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# Improvement of Visual Attention and Working Memory through a Web-based Cognitive Training Program

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**Context:** Prior work has revealed that cognitive ability is adaptive and can be improved with cognitive behavioral training methods; however, use of these methods is limited outside of the lab.

**Objective:** To investigate the efficacy of *Lumosity*, a web-based cognitive training program developed by Lumos Labs to improve attention and memory in healthy adults.

**Design, Settings, and Participants:** Randomized, controlled experiment consisted of assessment, training intervention, and post-training assessment. Volunteer participants (n=23, mean age=54) were recruited from various locations across the US. Training and testing were conducted on each participant's personal computer to simulate conditions of actual use. Both groups used computers on a regular basis. Results and compliance data were captured automatically via the online program.

**Intervention:** Online cognitive training for twenty minutes once daily for five weeks. Trained participants completed an average of 29.2 sessions, and control participants received no training. Training sessions consisted of five distinct exercises.

**Main Outcome Measures:** Tests of working memory and visual attention. Assessment pre- and post-training was conducted via a separate web-based application.

**Results:** The trained group improved significantly in measures of visual attention and working memory, while the control group did not. Training reduced the average error in localization of transient, non-central visual stimuli ($p<0.01$, two-tailed t-Test). Trained subjects also improved in the measure of spatial working memory ($p<0.01$, two tailed t-Test). There were no significant changes in the control group.

**Conclusions:** The results of the study indicate that training and improving fundamental cognitive abilities such as working memory and visual attention is possible outside of a laboratory setting with a web-based application.

## Introduction

Fundamental cognitive abilities such as memory, attention, sensory perception, and processing speed influence how well people perform at work, interact socially, and conduct tasks of daily living from problem-solving to driving. It is now believed that people can improve these basic abilities with appropriate training. The ACTIVE study demonstrated that even older adults (age 65-94) are capable of achieving significant gains in processing speed, memory and reasoning after several hours of directed training (Ball et al., 2002). Furthermore, these gains are still present 5 years after the original training took place (Willis et al., 2006).

Lumos Labs developed a web-based cognitive training program that makes cognitive training tools accessible to a larger audience. The program is composed of a set of exercises designed to improve attention, working memory, processing speed, and response inhibition among other executive processes.

Since cognitive training exercises can be tedious, these exercises have been structured to make them more engaging and encourage long-term consistent usage. Although the tasks are based on experimentally validated approaches to cognitive improvement, they have not been evaluated in this new format.

Working Memory: Working memory, the process of temporarily storing and manipulating information, underlies performance in many other activities, including logical reasoning and reading comprehension. Working memory capacity has a strong relationship with general intelligence (Conway et al., 2003; Kane et al, 2005).

Visual Attention: The allocation of attention determines, to a large extent, what information about the environment is perceived. Improvement in visual attention can lead to a variety changes in behavior, from more efficient information processing to safer driving.

## Training Program Overview

The training program consists of a set of exercises designed to train and improve attention, working memory, processing speed and executive function.

The program is composed of five discrete exercises. Each exercise was developed to specifically train one or more cognitive functions. Key components of the program are:

- Dynamic difficulty changes to consistently challenge each individual and enhance their progression
- Web-based platform ensures ease and ubiquity of access
- Game-like features and motivations (such as scoring, unlocking of levels, etc.) transform a tedious training task into an entertaining game, leading to better compliance and more effective training
- Simple self-instruction: No human trainer required

Training related to visual attention:

*Birdwatching* is an exercise designed to improve attention by increasing the spatial extent of visual information that can be processed in a short amount of time. The goal is to score points by accurately identifying a letter in the center of the screen, while simultaneously detecting the location of a bird graphic in the periphery. The level of difficulty was adjusted automatically by decreasing the stimulus duration (range: 30-200ms), increasing the eccentricity of the non-central stimulus, and increasing non-relevant information (distractors).

Training exercises related to working memory:

*Memory Match* and *Monster Garden* exercises both target the improvement of working memory. *Memory Match* is a speeded n-back task where users must compare the current stimulus with those presented previously. The goal of *Monster Garden* is to navigate through a maze while relying on spatial memory to avoid obstacles. The number of obstacles increases as the user's ability to navigate the maze improves. Both exercises incorporate game-like elements such as scoring and bonus points.

