



THE EFFECTIVENESS OF BRAIN TRAINING

Goal. The goal of the Handout is to evaluate the evidence for including brain training such as Luminosity for cognitive restoration in a treatment program for food addiction. The purpose is to encourage food addicts to engage in brain training.

Why Engage in Brain Training?

- There is significant evidence that chronic processed food abusers have significant impairment in memory, learning, decision-making, and restraint.
- These functions are needed for the crucial job of learning how to manage a recovery food plan which is necessary for maintaining abstinence from addictive processed foods.
- Successful execution of a recovery food plan requires a range of cognitive skills including
 - Planning ahead
 - Making shopping decisions in heavily-cued environments
 - Batch-cooking
 - Organizing meals that are portioned, balanced, free-from-addictive foods, and readily available.
- For a variety of reasons, food addicts face barriers to traveling from their homes for therapeutic activities.
- It would be helpful if food addicts could engage in cognitive restoration in their homes.
- A program such as Luminosity is attractive because it's available over the internet.

Research Supporting the Use of Brain Training in Recovery from Food Addiction.

Ballesteros, S., et al. (2015). "A randomized controlled trial of brain training with non-action video games in older adults: results of the 3-month follow-up." *Front Aging Neurosci* 7: 45. This randomized controlled study (ClinicalTrials.gov NCT02007616) investigated the maintenance of training effects of 20 1-hr non-action video game training sessions with selected games from a commercial package on several age-declining cognitive functions and subjective wellbeing after a 3-month no-contact period. Two groups of cognitively normal older adults participated in both the post-training (posttest) and the present follow-up study, the experimental group who received training and the control group who attended several meetings with the research team during the study but did not receive training. Groups were similar at baseline on demographics, vocabulary, global cognition, and depression status. Significant improvements in the trained group, and no variation in the control group had been previously found at posttest, in processing speed, attention and visual recognition memory, as well as in two dimensions of subjective wellbeing. In the current study, improvement from baseline to 3 months follow-up was found only in wellbeing (Affection and Assertivity dimensions) in the trained group whereas there was no change in the control group.

Previous significant improvements in processing speed, attention and spatial memory become non-significant after the 3-month interval. Training older adults with non-action video games enhanced aspects of cognition just after training but this effect disappeared after a 3-month no-contact follow-up period. Cognitive plasticity can be induced in older adults by training, but to maintain the benefits periodic boosting sessions would be necessary.

Donner, Y. and J. L. Hardy (2015). "Piecewise power laws in individual learning curves." Psychon Bull Rev 22(5): 1308-1319.

The notion that human learning follows a smooth power law (PL) of diminishing gains is well-established in psychology. This characteristic is observed when multiple curves are averaged, potentially masking more complex dynamics underpinning the curves of individual learners. Here, we analyzed 25,280 individual learning curves, each comprising 500 measurements of cognitive performance taken from four cognitive tasks. A piecewise PL (PPL) model explained the individual learning curves significantly better than a single PL, controlling for model complexity. The PPL model allows for multiple PLs connected at different points in the learning process. We also explored the transition dynamics between PL curve component pieces. Performance in later pieces typically surpassed that in earlier pieces, after a brief drop in performance at the transition point. The transition rate was negatively associated with age, even after controlling for overall performance. Our results suggest at least two processes at work in individual learning curves: locally, a gradual, smooth improvement, with diminishing gains within a specific strategy, which is modeled well as a PL; and globally, a discrete sequence of strategy shifts, in which each strategy is better in the long term than the ones preceding it. The piecewise extension of the classic PL of practice has implications for both individual skill acquisition and theories of learning.

NOTES: This study used four Lumosity games: "The tasks included one-back speed-of-processing (1B, *Speed Match*), two-back memory updating (2B, *Memory Match*), Eriksen flanker (EF, *Lost in Migration*), and verbal fluency (VF, *Word Bubbles*) tasks." *The study proceeds from the premise that learning took place, and skills were developed over time.*

Finn, M. and S. McDonald (2014). "A single case study of computerised cognitive training for older persons with mild cognitive impairment." NeuroRehabilitation 35(2): 261-270.

