**Screening/Covariates:**

*Urine Pregnancy Test (females only):* A urine pregnancy test (females only) will be administered at the Intake Visit and at each fMRI scan visit **(~weeks -3, -1 and 10).** Participants with a positive pregnancy test at the IntakeVisit or either fMRI scan will be deemed ineligible.

*Breath Alcohol Concentration:* The BrAC assessment will be administered at the Intake Visit and at both fMRI scans. The breath alcohol monitor is a handheld device that uses a disposable mouthpiece and reports the concentration of alcohol in exhaled breath. Any reading > 0.000 indicates alcohol consumption within the last 14 hours. Participants with a BrAC greater than or equal to 0.01 at the Intake Visit will be ineligible. Participants who have a BrAC reading greater than or equal to 0.01 at either fMRI scan visit **(~weeks -1 and 10)** may be ineligible to continue with the fMRI scan and will only be rescheduled/allowed to proceed with the fMRI scan at the discretion of the Principal Investigator.

*Demographics:* Standard surveys will collect demographics (e.g., age and gender).

*Medical and Psychiatric History:* Height and weight will be measured and recorded. Psychiatric diagnoses noted under the exclusion criteria will be determined by self-report.

*Magnet Safety Form:* This standard assessment form created by the Department of Radiology at the Hospital of the University of Pennsylvania will be completed by the participant at Intake Visit and on ~**weeks -3, -1 and 10** prior to entering the scanner at each fMRI scan visit. The form assesses history of specific prostheses, surgical implants, and other potential MRI contraindications (including those which could potentially interfere with fMRI imaging/data collection processes).

*Scanning Registration Form:* A standard form used to collect participant emergency contact information and their mother/father’s first names (administered at Intake Visit). This information is used in adherence with the Department of Radiology at the Hospital of the University of Pennsylvania’s requirement that any person(s) entering a Department of Radiology facility must be registered within UPENN’s central patient database. This form will also be used as a log to record a participant’s medical record number (MRN) via central registration and MRI scheduling information via central radiology's DECRAD scheduling system.

*Shipley Institute of Living Scale:* All participants will complete the Shipley Institute of Living Scale (SILS)at the Intake Visit. The SILS is a self-administered test designed to assess general intellectual functioning in adults and adolescents and to aid in identifying cognitive impairments ([89](#_ENREF_89))[[89](#_ENREF_89)]. The scale consists of two subtests: a 40-item vocabulary test and a 20-item test of abstract thinking. The total administration time is 20 minutes (10 minutes per subtest). A trained member of the study staff will score the test. The SILS correlates with the Wechsler Adult Intelligence Scale-Revised (WAIS-R) Estimated IQ Test; those participants earning less than an estimated WAIS-R IQ of 90 will be ineligible. The SILS is considered a highly reliable assessment tool, with a good total score internal consistency (Cronbach’s alpha= .92).

*Program Referral Form:* Participants enrolling in the study with a personal friend or family member may share information exclusive to their assigned condition (CT/CS). To protect blind integrity, participants may be randomized to the same condition (CT/CS) if they report enrolling into the study with someone they know, if they know someone who is currently enrolled in the study, or if they know someone who has completed the program on this form. This form will be completed at the Intake Visit.

*DNA for Genetic Studies:* The 2ml saliva sample via the Oragene™ collection kit will be used to explore associations of genes relevant to cognitive function with responses to cognitive training. Because all genetic analyses are exploratory, participants will not be informed of their genetic test results. All samples and results will be kept confidential and secure. The saliva Oragene™ sample will be collected at the Intake Visit.

*Cotinine:* A 5ml saliva sample will be collected to assess cotinine levels at the Intake Visit and Post-treatment visit (to be collected at **week -3 and week 10**). This sample will only be collected from participants reporting smoking in the last 7 days.

*Carbon Monoxide*: Carbon monoxide (CO) levels (analyzed by Vitalograph) will be recorded at each visit except follow up as a biochemical verification of smoking exposure.

**Treatment:**

*CT:* The CT condition will utilize web-based exercises via the Lumosity System (www.Lumosity.com), and will run from **weeks 0 to 9**. Participants will complete their assigned web-based training exercises 5x/week for 10 weeks (25 total hours) from home. Each session will be approximately 30 minutes.

