Clear Selection” button and think about the four word sentence formation again. After a participant was satisfied with his or her choice of four words, he or she clicked a submit button and a new set of five words was presented.

In our game, points were assigned to each of the words and participants attempted to maximize their point score. The words designed to induce priming were assigned the most points to encourage participants to focus on them.

The words in the game were also assessed using the Affective Norms of English Words (ANEW) database [8]. The ANEW database contains thousands of words that have been rated on arousal and valence. Arousal describes the level of an individual’s emotional activation, varying from calm to aroused [25]. Valence describes the amount of individual attraction towards an object, ranging from attraction and pleasure to aversion and displeasure [25]. In the ANEW database, arousal is rated on a scale from 1 (low arousal) to 9 (high arousal). Similarly, valence is rated from 1 (negative) to 9 (positive). For the achievement oriented priming computer game, we would ideally want words that are high in arousal and have a positive valence. For the neutral computer game, we would ideally want words that are moderate in both arousal and valence. The achievement oriented computer game words had high arousal (M = 5.73, S.D. = 0.98) and positive valence scores (M = 7.22, S.D. = 0.93). The neutral computer game, words were moderate in arousal (M = 4.44, S.D. = 0.75) and moderate in valence (M = 4.89, S.D. = 0.59). There were significant differences between the sets of words for both arousal (t(248) = 13.19, p < .001) and valence (t(298) = 25.74, p < .001).

Most high-stakes testing attempt to assess a student’s cognitive ability on both verbal and quantitative reasoning. Verbal reasoning in high-stakes testing often examines an individual’s vocabulary, grammar, and reading comprehension, while quantitative reasoning assesses an individual’s basic arithmetic, algebra, and geometry [1]. We do not expect there to be a differential effect of the game on verbal or quantitative achievement because increasing the expectation of success should affect both parts equally.

It is hypothesized that playing a computer word game designed to prime the concept of achievement prior to taking a cognitive ability test will increase test-taking performance. We hypothesize test-taking performance will be improved on both verbal and quantitative testing. Therefore,

H1a: Playing a computer word game delivering achievement oriented priming will increase performance on a subsequent verbal cognitive ability test.
H1b: Playing a computer word game delivering computer oriented priming will increase performance on a subsequent quantitative cognitive ability test.

3. Method

3.1. Participants

Sixty-one freshman and sophomores were drawn from an introductory business course and received extra credit for participating in the study. The average age of the participants was 19.4 years and 44 percent were male. 35 participants received the achievement prime, while 26 received the neutral prime.

3.2. Task

The participants worked on a cognitive ability test. The questions on the test were drawn from a set of practice SAT tests. The questions were a mix of both quantitative and verbal reasoning questions. There were 21 quantitative reasoning questions comprised of the topic areas: numbers and operations, geometry, algebra, and statistics and probability. There were 28 verbal reasoning questions comprised of the topic areas: sentence completion and critical reading.

3.3. Treatments

There were two treatments: the achievement oriented computer game and the neutral computer game. Participants were randomly assigned to one of the two treatments.

The achievement oriented computer game was designed to prime the concept of “achievement,” while the neutral computer game was designed to have no effect. In the achievement priming treatment, one or two words in each set of five words was an achievement-oriented word based on words used in an achievement activation priming experiment [6]. These words include win, leader, strive, aspire, scholar, genius, award, and honor. Furthermore, the neutral words were chosen to have no effect. These words include worker, break, room, leaves, bench, dirt, dwell, and table.
3.5. Measures

There were 6 measures. The first measure was performance on the quantitative reasoning test. The second measure was performance on the verbal reasoning test. Consistent with SAT scoring, participants received one point for each correct answer, zero points for skipping a question, and lost .25 points for incorrectly answering a question.

The remaining four measures came from a survey each participant filled out at the end of the session. The instrument assessed the “ease of use” and “enjoyment” of the computer game. The “ease of use” construct contained 3-items, with a Cronbach’s alpha of .72. A sample ease of use item is: “The computer game was easy to learn. The “enjoyment” construct had 4-items, with a Cronbach’s alpha of .90. A sample “enjoyment” item is: “The computer game was interesting.”

The other two measures were self-reported GPA and gender, used as controls. Self-reported GPA has been shown to be a reasonable proxy for cumulative GPA [23].