The results of a multiple baseline single case study using computerised cognitive training in older adults with Amnesic Mild Cognitive Impairment (aMCI) are reported. Two participants each completed 40 sessions of training in two phases: an initial phase that trained attention, processing speed and cognitive flexibility, followed by a mixed memory and execution functions phase. It was hypothesised that participants would improve with practice on the trained tasks, that the benefits of training would generalise to non-trained neuropsychological probe measures, and that training would result in improved perceptions of memory and mood. Results indicated that one participant showed improved performance on untrained measures of attention and reasoning. On pre/post measures both participants reported less frequent cognitive failures in everyday life and improved mood following training. The results are discussed along with suggestions for future research.

NOTE: This study used "Trail-Making" at Lumosity.

Finn, M. and S. McDonald (2015). "Repetition-lag training to improve recollection memory in older people with amnesic mild cognitive impairment. A randomized controlled trial." Neuropsychol Dev Cogn B Aging Neuropsychol Cogn 22(2): 244-258.

The results of a randomized controlled trial of repetition-lag training in older adults with amnesic mild cognitive impairment (aMCI) are reported. A modified repetition-lag training procedure with extended encoding time and strategy choice was used. The training required discriminating studied words from non-studied lures that were repeated at varying intervals during the test phase. Participants were assessed pre/post using untrained measures of cognition and self-report questionnaires. Primary outcome measures were recall of unrelated word pairs both immediately following presentation and following a delay. Secondary outcomes were a measure of attention, cognitive flexibility, and visual working memory. Participants were also asked to report on the frequency of cognitive failures and mood before and after training. Participants (N = 31) were randomized into either the treatment or a no-contact control group and attended the clinic twice per week over a four week period. Twenty-four participants completed the study (twelve in each group).

Results indicated that the training group improved at recalling unrelated word pairs after a delay. There were no significant effects of training on other outcomes, self-reported cognitive failures or mood. The results are discussed along with suggestions for future research.

Hardy, J. L., et al. (2015). "Enhancing Cognitive Abilities with Comprehensive Training: A Large, Online, Randomized, Active-Controlled Trial." *PLoS One* 10(9): e0134467.

BACKGROUND: A variety of studies have demonstrated gains in cognitive ability following cognitive training interventions. However, other studies have not shown such gains, and questions remain regarding the efficacy of specific cognitive training interventions. Cognitive training research often involves programs made up of just one or a few exercises, targeting limited and specific cognitive endpoints. In addition, cognitive training studies typically involve small samples that may be insufficient for reliable measurement of change. Other studies have utilized training periods that were too short to generate reliable gains in cognitive performance. **METHODS:** The present study evaluated an online cognitive training program comprised of 49 exercises targeting a variety of cognitive capacities. The cognitive training program was compared to an active control condition in which participants completed crossword puzzles. All participants were recruited, trained, and tested online (N = 4,715 fully evaluable participants). Participants in both groups were instructed to complete one approximately 15-minute session at least 5 days per week for 10 weeks. **RESULTS:** Participants randomly assigned to the treatment group improved significantly more on the primary outcome measure, an aggregate measure of neuropsychological performance, than did the active control group (Cohen's d effect size = 0.255; 95% confidence interval = [0.198, 0.312]). Treatment participants showed greater improvements than controls on speed of processing, short-term memory, working memory, problem solving, and fluid reasoning assessments. Participants in the treatment group also showed greater improvements on self-reported measures of cognitive functioning, particularly on those items related to concentration compared to the control group (Cohen's d = 0.249; 95% confidence interval = [0.191, 0.306]). **CONCLUSION:** Taken together, these results indicate that a varied training program composed of a number of tasks targeted to different cognitive functions can show transfer to a wide range of untrained measures of cognitive performance. **TRIAL REGISTRATION:** ClinicalTrials.gov NCT-02367898.