## Methods

**Design:**
This study used a single arm design with participants placed randomly into a training or control group. Trained participants completed a daily program of computer-based exercises delivered via the internet from a secure server. Subjects trained an average of 29.2 sessions, each of which was completed within 20 minutes. The intervention period lasted 5 weeks.

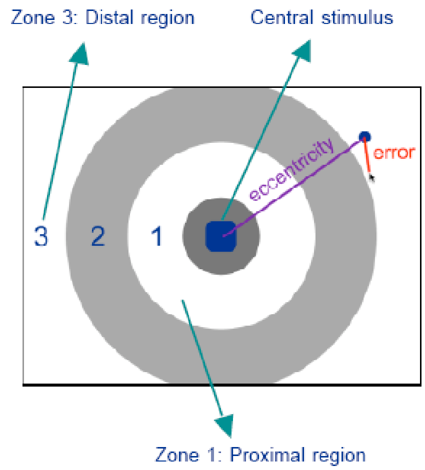
Both trained and control participants completed a battery of cognitive assessments at the beginning and end of the study. The assessments were each completed in one session from home on a web browser communicating with the administrating server. There was no contact with the control group between assessments.

**Volunteers/Participants:**
Volunteers were recruited by email and word of mouth from locations across the United States. All participants were mentally and physically healthy. Participants' only compensation was continued access to the program after the experiment concluded.

Trained: n = 14 (8 female), mean age = 57

Control: n = 9 (3 female), average age = 50. (One control did not complete the second visual attention assessment and was excluded from this analysis.)

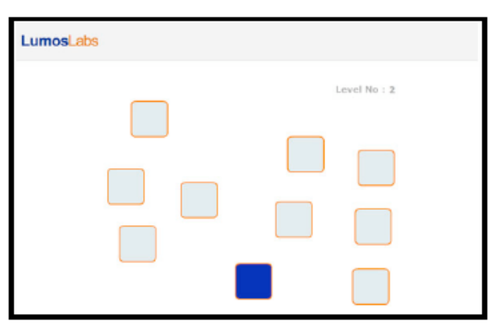
**Figure 1:** Visual attention test




**Assessment:**
Cognitive performance was assessed using the web-based testing application.

<u>Visual Attention:</u>
Visual attention was assessed using a test of the ability to interpret information outside of the central field of view. In this divided attention task, subjects were required to fixate on and identify a stimulus in the center of the computer screen, and simultaneously locate stimuli presented for 100ms outside of their central view. Non-central stimulus eccentricity varied between 120 and 600 pixels from the central stimulus. The distance between target and response was averaged across all trials, providing a measure of localization error. See Figure 1.

**Figure 2:** Spatial working memory test



<u>Working Memory:</u>

Working memory span was measured with a computerized version of the reverse span board test (see Figure 2). Subjects needed to recall the order and location in which randomly placed squares were highlighted. After each correct trial, the number of highlighted squares incremented by one until the subject committed two mistakes on the same level. The ultimate level reached indicated each participant's spatial working memory span.

## Results:

In the visual attention test, trained subjects improved significantly more than the untrained controls ($p<.01$, two-tailed t-Test, see Figure 3). The largest training effects were seen on the most difficult trials, where the non-central stimulus was most distant from the center of the screen (p<01, two-tailed t-Test with Bonferonni correction; Figure 4). This result indicates that the trained subjects could more precisely locate rapidly presented visual stimuli, and could accurately evaluate a larger scope of visual information.