3.6. Procedures

Participants began by playing one of the priming games for eight minutes; all participants received either the achievement or neutral prime. Participants played the priming game for eight minutes or until they completed 30 sets of priming words. Approximately 80 percent of the students were still working at the end of the 8 minutes. Participants then worked on a cognitive ability test for 30 minutes. They then completed short survey collecting demographic information and reactions to the game. The participants were debriefed and the session concluded.

3.7. Analyses

All statistical analyses were completed in SPSS PASW Statistics 18.0. A repeated-measures GLM was used to examine differences between the achievement and neutral computer word games and the verbal and quantitative tests.

4. Results

4.1. Cognitive ability testing performance

A summary of the results is provided in Table 1. The omnibus hypothesis was supported. Participants exposed to the achievement prime performed significantly better than individuals exposed to the neutral prime (F(1, 57) = 5.60, p = .021). There were no differences in the effectiveness of the game on the quantitative or verbal questions (F(1, 57) = 0.09, p = .767). Hypotheses 1a and 1b were both supported; participants performed significantly better on verbal reasoning and quantitative reasoning test questions following achievement priming game compared to the neutral priming game. The effect was moderate in size with Cohen’s d = .63.

As an aside, we note that self-reported GPA was not significantly related to overall test performance (F(1, 57) = 2.64, p = .110) – although it was significant for verbal reasoning questions (t(57)=2.14, p=.037. Participants’ gender was significantly related to test performance with males scoring significantly higher than females (F(1, 57) = 4.29, p = .043).

4.2. Student perceptions

No significant differences were observed between the achievement oriented computer game and neutral computer game for ease of use (F(1, 57) = 0.05, p = .827) or enjoyment (F(1, 57) = 0.10, p = .751). As an aside we note that no significant differences due to gender were observed for ease of use (F(1,57) = 0.65, p = .425) or enjoyment (F(1, 57) = .48, p = .491).

We compared the mean ratings of the achievement priming game to the neutral value of 3.00 for both perception scales. We found that the students perceived the game to be significantly greater than neutral for ease of use (t(35) = 4.13, p < .001) and no different than neutral for enjoyment (t(35) = 1.43, p = .162).

5. Discussion

Our study provides evidence that a computer word game designed to influence the achievement of participants improves performance on subsequent cognitive ability tests. We found that individuals who played an achievement oriented computer game had significantly better quantitative and verbal reasoning performance on an SAT style test than individuals playing a neutral game designed to have no effect on performance.

The effect size is considered “moderate,” with a Cohen’s d of .63, which Cohen describes as visible to the naked eye [14]. Translating this to SAT scores, this effect would translate into an average improvement of 50 to 60 points in individual SAT scores; see [1].

We believe the achievement oriented computer game activated a nonconscious motivation towards “high-performance.” Motivation towards an activity is comprised of the individual’s belief of the importance...
of that activity multiplied by the individual’s expectancy of success [43]. We believe the game nonconsciously influenced the individual’s expectancy of success by activating networks semantically related to “achievement,” which in turn created a more achievement oriented mindset.

We believe the computer game enhanced individual performance by helping them reach individual optimal cognitive performance. The findings illustrate that serious games can influence test-taking performance of individuals and future research could elucidate the precise mechanisms through which individual performance is influenced. We believe that these results have several theoretical and practical implications.

5.1. Implications for research

The study presented in this paper theorizes the effect of priming on test performance and the results indicate a significant effect. Future research could focus on understanding the mechanism of how priming influences the test performance. While self-reported methods like surveys or interviews are commonly used in behavioral studies, it might not be appropriate to use such methods to understand the mechanism of priming since its effect is nonconscious in nature. Researchers could explore the possibility of using NeuroIS tools like EEG or fMRI, which can examine the corresponding neural activation that forms the basis of priming-induced nonconscious behavior.

This paper studies the effect of priming on SAT test specifically. Also, the results indicate a significant 50 to 60 points improvement in the test scores of participants who were subjected to achievement priming as compared to those who were subjected to neutral priming. Future research could explore the effect of such computer based priming games on tests like the GRE, GMAT and other type of standardized test. Students across the globe, whose first language is not English, have to take English ability tests like the TOEFL or IELTS if they wish to pursue their education in countries where English is the first language. Researchers can focus on understanding the effect of priming delivered through a word based computer game, such as the one used in this study, on the performance of students who take such English ability tests.

