The Effect of Varied Cognitive Training on Performance in Untrained Tasks

Steven Baum

University of California, Berkeley

Abstract

With the advancements of technology in the last decade permitting the use of more sophisticated equipment – primarily with electronics – cognitive scientists have taken considerable interest in the notion of cognitive training as it relates to neural plasticity – the ability of the brain to strengthen connections and functional complexes through repeated use of relevant anatomical areas. In this study, 62 young adults utilized two specialized simulation environments (videogames) to train particular neural structures. After short training sessions, two untrained tasks were administered – paired word recall and physical reaction time - with each task requiring skills pertinent to the areas just trained via simulation. By recording the performance of subjects in these untrained tasks, and comparing group performances over a month-long period, patients who underwent some form of simulation training demonstrated an increase in performance rate over the control group, which performed no simulation training. Furthermore, subjects experienced the most performance gains in the first of their two tasks, which always came directly after the training session that strengthened the relative area. The second task, which was not directly in succession of its relevant training session, experienced a lesser – but significant – improvement in performance. The data aligns with previous studies and their empirical evidence that cognitive training allows for individual improvements in tasks relative to the training; multiple forms of cognitive training, furthermore, can improve multiple areas, but at the cost of reduced gains in areas whose functions are tested later than others.

Introduction

Within recent decades, cognitive neuroscience and cognitive psychology have begun to investigate the notion of strengthening certain mental faculties through the use of electronic aids, namely videogames. There already exists an empirical set of studies that demonstrate the effectiveness of cognitive training as it relates to performance on untrained tasks (Van Muijden et al., 2012). However, the premises of these experiments has consistently dealt with a single training session followed thereafter by an untrained task that utilizes a cortical area that was just strengthened by the training session (Nikolaidis et al., 2013). Because of the already-solid body of evidence speaking to the plasticity in single-training single-test scenarios, the question then moves on to the noisier environment of a multiple-training multiple-test environment. Although the controlled environment of a lab setting is ideal for isolating neural areas and their relevant behaviors, the day-to-day interactions of most humans lend themselves more to the notion of a wide variety of neurological stimulations and resulting effects. The purpose of this study, then, was to examine if the same enhancements of performance found from previous studies will still hold when subjects must train between two different simulations and test themselves in two equally different untrained tasks. Subjects were then assessed under these conditions of multiple training environments and multiple tests to see if the plasticity gained from the respective training would have any impact on the tasks not relevant to the respective benefits gained.

Methods

Training Apparatuses

One video game consisted of a simple tile-matching puzzle (Figure 1) wherein participants were instructed to select pairs of tiles; if the tiles flipped over to reveal identical shapes, a single point was added to the score and the tiles were removed from the board. If the tiles did not match, a single point was added to the "missed" category and the tiles were flipped back over to the "?" face. To clear this training session patients had to successfully remove all tiles by finding successive pairs of identical shapes. A total score was then taken by the difference of correct pairs and number of incorrectly-matched tiles. The intent of this simulation environment was to challenge patients' working memory by remembering pairs of tiles hidden amongst the array of "?" faces.

The other video game challenged patients' reflex and motor skills by placing them in control of a single arrow that had to maneuver and escape a series of oncoming rocks in an enclosed hallway (see Figure 2). By manipulating a simple joystick patients accumulated points by dodging incoming boulders, with a particular amount of points assigned based on the size and speed of the given rock. Subjects cleared this session by progressing as far as possible without getting hit; the first hit would halt the game and present a final score based on the total amount of rocks successfully dodged.

Testing Apparatuses

There were two testing environments to gauge subjects' performances on untrained tasks that still had some form of cognitive relevance to the training apparatuses.

The first test consisted of a cued recall word-pairing test (see Figure 3) wherein subjects were given a study phase of 30 seconds to look at a list of 15 X → Y word pairings, with no intrinsic connection between the words, after which they were given a 20 second interval period. After this interval period, subjects were then prompted with a series of X → ??? pairings and asked to replace the "???" with as many "Y" words from the original list.

The second test involved giving subjects a clicker and making them view a screen. At randomly-scheduled intervals, a single flash icon would appear (see Figure 4), at which point subjects were instructed to press their clicker as quickly as possible to measure their reaction time.

