Published in final edited form as:

J Cogn Enhanc. 2017 December ; 1(4): 513–525. doi:10.1007/s41465-017-0045-0.

Working Memory Training in Adolescents Decreases Laboratory Risk Taking in the Presence of Peers

Gail M. Rosenbaum^a, Morgan A. Botdorf^b, Jamie L. Patrianakos^c, Laurence Steinberg^d, and Jason M. Chein^d

^aDepartment of Psychology, New York University

^bDepartment of Psychology, University of Maryland, College Park

^cDepartment of Psychology, Loyola University Chicago

^dDepartment of Psychology, Temple University

Abstract

Adolescence is a period of heightened risk-taking relative to both adulthood and childhood, due in part to peers' increased influence on adolescent decision making. Because adolescents' choices have harmful consequences, there is great interest in specific interventions that might attenuate risk taking. We hypothesized that it might be possible to reduce adolescent risk taking through an intervention targeting the ability/tendency to engage cognitive control processes. While some studies of Working Memory Training (WMT) have indicated subsequent enhancement of adults' cognitive control abilities, potential impacts on adolescent cognitive control have not been explored. Accordingly, we tested whether four weeks of WMT (relative to Active Control Training, ACT) might increase performance on cognitive control measures and decrease risk-taking in adolescents. Adolescents receiving WMT, compared to those receiving ACT, exhibited some evidence of improved short-term memory performance following the 4-week training period. Improvements did not significantly transfer to performance on basic cognitive control measures. However, on two risk-taking tasks administered at post-training either with or without an anonymous peer audience, adolescents who received WMT evinced suppressed levels of risk taking when observed by peers, an effect not seen in ACT. Further work is needed to more fully characterize the potential of WMT interventions in stemming risk behavior within adolescent samples.

Keywords

Adolescents; Working Memory Training; Risk Taking

Adolescence is a period of heightened risk taking, including increased drug use, reckless driving, and risky sexual behavior (Kann et al., 2012). Despite a considerable body of research delineating the neural, behavioral, and psychosocial underpinnings of adolescent risk behavior, this work has yet to meaningfully influence risk prevention or reduction programs, many of which remain rooted in the discredited assumption that adolescents take risks because they lack the knowledge necessary to evaluate risky circumstances or recognize their vulnerability to negative outcomes. In light of the limited efficacy of extant

risk education programs (Clayton, Cattarello, & Johnstone, 1996; Ennett, Tobler, Ringwalt, & Flewelling, 1994; West & O'Neal, 2004; Wyson & Wright, 1995), researchers concerned with adolescent public health have been exploring new ways to translate foundational knowledge about the origins of adolescent risk behavior to theoretically coherent interventions. Motivated by a neurodevelopmental framework for understanding adolescent risk behavior, and informed by methods arising from the Working Memory Training (WMT) literature, in the present study we examine the use of a cognitive training intervention to enhance adolescents' self-regulatory capabilities and thereby reduce their propensity to engage in risky behaviors.

Our guiding neurodevelopmental framework, typically referred to as the “dual systems” or “imbalance” model (Casey, Galvan, & Somerville, 2016; Shulman et al., 2016; Steinberg, 2008) derives from evidence pointing to the discordant developmental trajectories of two interacting brain systems as the root of adolescents' heightened risk taking. One system, closely associated with reward-related and social-emotional information processing, undergoes dramatic remodeling around the time of puberty, resulting in normative increases in sensitivity to rewards and social inputs in early to middle adolescence. However, a brain system associated with cognitive control and the execution of goal-directed behavior matures along a more protracted trajectory extending well into the early 20s, and supports gradual gains in self-regulatory abilities. Within the dual systems framework, the imbalance between the two systems leads to heightened sensation/reward seeking at a point in development when the individual does not yet possess an adequate capacity to control or constrain impulsive and risky choices.