NOTE: I think this is the best study. It used the full range of Lumosity games.

Kesler, S., et al. (2013). "Cognitive training for improving executive function in chemotherapy-treated breast cancer survivors." *Clin Breast Cancer* 13(4): 299-306.

BACKGROUND: A majority of breast cancer (BC) survivors, particularly those treated with chemotherapy, experience long-term cognitive deficits that significantly reduce quality of life. Among the cognitive domains most commonly affected include executive functions (EF), such as working memory, cognitive flexibility, multitasking, planning, and attention. Previous studies in other populations have shown that cognitive training, a behavioral method for treating cognitive deficits, can result in significant improvements in a number of cognitive skills, including EF. **MATERIALS AND METHODS:** In this study, we conducted a randomized controlled trial to investigate the feasibility and preliminary effectiveness of a novel, online EF training program in long-term BC survivors. A total of 41 BC survivors (21 active, 20 wait list) completed the 48 session training program over 12 weeks. The participants were, on average, 6 years after therapy. **RESULTS:** Cognitive training led to significant improvements in cognitive flexibility, verbal fluency and processing speed, with marginally significant downstream improvements in verbal memory as assessed via standardized measures. Self-ratings of EF skills, including planning, organizing, and task monitoring, also were improved in the active group compared with the wait list group. **CONCLUSIONS:** Our findings suggest that EF skills may be improved even in long-term survivors by using a computerized, home-based intervention program. These improvements may potentially include subjective EF skills, which suggest a transfer of the training program to real-world behaviors.

NOTE: This is a small sample. It was a customized program that used a variety of Lumosity game.

Kesler, S. R., et al. (2011). "A pilot study of an online cognitive rehabilitation program for executive function skills in children with cancer-related brain injury." *Brain Inj* 25(1): 101-112.

PRIMARY OBJECTIVES: Children with a history of cancer are at increased risk for cognitive impairments, particularly in executive and memory domains. Traditional, in-person cognitive rehabilitation strategies may be unavailable and/or impractical for many of these children given difficulties related to resources and health status.

The feasibility and efficacy of implementing a computerized, home-based cognitive rehabilitation curriculum designed to improve executive function skills was examined in these children. **METHODS:** A one-arm open trial pilot study of an original executive function cognitive rehabilitation curriculum was conducted with 23 paediatric cancer survivors aged 7-19. **RESULTS:** Compliance with the cognitive rehabilitation program was 83%, similar to that of many traditional programs. Following the cognitive intervention, participants showed significantly increased processing speed, cognitive flexibility, verbal and visual declarative memory scores as well as significantly increased pre-frontal cortex activation compared to baseline. **CONCLUSIONS:** These results suggest that a program of computerized cognitive exercises can be successfully implemented at home in young children with cancer. These exercises may be effective for improving executive and memory skills in this group, with concurrent changes in neurobiologic status.

NOTE: This was also a customized program using Lumosity games.

Kesler, S. R., et al. (2011). "Changes in frontal-parietal activation and math skills performance following adaptive number sense training: preliminary results from a pilot study." *Neuropsychol Rehabil* 21 (4): 433-454.

Number sense is believed to be critical for math development. It is putatively an implicitly learned skill and may therefore have limitations in terms of being explicitly trained, particularly in individuals with altered neurodevelopment. A case series study was conducted using an adaptive, computerised programme that focused on number sense and general problem-solving skills. The study was designed to investigate training effects on performance as well as brain function in a group of children with Turner syndrome who are at risk for math difficulties and altered development of math-related brain networks. Standardised measurements of math and math-related cognitive skills as well as functional magnetic resonance imaging (fMRI) were used to assess behavioural and neurobiological outcomes following training. Participants demonstrated significantly increased basic math skills, including number sense, and calculation as well as processing speed, cognitive flexibility and visual-spatial processing skills. With the exception of calculation, increased scores also were clinically significant (i.e., recovered) based on reliable change analysis. Participants additionally demonstrated significantly increased bilateral parietal lobe activation and decreased frontal-striatal and mesial temporal activation following the training programme. These findings show proof of concept for an accessible training approach that may be potentially associated with improved number sense, math and related skills, as well as functional changes in math-related neural systems, even among individuals at risk for altered brain development.