Participants

This study was performed through a university psychology department, and as such the bulk of participants were of a collegiate demographic. Explicit requests were made for **(1)** Right-handed individuals, **(2)** Vision-corrected or 20/20 individuals, **(3)** Non-epileptic individuals, **(4)** Ages between 18 and 30, **(5)** Normal color vision, and **(6)** Consenting individuals via filling out relevant paperwork and self-declared freedom from neurological illness. Under these parameters there were a total of N = 62 students who qualified for participation in the study. 37 identified as female, with 25 left identifying as male. The mean age was 21.3 years old and the average level of education was 16.1 years.

From here the 62 subjects were split amongst three groups, from here on labeled *Group A, Group B* and *Control Group (Group C)*. Groups A and B consisted of 21 individuals, while the control group had 20 of the remaining subjects. The purpose of these groups was to determine the order in which they would undergo each training apparatus and the resulting test scenario that would follow as well. Groups A and B were given instructional videos on the use of the training apparatuses and allowed small periods to practice with the simulation environment. Group C received no training on any of the apparatuses. Tests and training sessions were performed in one-hour blocks, and done six times over the course of one month. For each one-hour block, ten minutes were devoted to each task/training environment with 5 minute rest gaps in between. Group A performed tasks in the following order: Motor Simulation → Tile Simulation → Cued Recall → Reaction Time Test. Group B performed tasks in the following order: Tile Simulation → Motor Simulation → Reaction Time Test → Cued Recall. Group C received no training and performed tasks in the following order: Motor Simulation → Reaction Time Test.

Evaluation

The primary method of evaluation dealt with subjects' performances on the untrained tasks after training in their simulation environments. For the cued recall word-pair task, performance was measured as the percentage of words correctly filled in during the testing phase. For the reaction time test, performance was measured as the number of milliseconds required for a subject to press their clicker after seeing the flash icon appear on-screen.

Results

As seen in Figures 5 and 6, subjects had their performances tracked with an initial reading on untrained tasks - before any simulation training occurred – and then again at each session after going through the sequence of training/testing delegated to the respective groups.

On the average, subjects who underwent some form of training displayed statistically-significant increases in performance across both tests. In the paired-word recall test (see Figure 5), the mean accuracy of group A registered at 60% before any training and yielded a 72% accuracy rate at the end of six weeks (paired t-test, $t = 2.8971$, $p = 0.02011$). Conversely, subjects from group B registered a 58% accuracy mean before training, and had a mean score of 65% accuracy after a month of training (paired t-test, $t = 2.6263$, $p = 0.0236$). The control group displayed statistically insignificant changes and fluctuated minimally from its initial recordings of 60% accuracy on the recall tests.

Results were very much similar for the performances on the reaction time test (see Figure 6). Groups that underwent the training simulations prior to the task showed statistically significant improvements over the course of the month, whereas the control group made no significant improvements in physical reaction time. Group A began (prior to any training) with a mean reaction time of 84ms and yielded a mean reaction time of 75ms after the six training sessions (paired t-test, $t = 2.349$, $p = 0.387$). Group B began with a pre-training mean reaction time of 79ms and had a 70ms mean by the end of the month (paired t-test, $t = 2.222$, $p = 0.0482$).

The primary distinction between each group – although each had significant improvements in performance during the course of training – was that the overall gains in performance varied between groups A and B depending on the ordering of training → testing. In both cases, the group's best performance gains were in the first test of their sequence; group A had larger gains in the paired-term recall test, while group B had larger gains in the physical response time test. No matter which group and which test, however, all performances surpassed the statistically-insignificant changes of the control group.

Discussion

The results speak to the ability of neuroplasticity to enhance the performance of multiple brain areas, rather than the single complexes targeted by previous studies. Because the tasks directly involved the use of motor cortices for reaction time and working memory for word association, it leads one to believe that the training provided by the simulation environments caused a progressively strengthened use of the relevant brain areas. Similarly, by having the word pairs lack any form of semantic association, the tests were more likely to focus on simply the working memory rather than any sort of salient experience or long-term association that could make recall easier.