The notion that adolescent risk behavior partly derives from the relative immaturity of a cognitive control system suggests the possibility that an intervention designed to accelerate or enhance adolescents' ability to recruit and successfully execute control and self-regulatory processes might also decrease risk taking. Though there is considerable controversy over the question of how broadly the skills acquired during WMT may transfer to other cognitive abilities (see, e.g., Melby-Lervåg & Hulme, 2013; Melby-Lervåg, Redick, & Hulme, 2016; Shipstead, Redick, & Engle, 2012), a sizable number of studies have demonstrated some generalized improvements from WMT in performance on measures thought to assess various aspects of self-regulatory control, including response selection, inhibition, planning, and attentional control (Au et al., 2015; Borella, Carretti, Riboldi, & De Beni, 2010; Karbach & Verhaeghen, 2014; Morrison & Chein, 2011; Salminen, Strobach, & Schubert, 2012). Accordingly, we sought to determine whether an intervention based on WMT methods might yield improvements in adolescent self-regulatory processing that would diminish risk taking under conditions that ordinarily encourage it.

Importantly, recent studies suggest that adolescents become capable of mature decision making in affectively neutral (i.e., “cool”) contexts significantly earlier than in affectively challenging (i.e., “hot”) ones (Defoe, Dubas, Figner, & Van Aken, 2015; Figner, Mackinlay, Wilkening, & Weber, 2009). For example, whereas adolescents behave similarly to adults on risk-taking tasks that minimize social and emotional arousal, adolescents take more risks than adults when the task conditions are especially affectively arousing (Figner et al., 2009) or include the presence of peers (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Smith,

Chein, & Steinberg, 2014). Consistent with this experimental evidence, real-world actuarial data show that among adolescents but not adults, dangerous driving and delinquent behavior are elevated by the presence of peers (Simons-Morton et al., 2011; Simons-Morton, Lerner, & Singer, 2005; Zimring, 2000). Thus, an intervention designed to strengthen self-regulatory processes might be most impactful when risk behavior is assessed in affectively or socially arousing situations.

While prior WMT studies provide an important foundation for the present work, it is worth noting that very few WMT studies have been carried out in a healthy and typically developing adolescent sample. Rather, most of the training studies involving adolescents have focused on teens with known WM deficits or with an Attention Deficit Hyperactivity Disorder diagnosis (Sala, Gobet, Sala, & Gobet, 2017; Weicker, Villringer, & Thöne-Otto, 2015). Indeed, a recent meta-analysis (Sala et al., 2017) examining WMT studies in typically developing youth identified only three studies that used neurotypical adolescent participants (Kun, 2007; Pugin et al., 2014; Shavelson, Yuan, & Alonzo, 2008) with participants' mean age in these studies falling between 12 and 14. Since the propensity for heightened risk taking is not limited to adolescents with poor WM or deficient attentional capabilities (though see Romer, Betancourt, Brodsky, & Giannetta, 2012), and seems to reach its peak somewhat later in adolescence (Burnett, Bault, Coricelli, & Blakemore, 2010; de Water, Cillessen, & Scheres, 2014; Gardner & Steinberg, 2005; Mitchell, Schoel, & Stevens, 2008; Paulsen, Carter, Platt, Huettel, & Brannon, 2012), the present work extends the literature by exploring transfer from WMT in a slightly older, neurotypical, community sample of adolescents.

Finally, to our knowledge, no prior WMT study has included laboratory-based risk taking tasks as an assessment measure (though see Bickel, Yi, Landes, Hill, & Baxter, 2011). To address this limitation, we deployed a training protocol combining two established WMT paradigms (n-back and complex WM span training), and tested whether such training would increase cognitive control, and decrease risk-taking, relative to an active control training (ACT) protocol. Participants completed 20 sessions (5 times per week for 4 weeks, approximately 40 minutes in each session) of their respective training program (WMT, ACT), along with a pre-training and post-training assessment. Three task categories were included in the assessment battery: near transfer tasks similar to the trained working memory tasks (i.e. tasks assessing short term/working memory), intermediate transfer tasks assessing cognitive control, and far transfer tasks assessing risk taking and impulsive decision making. We hypothesized, first of all, that teens who completed WMT, relative to ACT, would show greater improvements on near-transfer tasks. Next, despite inconsistency in the cognitive training literature regarding transfer of WMT to cognitive tasks, we hypothesized that adolescents (who generally exhibit weaker cognitive control than do adults) might be especially susceptible to transfer effects in this domain. In order to test cognitive control under conditions of affective arousal, we included two versions of each cognitive control task: one using emotionally neutral stimuli and one using emotionally valenced stimuli. Finally, motivated by the dual systems model (Shulman et al., 2016; Steinberg, 2008), we hypothesized that, by increasing cognitive control through WMT, particularly in the emotional cognitive control tasks, adolescents in the WMT condition would also exhibit a reduced tendency to engage in risk taking in arousing conditions at post-training. To assess