While this paper focuses on delivery of the priming base game through a computer, future research can focus on use of different game delivery mechanisms. For example, instead of using a computer-based game, a paper-based game could be used to deliver priming. This paper based game can be a replica of the computer game. This could help develop an understanding on the differences between the priming produced by a computer game as compared to a paper based game. Researchers can further explore other methods of delivering priming games, which might be more effective than a computer game based priming.

In this paper, we focused on effect of achievement priming on SAT performance as a whole. Future research could focus on understanding the effect of priming on specific sections of the SAT exam. It is possible that the achievement priming might affect the scores on one section of the SAT exam more or less than the other section. For example, the priming might improve the score on the verbal section more than the score on quantitative section. This could provide further research opportunities to understand what kind of priming affect quantitative section scores and what kind affect the verbal scores.

While this paper focuses on implementation of achievement priming delivered through a scrambled sentence computer game, future research can focus on understanding the effects of other types of priming. Instead of using achievement oriented words, researchers can explore other types of priming to see the effect on test performance. There are many ways to prime individuals. Subliminal priming, negative priming, and attentional inhibition priming could further our understanding of the nonconscious drivers of individual test performance. For example, creativity priming could be used to find out if it affects test performance or scores on certain sections of the test. Also, researchers can explore if priming using words affects performance on certain sections of the test as compared to priming using numbers or pictures.

Previous research in the education domain has focused on the aspect of how motivation before the test affects the performance on a cognitive ability test [1, 21]. This paper contributes to the literature by introducing the effect of priming on performance improvement. Future research can explore the relationship between priming and motivation. Researchers can focus on finding out if priming helps improve the underlying motivation for taking a test or performing well in it. Also, by using multiple surveys, researchers can conduct a comparative analysis of motivation levels before and after the priming tasks. Thus, motivation can be proposed as a mediator between priming and test performance.

A recent area of interest among researchers is the role of computer games to improve student learning [42]. While it is known that computer games can lead to cognitive benefits, incorporating priming tasks into these computer games could help students further improve their learning capabilities. Researchers can focus on understanding if different type of priming
delivered through a computer game help students activate certain mental representations that help them learn concepts quicker and better. Students can be asked to undertake different kinds of priming tasks before or during each tutoring session. Their learning performance during these sessions can be compared with their learning during the session when no priming was used. This will open avenues for research in the areas of accelerated learning, advanced tutoring systems and so on.

5.2. Implications for practice

The study presented in this paper shows that students can achieve a significant improvement in their test score by incorporating a computer based word game into the process of test taking. Students can use such computer based games prior to taking a cognitive ability test. While use of such games might not be a regular part of the current testing systems, an ethical way of incorporating such games into the testing structures could help students perform better. Students can also use such games when they are preparing for an upcoming test. This will not only help them raise their confidence level for the test but could also help them learn the concepts better.

The applicability of the results shown in this paper can be extended to testing structure used in educational institutions. By introducing priming into the test taking process, educational institutions can see an improved performance in the tests by their students. The 50 to 60 points improvement in the test score seen in this study is significant. With the increasing computerization of various cognitive ability tests, incorporating computer based priming into the flow of test taking activities might not be a difficult task to accomplish.

The results of this study have implications for testing and tutoring software development companies like Kaplan and Educational Testing Service. Such companies can incorporate computer based priming games into the structure of their cognitive ability tests. Similar games could also be incorporated into tutoring systems which involve tests at the completion of a certain course. With such priming games as an integral part of the testing or tutoring software, these companies can see significant improvement in the performance of the customers who use their testing or tutoring systems.

6. Conclusion

Cognitive ability test performance and the various factors affecting it has been the focus of many studies in the education literature. In this study, we investigated the effect of achievement priming, delivered through a computer based word game, on SAT test performance. The results suggest that the performance of the participants subjected to the achievement priming condition was significantly better than the performance of subjects who were subjected to neutral priming. The results of this study opens many avenues for research studies that can explore different type of priming conditions and the effect on test performance. Also, educational institutions as well as companies developing tutoring or testing software can use this study to incorporate priming into their tutoring methodology and testing structure. This might not only help improve student test performance but also help improve their learning capabilities.

7. References


Figure 1. Screenshot of the priming word game

Table 1. Means, standard deviations, and results of statistical analyses

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