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Effective mitigation of anchoring bias, projection bias, and representativeness bias from serious game-based training

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Abstract

Although human use of heuristics can result in 'fast and frugal' decision-making, those prepotent tendencies can also impair our ability to make optimal choices. Previous work had suggested such cognitive biases are resistant to mitigation training. Serious games offer a method to incorporate desirable elements into a training experience, and allow the use of mechanisms that enhance learning and retention. We developed a game to train recognition and mitigation of three forms of cognitive bias: anchoring, a tendency to be inordinately influenced by one piece of information; projection, an implicit assumption that others thinkor know what you do; and representativeness, judging the likelihood of a hypothesis by how much the available data resembles it. Participants were randomly assigned to play the training game once,twice spaced by 10 to 12 days, or a control condition that used a training video. External questionnaire-based assessments were givenimmediately post-training and 12 weekslater. Superior training was seen from the game. An independent group usingour training game with their own novel bias assessment instruments (to which the researchers and game-developers had no access or content information) validated the key finding. These results demonstrate the viability and high value of using serious computer games to train mitigation of cognitive biases.

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Keywords: Serious computer games; Training; Bias mitigation

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1. Introduction

Although decision-making using heuristics can lead humans to reach effective and efficient choices[1], cognitive biases can be considered the systematic errors that sometimes result from these heuristics [2]. To the extent that these biases reflect automatic and unconscious influences on behavior[3] they can impair optimal decision-making in ways that people do not typically notice and cannot readily overcome.The deleterious effects of cognitive biases on a wide range of tasks have been discussed within business, medical, legal, and military settings [4]. Cognitive biases have been considered highly resistant to generic training at individual level[5,6].Recently, however, we developed a serious computer game that effectively trains participants to recognize and mitigate confirmation bias, fundamental attribution error, and bias blind spot [7] from relatively short sessions of just 30 minutes this game-based training. These findings suggested that a game format offers excellent potential to train higher order cognitive skills such as biases and decision-making. The current study sought to replicate and extend these findings by examining whether other types of bias could be trained and whether even greater levels of training could be achieved.

We developed a new game to train the recognition and mitigation of three different common forms of cognitive bias. Anchoring bias isa tendency to be inordinately influenced by one piece of information (often a first piece of information encountered or initial idea). Projection bias is a tendency to hold an implicit assumption that others think, believe, or know what you do. Representativeness bias is a tendency to judge the likelihood of a hypothesis by how much the available data resembles it.

The game is a two-dimensional Flash-based game with keyboard and mouse interface. Headphones were used for the player to listen to sound effects and music audio. No voiceover was used.The game was divided into units (“challenges”). Data on player actions in the game were recorded in a custom log format. All salient and discrete events that occur during game play werecaptured.

The pedagogical structure within the game used situation-based lessons that introduced terms, definitions, patterns and mitigation strategies followed by a chance to explore, or play with ideas and then concrete applications of lessons (see Figure 1 for an example from the game). The game also used multiple testing opportunities to encourage players to recall key information and put lessons into practice. These tests occurred asboth in-game activities in the form of mini-games, and text-based quizzes presented outside the game world. The latter are based on real world scenarios to enhance transfer outside the game.The game format readily allowed the inclusion of a range of phenomena known to enhance learning. These included *spaced practice* (e.g., [8]), *testing effects* (e.g., [9]), and *generation effects*(e.g., [10]).Generally, the game followed a teach-play-apply-test structure for each bias. The primary research question concerns the extent to which the inclusion of such elements within a game context can improve training beyond that achieved with more typical instructional materials.

Instruction that accelerates learning sometimes creates a trade-off between benefits on immediate performance at the end of acquisition versus learning indexed from the retention of knowledge [11]. Knowledge and mitigation of the biases were therefore examined both immediately after training and at 12 weeks after training (with no refresher training between acquisition and retention). Our independent variable manipulated a spaced repetition of game play in contrast to a single encounter. Such a repetition, especially when spaced by 10%-20% of the required retention interval [12], has been shown to enhance retention with other types of material.

2. Methods

2.1. Participants

College students from three universities were recruited to participate in a “multimedia research study” (intentionally incorporating no mention of video games), using psychology research pools at two universities, and through announcements in communication classes at all three universities. Three hundred and ninety eight participated in training and completed the initial bias assessment instrument before and after training. One hundred and ninety one participants (48% of the original sample) completed the retention survey.

Fig. 1. Example of a Representativeness Bias challenge within the game. Participants must learn to recognize the bias in operation and apply the correct mitigation strategy to succeed within a challenge.