The web-based cognitive training in this condition includes user-friendly game-like tasks designed to train sustained attention, working memory, and response-inhibition. To increase novelty and maintain engagement, the task difficulty increases as the participant’s performance improves. The Lumosity.com tasks have been used in prior research on the effects of cognitive training ([90-92](#_ENREF_90)).

*CS:* Similar to the CT condition, the CS condition will utilize web-based games and will run from **weeks 0 to 9**. Participants will complete their assigned web-based training exercises 5x/week for 10 weeks (25 total hours) from home. Each session will be approximately 30 minutes. The important difference between the CT games and the CS games is that the CS games are not designed to improve working memory, attention or response inhibition. For example, games may include arithmetic and visual field tasks. Also, these games will not be adaptive, meaning they will not increase in difficulty as the participant’s performance improves.

**Intermediate Outcomes:**

*Adherence*:

Cognitive Training.Web-based CT and CS adherence will be closely monitored by study staff. CT/CS adherence will be reviewed on a weekly basis during the 10 week treatment period**.**

*Neurocognitive Assessments*:Participants will complete the following computer-based neurocognitive assessments (in the order listed below) on weeks **-1, 5, 10 and 16** in a quiet room at our Center.

Fractal N-Back Task:In the traditional N-back task, sequences of letters or numbers are displayed and participants respond with a button press to a single target using the following rules. During the 1-back condition, participants respond if the image is identical to the one preceding it. In the 2-back condition, they respond if the stimulus is identical to the one two trials before. In the 3-back condition they respond if the stimulus is identical to the one three trials before. The active baseline condition (0-back) is a simple target detection task. We will use the fractal N‑back task, developed and validated by Brain Behavior Laboratory. (Total task time: ~8 min).

Visual/Spatial-N-Back: 3-back version (VSNB3). The n-back is one of the most commonly used paradigms in neuroimaging studies investigating the neurological underpinnings associated with maintenance and retrieval of information in working memory ([93](#_ENREF_93)). The current study employs a visuo-spatial working memory task that is based on the visuo-spatial n-back paradigms used in prior research ([93-95](#_ENREF_93)). During the n-back, participants are instructed to remember the location of a stimulus, a grey circle that is approximately 5 cm in diameter, as it appears randomly in 8 possible locations around the perimeter of a computer screen. The stimulus will appear for 200 ms, followed by an interstimulus interval (ISI) of 2800 ms. A cross hair will remain visible during the stimulus presentation to cue participants to look at the center of the screen so that all stimuli appearing around the perimeter of the screen can be seen clearly. The n-back task includes 4 conditions of varying difficulty levels: the 0-back, 1-back, 2-back, and 3-back. Participants respond only to targets (30% of stimuli) by pressing the SPACEBAR. They are instructed to do nothing on other trials.

Each of the task conditions (0-, 1-, 2- & 3-back) will be administered in a pseudorandomized counterbalanced order. Each difficulty level will consist of 1 block of 50 trials, preceded by a practice block of 20 trials. During the 0-back, participants are instructed to press the SPACEBAR if the stimulus appears in a predetermined location (designated as the upper left corner of the computer screen. The 0-back serves as a baseline condition of the n-back, during which participants are engaged in a task that does not require storage or manipulation of information in working memory, but is otherwise analogous to the other n-back conditions. During the 1-back, participants are instructed to press the SPACEBAR whenever the stimulus appears in the same location as the stimulus that immediately preceded it and to do nothing if it the stimulus appears in any other location. During the 2- and 3-back conditions, participants are instructed to press the SPACEBAR whenever the stimulus appears in same location as the stimulus that preceded it by 2 or 3 trials, respectively. The primary dependent variables for this task are total number of correct responses and reaction time. Time: approximately 16 min.

Penn Continuous Performance Test - Number/Letter Version (PCPT-nl). The PCPT-nl is a measure of visual attention and vigilance based on the Penn CPT (Kurtz et al., 2001). In this task, a series of red vertical and horizontal lines (7-segment displays) flash in a digital numeric frame (resembling a digital clock). The participant must press the spacebar whenever these lines form complete numbers or complete letters. The task is divided in two parts, each lasting three minutes: in the first part the participant is requested to respond to numbers and in the second part the response is to letters. The participant practices both sets of trials before the task begins. Time: approximately 10 min with practice.