The discrepancy in each group's performance increases relative to its testing sequence, however, suggests that the intricacy of training and testing prevented the full achievements for *both* untrained tasks, and instead created a more substantial improvement in one task, coupled with a minor improvement in the other task. For reference, group A had a more substantial improvement in the word recall, while group B had a more substantial improvement in physical response time. It is worth noting that group A had the pairing of "Tile Simulation → cued memory recall test" while group B had the pairing of "Motor Reflex Simulation → reaction time test" in their respective training → testing orderings. One possibility for the disparity in task improvement deals with this proximity of relevant events; having just done a simulation that strengthens cortical areas relative to the untrained task will likely cause improvements in said task. Conversely, having an "obscuring" simulation in between, as was the case with "Tile Simulation → Motor Reflex Simulation → cued memory recall test" with group A, likely posed some interference or distortion in the subject's neural plasticity, as the brain had to utilize novel areas when training for the Motor Reflex Simulation and said areas gave no utility in performing the subsequent word recall. One must also consider the limitations of this experiment; having one-hour training sessions for subjects gave relatively small windows of time to observe a deeply intricate phenomena, and accounting for the mean performance of the group over individual improvements causes the data to represent a broader (and vaguer) swath of samples.

While the data suggests that the brain is capable of using multiple modalities of training to temporarily improve multiple areas, the same form of mental gymnastics can limit the gains of said training depending on the sequence of actions one takes and the respective brain structures used to perform them.

Figures & References

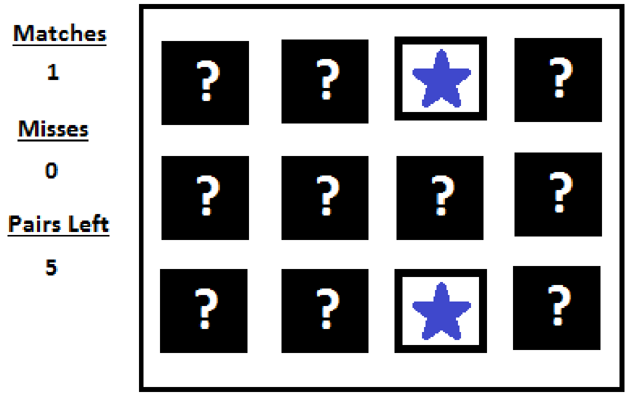

Figure 1
Tile matching game used during training periods. Subjects select tiles from the same array of colored shapes, completing the game only when all pairs of colored shapes are successively picked.

The same grid is used for all training sessions.

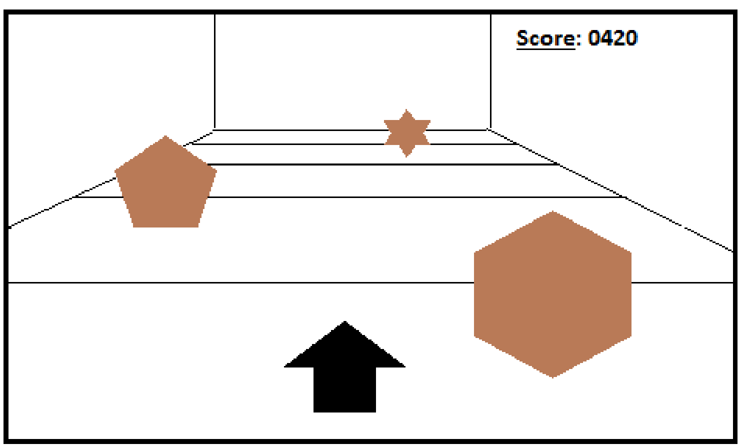

Figure 2
Motor reflex game used during training periods. Subjects control the single arrow at the bottom of the screen and receive point awards based on manuevering around incoming brown rocks, with higher points awarded to dodging faster-moving boulders.

The same game and difficulty settings are used for all training sessions.

Study Phase	**Test Phase**
sink --> arrow	sink --> ???
cushion --> apricot	cushion --> ???
feather --> candle	feather --> ???
mouse --> racquet	mouse --> ???
…	…
…	…

Figure 3
Cued-recall test administered to subjects. If subject was in group A, this test was given directly after training with the tile-matching simulation.
If subject was in group B, this test was given directly after training with the motor-reflex simulation game.