2.2. Design

Participants were randomly allocated to one of 3 conditions: *Single* play of the game, *Repeat* play of the game (with two game play sessions spaced by 10-12 days), or the control *Video* condition. To assess whether the game was able to train recognition and mitigation of the biases and whether those effects would be enhanced (particularly at a retention interval) by spaced repeat play of the game, participants in the game play conditions played the game either once or twice (see below). To determine the efficacy of the training within the game, a control condition with a training video was used. The training video supplied to us had been written with input from subject matter experts, was professionally acted and produced, and provided the same core information as the video game with regard to the definitions and general bias mitigation strategies. The video provided a series of vignettes in which people exhibited cognitive biases. Those scenarios were then dissected by a "professor" who explained the interaction, the causes of bias and the ways to mitigate the bias. The video employed humor and real-world relevant examples to maintain interest and engagement.

2.3. Procedure

Participants were scheduled to come to a campus computer lab for 3 hours. After filling out a consent form, they answered a 60-minute questionnaire on the computer presented using Qualtrics, and then played the game or watched the 30-minute video. Participants in the single play condition played an average of 60 (sd = 8.1) minutes; in the repeat condition, they played for 57 (sd = 10.1) minutes on the first play, and 58.9 (sd = 8.9) minutes on their second play. Immediately after completing the single game and video conditions, participants answered a 45-minute post-session questionnaire. Because lab sessions were limited to 3 hours, participants who took more than 75 minutes to play the game were stopped and asked to proceed to the post-session survey. These participants were retained in the dataset. Participants randomly assigned to the repeat game play condition did not take the post-session survey immediately after their first play sessions. They instead returned 10-12 days later, played the game a second time, and then took the post-session survey. Twelve weeks after they took the immediate post-session survey all participants were emailed a link to take a follow-up retention survey.

2.4. Measures

Bias knowledge and mitigation was assessed outside of the game using questionnaire-based items designed to test declarative knowledge, and also items to elicit the biases. Three matched forms of a bias instrument were constructed through the collaboration of a team of researchers (with each form only seen once by each participants and the order counterbalanced across test phases between participants). A range of items for each bias was developed to capture the facets of biases seen in the existing literature. For anchoring, items included numeric anchoring with external and internally generated anchors that were both relevant and irrelevant/implausible to the item being estimated (see, for example, [13]), and focalism items[14]. For projection bias items were created for both attributive similarity [15]and false consensus[16]. For representativeness bias items examined conjunction [17], randomness and gambler's fallacy[2], base rate neglect[18], and sample size [19].

Items were converted to scores ranging from 0 (completely biased) to 1 (completely unbiased). Reliabilities for each subscale were low for anchoring (pretest =.37, posttest =.44); but larger for projection (pretest =.62, posttest=.91) and representativeness (pretest =.70, posttest = .83).

Recognition and discrimination were multiple-choice questions, with items testing the extent to which participants knew definitions of the biases and could determine within a scenario or vignette which bias was in operation.

3. Results

3.1. Anchoring bias – immediate post-test

Performance on anchoring bias(see Figure 2, panel A) showed evidence of training from a pre-test vs. post-test main effect (F(1,395)=155.58, p<.05), but no interaction of condition and training (F(2,395)=2.33, p=.10), and no main effect of condition (F(2,395)<1). Evidence of training was apparent for the single game (t(149)=6.52, p<.05, d=0.53), repeat game (t(105)=7.37, p<.05, d=0.72), and the video control condition (t(141)=7.44, p<.05, d=0.62).Planned comparisons showed that the repeat game did not significantly outperform the control video on the immediate test (t(395)=1.63, p=.10), but repetition of the game did improve performance over a single play session (t(395)=2.18, p<.05).