Stop Signal Task. The Stop Signal Task (SST) is a measure of response inhibition, or the ability to inhibit a prepotent response and has been used in previous work with smokers ([96](#_ENREF_96)). In this task, participants are instructed to press labeled keyboard keys as quickly and as accurately as possible to indicate the direction the arrow faced (“z” for left; “/” for right). Following a 32-trial practice, stop signals (an 800-Hz, 100-ms, 70-dB tone) are presented on 25% of trials for a 32-trial practice and three task blocks of 64 trials each. The initial stop delay in each block is 250 ms and adjusts by 50 ms increments depending on whether the participant is able to successfully inhibit a response ([97](#_ENREF_97)). The adjusting stop delay allows the determination of the delay at which inhibition occurs on approximately 50% of trials. All trials consist of a 500-ms warning stimulus followed by a 1,000-ms go signal (left- and right-facing arrows) and 1,000-ms blank screen intertrial interval.

Mean RT for each block is calculated based on valid responses (i.e., RT > 200 ms), and only blocks with 20–80% inhibition and at least 80% accuracy are included in analyses. Stop signal reaction time (SSRT) is the primary dependent variable and is calculated by subtracting the mean stop delay from the mean RT on go-trials. Time: approximately 10 min.

Stroop test. The Stroop test is a measure of interference control, or the ability to screen out distracting stimuli ([98](#_ENREF_98)). In this task, participants view a series of words on a computer monitor and using the keyboard, are asked to press the key associated with the color of the word rather than the word itself. Congruent trials are trials in which the word and color match (e.g., the word “green” appears in the color green). Incongruent trials are trials in which, the words are printed in colors that do not match the colors of the words (e.g., the word "red" might appear in green). The primary outcomes will be the number of correct trials and reaction time (RT) for congruent and incongruent trials. An interference score is also calculated (e.g., RT incongruent – RT congruent), which measures the ability to suppress a habitual response in favor of an unusual one, taking into account overall speed of naming. Time: approximately 5 min.

Color Shape Task: The Color Shape Task is a measure of flexibility. In each trial of this task ([Miyake, Emerson, Padilla, & Ahn, 2004](http://www.ncbi.nlm.nih.gov/pubmed/14962397)), a cue letter (C or S) appears above a colored rectangle with a shape in it (outline of a circle or triangle). Participants are instructed to indicate whether the color is red or green when the cue is C, and whether the shape was a circle or triangle when the cue is S. The colored rectangles are approximately 1.7” wide and 1.4” high, the circles were approximately 1.1” in diameter, and the triangles were 1.25” on each side. The color-shape figure appears in the center of the screen and the cue letters are centered 3/8” above its top edge.

International Personality Item Pool version of the NEO Revised Personality inventory (IPIP NEO PI-R): This 300-item questionnaire is a measure of five major domains of personality, and measures 6 dimensions of each domain. This test is a measure of normal adult personality, and is not diagnostic, nor does it provide a measure of psychopathology. Time: approximately 40 min.

Vividness of Visual Imagery Questionnaire: The VVIQ is a 16-item questionnaire that measures individual differences in vividness of visual imagery. Participants imagine different scenarios and rate their imaginations on a 4-point scale.

Zimbardo Time Perspective Inventory Questionnaire: The ZTPI is a 56 question questionnaire that measures how people project themselves in time according to their orientation and attitudes. Participants rate their agreement with each statement on a 5-point scale.

Dispositional optimism questionnaire/LOTR:  Life orientation test (revised) is a 10-item questionnaire. Participants rate their agreement with each statement on a 5-point scale.

**Primary outcomes:**

fMRI Assessments **weeks -1 and 10**/ computer assessment (out of scanner) **week -1 and 16**:

Neuroimaging studies will be conducted **~weeks -1 and 10*.*** fMRI scans will be performed at UPenn using a Siemens Trio (Erlangen, Germany) 3T scanner and a Siemens product 32-channel head coil optimized for parallel imaging.