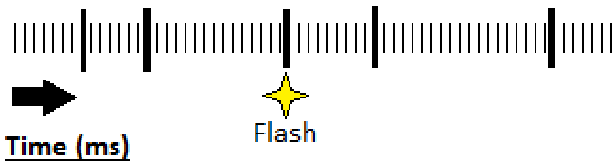

Figure 4

Timed progression of "flashes" testing subjects on their raw reaction time abilities. Subjects pressed a button as soon as possible when shown each flash. Flashes were presented at varying & intermittent times.
If subject was in group A, this test was given directly after training with the motor-reflex simulation game.
If subject was in group B, this test was given directly after training with the tile-matching simulation.

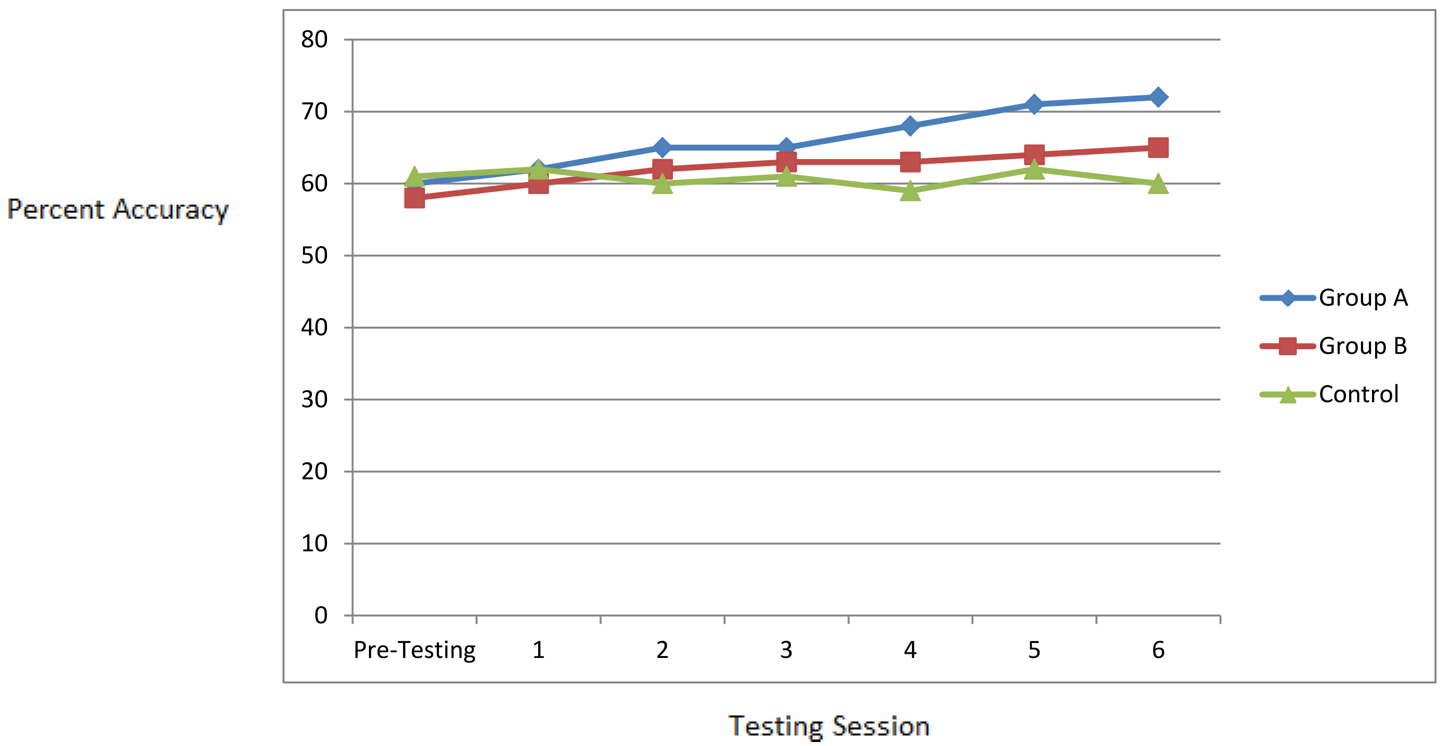

Figure 5: **Percent Accuracy on cued-recall test**

The above graph plots the percent of correctly-recalled pairs from subjects of each group (A, B, control) after their respective training sessions (or lack thereof, for the control group).