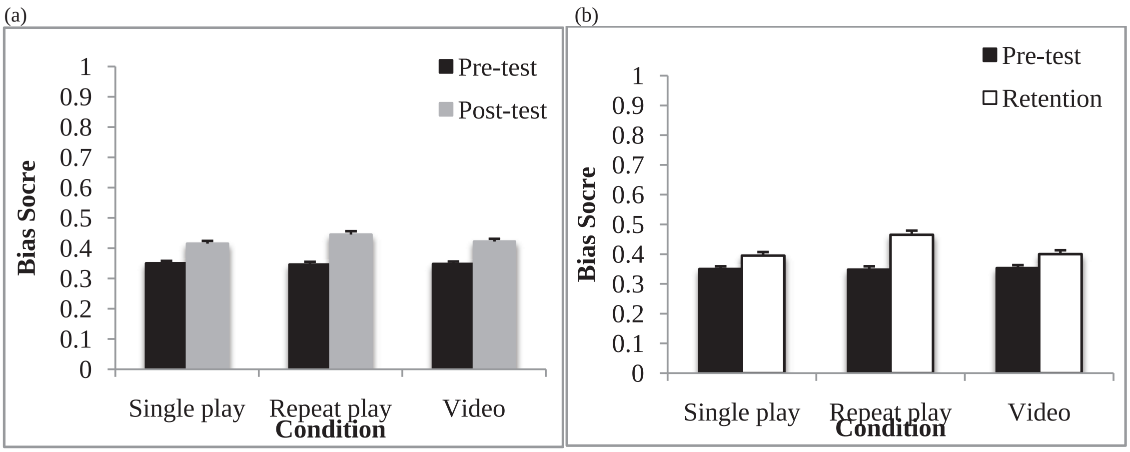

Fig. 2. Anchoring Bias Mitigation by Condition: (a) Pre-test and Immediate Post-test. (b) Pre-test and Retention test. (Error bars show S.E.)

3.2. Anchoring bias – retention test

Performance on anchoring bias (see Figure 2, panel B) showed evidence of retention of training from a pre-test vs. retention main effect (F(1,288)=60.20, p<.05), an interaction of condition and training (F(2,288)=6.39, p<.05), and a main effect of condition (F(2,288)=4.53, p<.05). Evidence of retention of training was apparent for the single game (t(110)=3.48, p<.05, d=0.33),repeat game (t(82)=6.58, p<.05, d=0.72),and the video control condition (t(96)=2.90, p<.05, d=0.29).Planned comparisons showed that the repeat game significantly outperformed the control video on the retention test (t(288)=3.43, p<.05), and repetition of the game did improve performance at retention over a single play session (t(288)=3.80, p<.05).

3.3. Projection bias – immediate post-test

Performance on projection bias (see Figure 3, panel A) showed evidence of training from a pre-test vs. post-test main effect (F(1,395)=979.85, p<.05), a significant interaction of condition and training (F(2,395)=165.78, p<.05), and a main effect of condition (F(2,395)=112.70, p<.05). Evidence of training was apparent for the single game (t(149)=23.24, p<.05, d=1.90),repeat game (t(105)=21.49, p<.05, d=2.09),and the video control condition (t(141)=5.09, p<.05, d=0.43).Planned comparisons showed that the repeat game significantly outperformed the control video on the immediate test (t(395)=16.83, p,.05), but repetition of the game did not improve performance over a single play session (t(395)=1.74, p=.08).

3.4. Projection bias – retention test

Performance on projection bias (see Figure 3, panel B) showed evidence of retention of training from a pre-test vs. retention main effect (F(1,288)=279.60, p<.05), an interaction of condition and training (F(2,288)=61.77, p<.05), and a main effect of condition (F(2,288)=44.67, p<.05). Evidence of retention of training was apparent for the single game (t(110)=9.86, p<.05, d=0.94),and repeat game (t(82)=15.21, p<.05, d=1.67), but not for the video control condition (t(96)=1.65, p>.05, d=0.17).Planned comparisons showed that the repeat game significantly outperformed the control video on the retention test (t(288)=11.91, p<.05), and repetition of the game did improve performance at retention over a single play session (t(288)=5.69, p<.05).

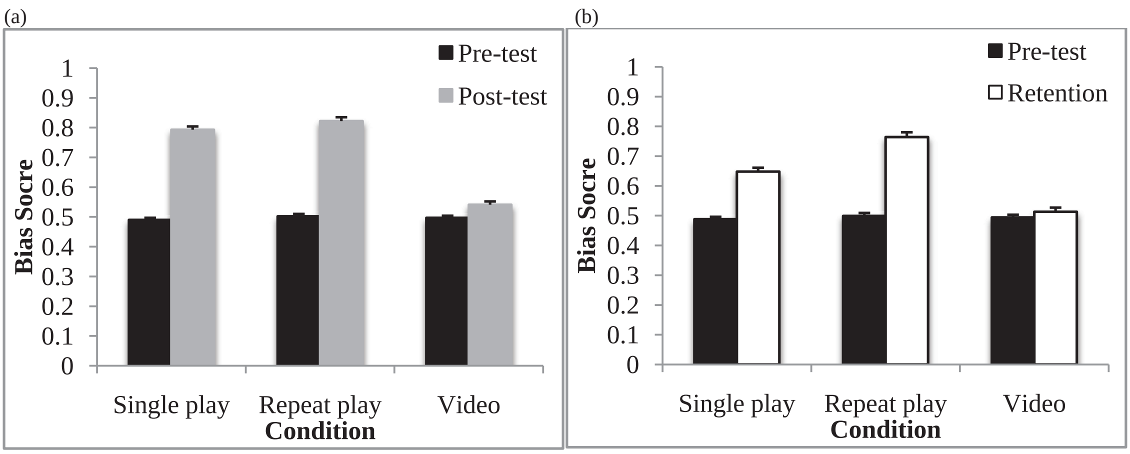

Fig. 3. Projection Bias Mitigation by Condition: (a) Pre-test and Immediate Post-test. (b) Pre-test and Retention test. (Error bars show S.E.)