We will utilize tasks implemented successfully in prior work and ongoing research with healthy subjects ([51](#_ENREF_51), [52](#_ENREF_52), [99](#_ENREF_99)). As in this prior research, these tasks will be administered while BOLD fMRI is acquired.

*Delay Discounting Task:* In this paradigm, participants choose between a smaller reward available immediately (e.g., $20 today) and a larger reward available after a longer delay (e.g., $40 in a month). In this task, people differ in their degree of *delay* *discounting*, the extent to which they forgo larger monetary magnitudes in the future in order to obtain immediate rewards. As in previous work, the immediate reward will be fixed and the magnitude and delay of the larger, later reward will vary from trial to trial. Subjects will make 144 choices, over three 8 min scans. The primary behavioral outcome will be the subject’s *discount rate.* Discount rates will be estimated by fitting a logistic regression that assumes a person’s decisions are a stochastic function of the difference in subjective value between the two options ([100](#_ENREF_100)). Keeping with standard behavioral findings ([51](#_ENREF_51), [52](#_ENREF_52), [101](#_ENREF_101), [102](#_ENREF_102)), we will assume that subjective value (*SV*) is a hyperbolic function of the reward amount (*A*) and delay (*D*): *SV* = *A*/(1+*kD*), where *k* is the participant’s discount rate. Larger values of *k* indicate a greater degree of discounting future rewards. We predict that training will decrease *k*.

There will be two primary *BOLD signal outcomes* and a third exploratory outcome: (a) Activity in DLPFC: We predict increased engagement of DLPFC after training, for the choice compared to baseline contrast, with an even greater increase specifically on those trials where the subject would have chosen the immediate reward previously; (b) Magnitude and delay responsivity in VS and VMPFC: Parametric regressors will be used to measure the response to the magnitude and delay of the larger, later reward, as this varies from trial-to-trial. Previous work has shown that activity in VS and VMPFC increases with the magnitude of the delayed reward, and decreases with the associated delay ([51](#_ENREF_51), [52](#_ENREF_52)). We predict that the neural sensitivity to delay will be reduced after training, so that high-magnitude delayed rewards will evince a greater response in VS and VMPFC; and (c) We will explore functional connectivity between DLPFC and VMPFC with a psychophysiological interaction (PPI) analysis comparing correlations with VMPFC activity during task compared to baseline epochs ([103](#_ENREF_103)). We expect that the functional connectivity between DLPFC and VMPFC will be increased after training.

*Risk Sensitivity Task:* In this paradigm, participants choose between a smaller reward available with certainty (e.g., 100% chance of $20) and a larger reward that is risky (e.g., 50% of $40). In this task, people differ in their degree of *risk sensitivity*, the extent to which they accept lower probabilities in order to have a chance at larger magnitudes. As in previous work, the certain reward will be fixed and the magnitude and probability of the larger, uncertain reward will vary from trial to trial. Subjects will make 144 choices, over three 8 min scans. The primary behavioral outcome will be the subject’s degree of *risk sensitivity.* Risk sensitivity will be estimated by fitting a logistic regression that assumes a person’s decisions are a stochastic function of the difference in subjective value between the two options. Keeping with standard behavioral findings ([99](#_ENREF_99), [104](#_ENREF_104)), we will assume that subjective value (*SV*) is a power-law function of the reward amount (*A*) and probability (*P*): *SV* = *P*\**Aα* where *α* is the participant’s degree of risk sensitivity. Larger values of *α* indicate a smaller degree of risk sensitivity. We predict that training will decrease α. We recognize that an alternative hypothesis, motivated by findings on cognitive skills ([85](#_ENREF_85)), is that training will shift risk-sensitivities toward risk-neutrality (where α=1 is risk neutrality) rather than decrease α in all subjects. We will be able to test this alternative hypothesis as well.

People’s decisions involving real consequences may differ from those involving purely hypothetical scenarios ([105-107](#_ENREF_105)). This difference may be most pronounced when social expectations are involved ([107](#_ENREF_107)). Because of this, and because we are concerned about the validity of the current paradigms for modeling real-world interventions, participants’ decisions in our experiments will have real consequences.