NOTE: This study used 2 math games and 1 logic game from Lumosity.

Mayas, J., et al. (2014). "Plasticity of attentional functions in older adults after non-action video game training: a randomized controlled trial." *PLoS One* 9(3): e92269.

A major goal of recent research in aging has been to examine cognitive plasticity in older adults and its capacity to counteract cognitive decline. The aim of the present study was to investigate whether older adults could benefit from brain training with video games in a cross-modal oddball task designed to assess distraction and alertness. Twenty-seven healthy older adults participated in the study (15 in the experimental group, 12 in the control group). The experimental group received 20 1-hr video game training sessions using a commercially available brain-training package (Lumosity) involving problem solving, mental calculation, working memory and attention tasks. The control group did not practice this package and, instead, attended meetings with the other members of the study several times along the course of the study. Both groups were evaluated before and after the intervention using a cross-modal oddball task measuring alertness and distraction. The results showed a significant reduction of distraction and an increase of alertness in the experimental group and no variation in the control group. These results suggest neurocognitive plasticity in the old human brain as training enhanced cognitive performance on attentional functions. **TRIAL REGISTRATION:** ClinicalTrials.gov NCT02007616.

NOTE: This study used 10 different Lumosity games.

Morrison, G. E., et al. (2015). "Reliability and validity of the NeuroCognitive Performance Test, a web-based neuropsychological assessment." *Front Psychol* 6: 1652.

The NeuroCognitive Performance Test (NCPT) is a brief, repeatable, web-based cognitive assessment platform that measures performance across several cognitive domains. The NCPT platform is modular and includes 18 subtests that can be arranged into customized batteries.

Here we present normative data from a sample of 130,140 healthy volunteers for an NCPT battery consisting of 8 subtests. Participants took the NCPT remotely and without supervision. Factor structure and effects of age, education, and gender were evaluated with this normative dataset. Test-retest reliability was evaluated in a subset of participants who took the battery again an average of 78.8 days later. The eight NCPT subtests group into 4 putative cognitive domains, have adequate to good test-retest reliability, and are sensitive to expected age- and education-related cognitive effects. Concurrent validity to standard neuropsychological tests was demonstrated in 73 healthy volunteers. In an exploratory analysis the NCPT battery could differentiate those who self-reported Mild Cognitive Impairment or Alzheimer's disease from matched healthy controls. Overall these results demonstrate the reliability and validity of the NCPT battery as a measure of cognitive performance and support the feasibility of web-based, unsupervised testing, with potential utility in clinical and research settings.

NOTE: The basis for the NCPT is a series of Lumosity games.

Ratray, B. and D. Smee (2013). "Exercise improves reaction time without compromising accuracy in a novel easy-to-administer tablet-based cognitive task." *J Sci Med Sport* 16(6): 567-570.

OBJECTIVES: Moderate intensity aerobic exercise is known to facilitate cognitive performance but new technologies enable increasing opportunities to investigate this phenomenon under different circumstances. This study aimed to describe the effect of exercise on executive function assessed through a novel tablet-based test. DESIGN: Twenty healthy, active participants volunteered to take part in the randomised fully controlled trial. METHODS: Participants undertook an initial test of maximal aerobic capacity as well as ventilatory threshold during an incremental cycle test. A touch screen tablet computer was placed in the middle of the handlebars at an angle of approximately 45 degrees, and participants were asked to complete the response-inhibition cognitive task (Speed Match, Lumos Labs Inc.) at set time points. A full familiarisation trial was performed prior to subsequent visits, in which participants completed either the control (no exercise) and exercise (90% ventilatory threshold (VT)) trials in a randomised order. During the 1h trials, the cognitive task was performed prior to, during and post the intervention. Reaction time and accuracy of participant responses were recorded. RESULTS: Performing the cognitive task resulted in elevated heart rates and ventilation rates during control and exercise. Exercise facilitated performance in the executive function task such that reaction time was enhanced with no change in accuracy. A range of reliability measures are also reported. CONCLUSIONS: This method of assessing executive function during exercise displays face validity and provides promise for further investigation of cognitive function using a simple, short duration, easily administered and widely available test.