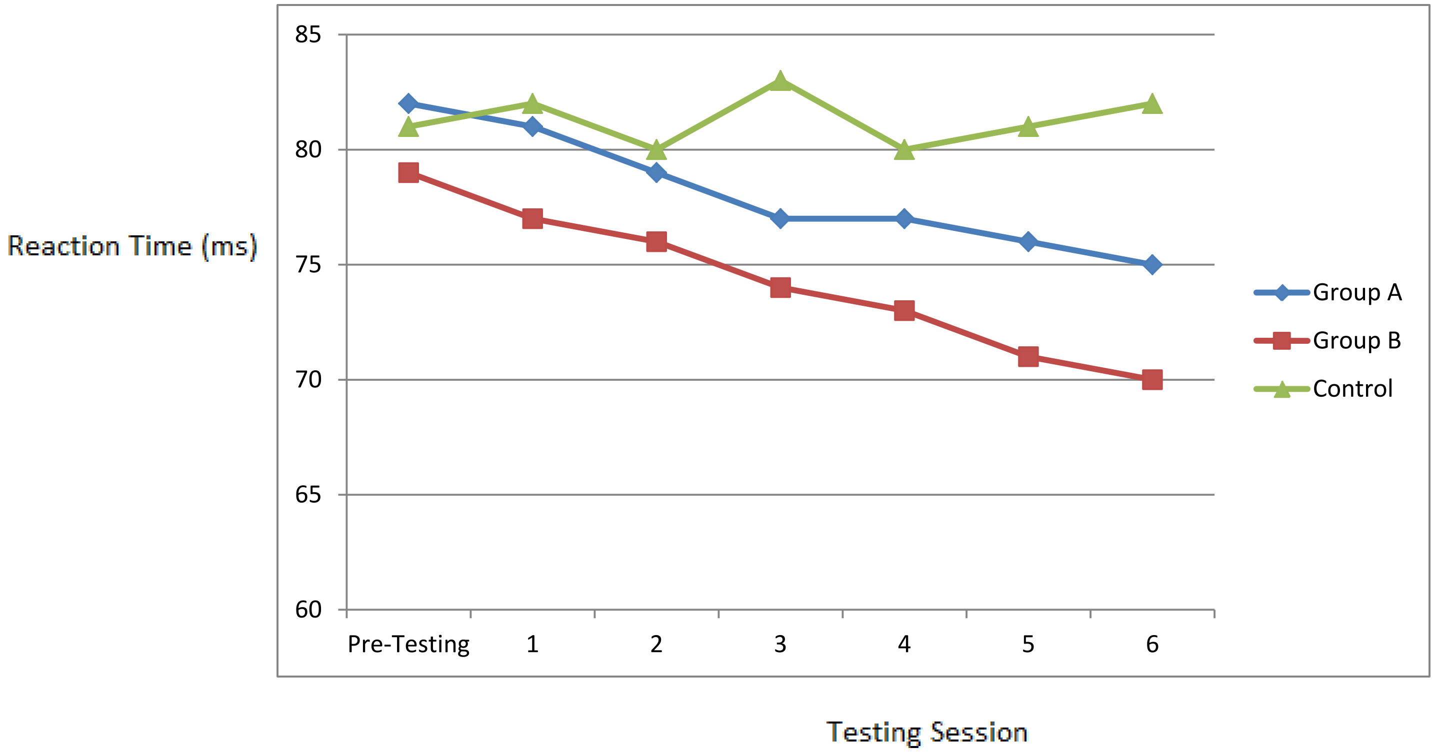

Figure 6: **Reaction Times on reaction time test**

The above graph plots the respective reaction times (after seeing flashes at various timed intervals) of each group (A, B, control) after their respective training sessions (or lack thereof, in the case of the control group).

References

Van Muijden J., Band G. P. H., Hommel B. (2012). Online games training aging brains: limited transfer to cognitive control functions. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3421963/

Nikolaidis A., Voss M. W., Lee H., Vo L.T.K. (2013). Parietal plasticity after training with a complex video game is associated with individual differences in improvements in an untrained working memory task. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3968753/#B56