At the end of each session, one task (Delay Discounting or Risk Sensitivity) will be randomly selected and then one trial will be randomly selected. Participants will receive the item they chose on that randomly selected trial in addition to visit compensation. All payments of immediate and delayed monetary rewards will be made using commercially available pre-paid debit cards, as described in our previous studies of delay discounting ([108](#_ENREF_108)).

The BOLD signal outcomes will be the same as those described above for delay discounting. However, instead of examining activation based on magnitude and delay of the larger delayed reward or the choice of immediate versus delayed, we measure the BOLD response to the magnitude and probability of the larger risky reward and to choices of safe versus risky. Previous work has shown that activity in VS and VMPFC increases with the magnitude of the risky reward, and decreases with the probability ([99](#_ENREF_99)). We predict that the neural sensitivity to probability will be enhanced after training, so that high-magnitude but low-probability rewards will evince a decreased response in VS and VMPFC. We will explore functional connectivity between DLPFC and VMPFC as described above.

**Behavioral Outcome measures.**

*Alcohol Use Disorders Identification Test (AUDIT)*: (weeks -1 & 16)The AUDIT is a 10-item screening measure designed to assess patterns of hazardous, harmful, or depending drinking and has demonstrated good reliability and validity across a range of populations ([109](#_ENREF_109)).

*Alexander* [*Fruit and Vegetable Screener*](http://appliedresearch.cancer.gov/surveys/chis/fvscreener/chis_fvscreener.pdf): (weeks -1, 10 & 16) is intended to measure fruit and vegetable consumption ([110](#_ENREF_110)). This 2 item screener asks respondents for information about their daily intake of fruits and vegetables. No portion size questions are asked.

*Behavioral Inhibition and Behavioral Activation (BIS/BAS)*: (weeks -1, 10 & 16) will be measured with the reliable and valid Behavioral Inhibition Scale and the Behavioral Activation Scale (24 items), respectively ([111](#_ENREF_111), [112](#_ENREF_112)). The Behavioral Inhibition Scale measures sensitivity to possible punishment and the Behavioral Activation Scale measures sensitivity to possible reward. Response options range from 1=very true for me to 4=very false for me.

*Cigarette Consumption, Alcohol and Recreational Drug Use (TLFB)*: (weeks -1, 10 & 16) At Pre-Treatment, Mid-Treatment, Post-Treatment and Follow-up visits daily smoking rate, alcohol and drug use for the past week will be collected using the TLFB ([113](#_ENREF_113)).

*Godin Leisure-Time Physical Activity Questionnaire*: (weeks -1, 5, 10 & 16) a brief, simple, and reliable measure of physical activity that has been widely used in intervention trials ([114](#_ENREF_114)).

*Percentage Fat Screener*: (weeks -1, 5, 10 & 16) A short 17-item assessment instrument to estimate an individual's usual intake of percentage energy from fat. The foods asked about on the instrument were selected because they were the most important predictors of variability in percentage energy from fat among adults in USDA's 1989-91 Continuing Survey of Food Intakes of Individuals (CSFII).

*UPPS-P Impulsivity Scale*:(weeks -1, 10 & 16) The UPPS-P impulsivity scale ([115](#_ENREF_115)) is a 59-item inventory designed to measure five distinct personality pathways to impulsive behavior: Negative Urgency, (lack of) Perseverance, (lack of) Premeditation, Sensation Seeking, and Positive Urgency. The first pathway, Negative Urgency, assesses an individual’s tendency to give in to strong impulses, specifically when accompanied by negative emotions such as depression, anxiety, or anger. The next pathway, (lack of) Perseverance, assesses an individual’s ability to persist in completing jobs or obligations despite boredom and/or fatigue. The third pathway, (lack of) Premeditation assesses an individual’s ability to think through the potential consequences of his or her behavior before acting. The fourth pathway, Sensation Seeking, measures an individual’s preference for excitement and stimulation. The final pathway, Positive Urgency, assesses an individual’s tendency to give in to impulses under conditions of high positive affect ([116](#_ENREF_116), [117](#_ENREF_117)).Each item on the UPPS is rated on a 4-point scale from Strongly Agree to Strongly Disagree.