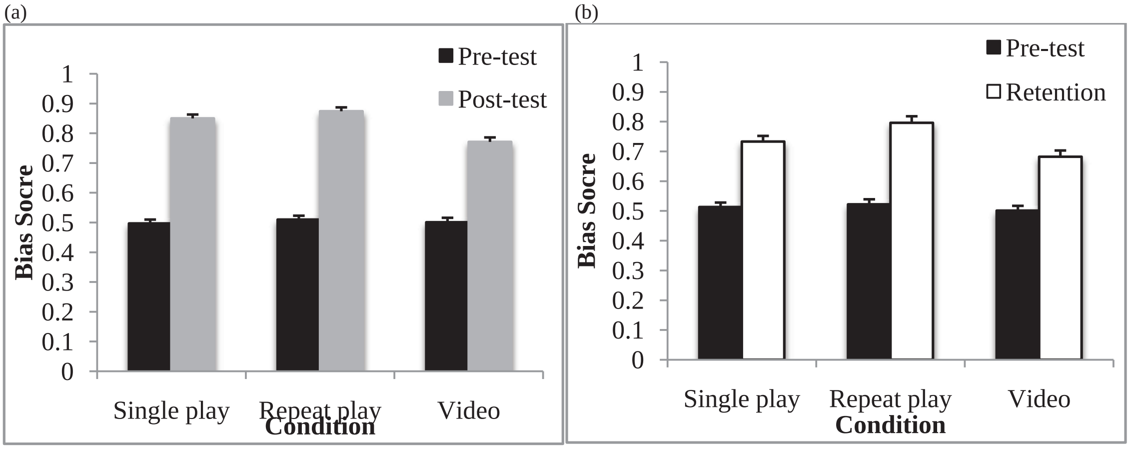

Fig. 4. Representativeness Bias Mitigation by Condition: (a) Pre-test and Immediate Post-test. (b) Pre-test and Retention test. (Error bars show S.E.)

3.5. Representativeness bias – immediate post-test

Performance on representativeness bias (see Figure 4, panel A) showed evidence of training from a pre-test vs. post-test main effect (F(1,395)=1600.77, p<.05), a significant interaction of condition and training (F(2,395)=13.42, p<.05), and a main effect of condition (F(2,395)=5.95, p<.05). Evidence of training was apparent for the single game (t(149)=26.69,p,<.05, d=2.18),repeat game (t(105)=23.40, p<.05, d=2.27), and the video control condition (t(141)=19.65, p<.05, d=1.65).Planned comparisons showed that the repeat game did significantly outperform the control video on the immediate test (t(395)=5.17, p<.05), but repetition of the game did not improve performance over a single play session (t(395)=1.22, p>.05).

3.6. Representativeness bias – retention test

Performance on representativeness bias (see Figure 4, panel B) showed evidence of retention of training from a pre-test vs. retention main effect (F(1,288)=410.04, p<.05), an interaction of condition and training (F(2,288)=5.51, p<.05), and a main effect of condition (F(2,288)=4.12, p<.05). Evidence of retention of training was apparent for the single game (t(110)=12.0, p<.05, d=1.14), repeat game (t(82)=14.70, p<.05, d=1.61), and the video control condition (t(96)=9.04, p<.05, d=0.92). Planned comparisons showed that the repeat game significantly outperformed the control video on the retention test (t(288)=3.72, p<.05), and repetition of the game did improve performance at retention over a single play session (t(288)=2.17, p<.05).

3.7. Bias recognition and discrimination – Immediate Post-test

Performance on recognition of the biases and discrimination between the biases(see Figure 5, panel A) showed evidence of training from a pre-test vs. post-test main effect (F(1,395)=1464.76, p<.05), a significant interaction of condition and training (F(2,395)=3.74, p<.05), and a main effect of condition (F(2,395)=3.19, p<.05). Evidence of training was apparent for the single game (t(149)=22.25,p<.05, d=1.82),repeat game (t(105)=22.41, p<.05, d=2.18), and the video control condition (t(141)=21.94, p<.05, d=1.84).Planned comparisons showed that the repeat game significantly outperformed the control video on the retention test (t(395)=2.79, p<.05), and repetition of the game did improve performance at retention over a single play session (t(395)=2.93, p<.05).