NOTE: This study used the Lumosity game, 'Speed Match.' Here are the researchers notes on this game: "We consider that this cognitive task fits within the broad definition of an executive function task as described by Etnier and Chang.⁸ As this task requires some inhibition of inappropriate actions we suggest that the task chosen fits most closely with the inhibition response domain of executive function."

Sternberg, D. A., et al. (2013). "The largest human cognitive performance dataset reveals insights into the effects of lifestyle factors and aging." *Front Hum Neurosci* 7: 292.

Making new breakthroughs in understanding the processes underlying human cognition may depend on the availability of very large datasets that have not historically existed in psychology and neuroscience. Lumosity is a web-based cognitive training platform that has grown to include over 600 million cognitive training task results from over 35 million individuals, comprising the largest existing dataset of human cognitive performance. As part of the Human Cognition Project, Lumosity's collaborative research program to understand the human mind, Lumos Labs researchers and external research collaborators have begun to explore this dataset in order uncover novel insights about the correlates of cognitive performance. This paper presents two preliminary demonstrations of some of the kinds of questions that can be examined with the dataset. The first example focuses on replicating known findings relating lifestyle factors to baseline cognitive performance in a demographically diverse, healthy population at a much larger scale than has previously been available. The second example examines a question that would likely be very difficult to study in laboratory-based and existing online experimental research approaches at a large scale: specifically, how learning ability for different types of cognitive tasks changes with age. We hope that these examples will provoke the imagination of researchers who are interested in collaborating to answer fundamental questions about human cognitive performance.

Tartaglione, E. V., et al. (2014). "Can computerized brain training games be used to identify early cognitive impairment in cirrhosis?" Am J Gastroenterol **109**(3): 316-323.

OBJECTIVES: We evaluated whether commercially available, computerized "brain-training" games can be used to identify subtle cognitive impairments in patients with cirrhosis. **METHODS:** We compared patients with cirrhosis who did not have overt encephalopathy (n=31), patients with pre-cirrhotic chronic liver disease (n=28), and normal controls without liver disease (n=16) with respect to their scores on the number connection test-A (NCT-A), the Inhibitory Control Test (ICT), and five, short (approximately 2.5 min), brain-training games that were administered on an Apple iPad and tested different cognitive domains. **RESULTS:** Patients with cirrhosis had similar scores to patients with pre-cirrhotic liver disease and slightly worse scores than normal controls in the NCT-A and the ICT, although these differences were not statistically significant. In contrast, patients with cirrhosis had significantly worse scores than patients with pre-cirrhotic liver disease and even more so than normal controls in all five of the brain-training games. After adjustment for age and educational attainment, these differences remained significant for two of the tests, "Color Match" which is a version of the Stroop test and measures selective attention, and "Memory Matrix", which measures visuospatial memory. The area under the receiver operating characteristic curve discriminating cirrhosis from pre-cirrhotic liver disease was 0.56 (95% confidence interval (CI) 0.41-0.72) for the ICT and 0.58 (95% CI 0.43-0.73) for the NCT-A, indicating no discrimination, while it was 0.75 (95% CI 0.63-0.87) for "Color Match" and 0.77 (95% CI 0.64-0.90) for "Memory Matrix", indicating good discrimination. **CONCLUSIONS:** Short, brain-training games administered on an iPad can be used as psychometric tests to detect subtle cognitive impairments in patients with cirrhosis without overt encephalopathy that could not be detected by the NCT-A or the ICT.