**Figure 3:** Visual attention improvement following training ($p<.01$, two-tailed t-Test).

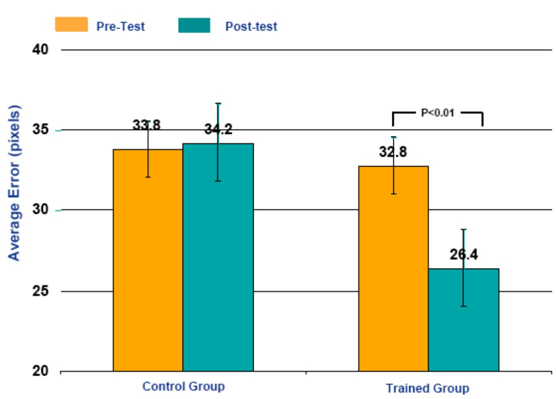
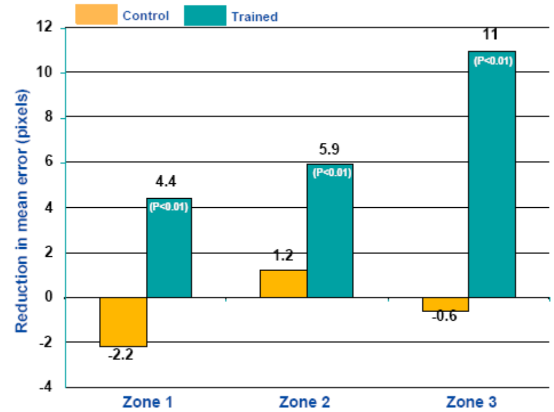
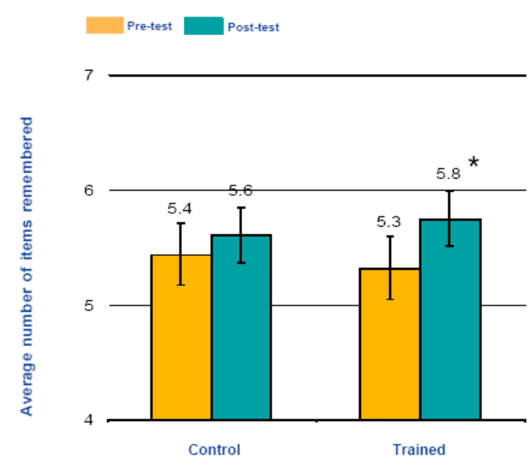



**Figure 4:** Largest improvement on trials farthest from central stimulus




The reverse span board test revealed that trained subjects had a significantly longer spatial working memory span following training ($p<.01$, Figure 5). The subjects averaged an increased working memory span of 15%, while control subjects showed no significant change.

**Figure 5:** Increased spatial working memory span following training ($p<.01$, paired t-Test)




## Discussion

All participants were able to use the testing and training software from a personal computer without guidance. Compliance and qualitative feedback suggest that the game structure motivated frequent training.

Trained participants improved significantly in measures of visual attention and spatial working memory. Since these tests were different than the exercises in the training program, this change represents an improvement in visual attention and spatial working memory that extends beyond the trained task itself.

The results of this pilot study demonstrate that training and improving a fundamental cognitive ability is possible with a web-based application. The study also demonstrates the viability of conducting an entire study online, including intervention and assessment.

This software introduces the possibility for individuals to change and improve their own fundamental cognitive abilities from a home PC in a relatively short amount of time. Lumos Labs intends to explore the effectiveness of a modified training program in the rehabilitation of cognitive impairment, such as that due to stroke, brain trauma, or aging. We invite other researchers to consider or discuss potential applications to their own human behavior research.

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## References

Schaie, K., Willis, S., Hertzog, C., & Schulenberg, J. (1987). Effects of cognitive training on primary mental ability structure. Psychology and Aging, 2(3):233-242.

Ball, K., Berch, D., Helmers, K., et al., Effects of cognitive training interventions with older adults: A randomized controlled trial. Journal of American Medical Association, 288(18):2271-2281.

Green, S. & Bavelier, D. (2003). Action video game modifies visual selective attention. Nature, 423:534-537.

Rebok, G., Rasmusson, D., & Brandt, J. (1996). Prospects for computerized memory training in normal elderly: Effects of practice on explicit and implicit memory tasks. Applied Cognitive Psychology, 10:211-223.

Klingberg, T., Forssberg, H., & Westerberg H. (2002). Training of working memory in children with ADHD. Journal of Clinical and Experimental Neuropsychology, 24(6):781-791.

 