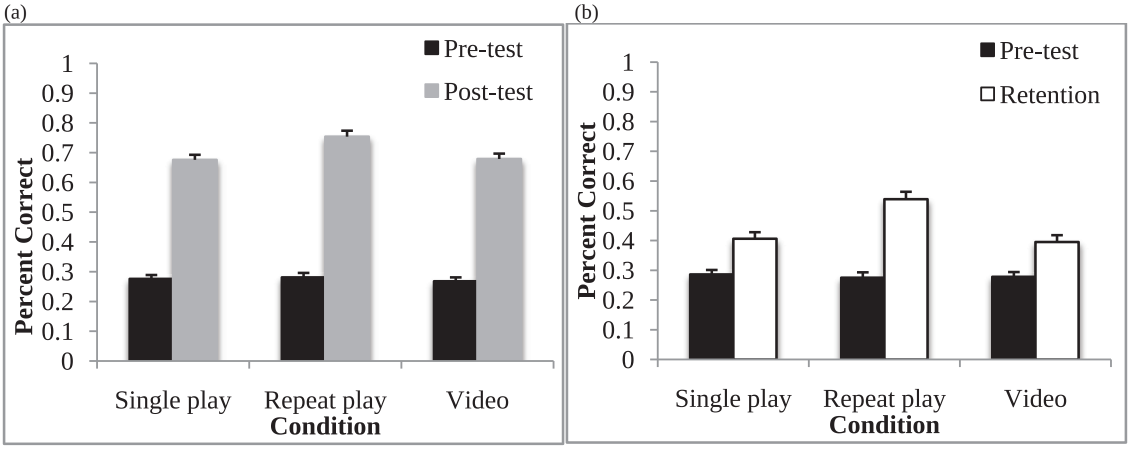

Fig. 5. Bias Recognition and Discrimination by Condition: (a) Pre-test and Immediate Post-test. (b) Pre-test and Retention test. (Error bars show S.E.)

3.8. Bias recognition and discrimination – Retention test

Performance on recognition of the biases and discrimination between the biases (see Figure 5, panel B) showed evidence of retention of training from a pre-test vs. retention main effect ($F(1,288)=171.96$, $p<.05$), an interaction of condition and training ($F(2,288)=13.51$, $p<.05$), and a main effect of condition ($F(2,288)=4.70$, $p<.05$). Evidence of retention of training was apparent for the single game ($t(110)=5.62$, $p<.05$, $d=0.53$),repeat game ($t(82)=10.97$, $p<.05$, $d=1.20$),and the video control condition ($t(196)=5.71$, $p<.05$, $d=0.58$).Planned comparisons showed that the repeat game significantly outperformed the control video on the retention test ($t(288)=4.21$, $p<.05$), and repetition of the game did improve performance at retention over a single play session ($t(288)=4.02$, $p<.05$).

4. Independent assessment

An additional assessment of the effectiveness of the game was conducted by an independent lab. These tests employed novel measures of cognitive bias, unknown to the research team who developed the game, that featured different matched materials at pre-test, post-test, and retention test. All participants were recruited and run by the independent lab. The independent test only featured the single play condition from the current study.The preliminary results available at this time for the immediate post-test showed a similar pattern for the most central question, with the game outperforming the video for both projection and representativeness, although with slightly muted effect sizes (Anchoring $d = 0.30$; Projection $d = 0.75$; Representativeness $d = 1.24$).

5. Discussion

The game trained both conceptual understanding of the biases and strategies to mitigate the biases very effectively. This benefit is seen in the current results on measures outside the game, and even on preliminary results from unknown materials in an independent test, showing transfer of learning beyond the material encountered. This supports the idea that general strategies are being learned rather than rote answers to specific problems.

The results show consistent superior performance from the game versus the professionally constructed video control condition. Moreover, the effect sizes observed from these very brief training opportunities are extremely large, falling well beyond the range of learning effects seen within typical training manipulations. Coupled with the evidence that training persists to the 12-week retention test, the game-based training delivers on the goal of the current study to replicate and enhance our earlier findings [7]. Overall the current data are congruent with the idea that serious computer games offer an excellent environment to train higher-order cognitive skills like bias mitigation.

While repetition produced few advantages for bias mitigation on the immediate post-test, the value of spaced practice to the durability of training was readily observed on the retention tests.Our data highlight the advantages for retention that can be gained from refresher training of the material.

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