risk behavior under an ecologically relevant affective challenge, participants at post-training completed each risk-taking task twice: once alone, and once under the impression that they were being observed by a same-aged, same-gender peer. This social context manipulation allowed us to test the hypothesis that training benefits might be most prominently displayed under the conditions in which teens are most likely to take risks – when with peers (Albert, Chein, & Steinberg, 2013; Chein, 2015).

Method

Participants

One hundred nine adolescents, ages 13-17 years old ($M=15.40$, $SD=1.41$), were recruited from the urban communities surrounding Philadelphia's city center, through advertisements in schools and community centers. The ethnically diverse sample (61% African American, 14% Caucasian, 16% Asian, 1% American Indian, 6% Other; 2% did not wish to answer) consisted of 62 females and 47 males. Prior to each experimental session, informed parental consent and assent were obtained. Attrition rates were high in the recruited cohort, perhaps due to the extended nature and particular demands of participation in this study, and due to the limited resources (e.g., transportation, access to technology) available to some of the participants. Only 60 participants ($N_{\text{WMT}} = 26$; $N_{\text{ACT}} = 34$) successfully completed the entire training protocol and both of the pre- and post-training assessments. The participants who dropped out of training did not differ from those who completed training with respect to age ($t(107) = .11$, $p = .916$) or gender ($\chi^2(1) = .002$, $p = .960$). The final sample after attrition had a mean age of 15.42 ($SD = 1.41$), and included 26 males and 34 females. Study participants were given the option to be compensated either monetarily or in the form of a refurbished laptop computer that could be kept upon completion of the study. If a participant opted for monetary compensation, he or she received \$30 after an initial pre-training assessment and \$75 after returning to the lab having finished the training regime and the post-training assessment. Participants who chose the laptop compensation signed an agreement to return the laptop in the event that they did not finish the study.

Procedures

The protocol consisted of a pre-training assessment, a 4-week training period, and post-training assessment. At the pre-training assessment, participants completed a 2-hour test battery that included 9 experimental tasks, which are described below. Test-retest reliability, as well as correlations among cognitive tasks, are provided in Tables 1 and 2, respectively. After completion of the battery, participants were given detailed instructions on training procedures, which were to be carried out at home. The at-home training sessions were to be completed 5 days per week, and would last approximately 40 minutes per session. After the participants finished the 20 training sessions, they were asked to return to the lab for the post-training assessment. The post-training assessment was administered in the same counterbalanced task order that participants first encountered during their pre-training assessment, with the addition of an extra round of the three risk-taking/decision making tasks (described further below) performed under a peer observation condition.

Pre-Training Assessment

Short-term and Working Memory

Simple Span: Participants completed both a short-term letter memory and a short-term location memory test, in counterbalanced order. In the location memory portion, participants were presented with a 4×4 grid. During each trial, specific squares in the grid were highlighted in succession, for 1 s each. Following presentation of the highlighted squares, participants were shown a blank grid and were asked to click the sequence of highlighted locations in the order in which they had appeared in the preceding displays. The number of locations started at 3 and increased with each correct trial. When the participant incorrectly recalled the sequence for a given number of locations, he or she was given a second chance to complete a new trial with that same number of locations. The task ended after a participant responded incorrectly to two trials in a row, and their “location span” was defined as the maximum number of locations remembered correctly.

The letter portion followed a design that paralleled the location memory task. Letters appeared one at a time in the center of the computer screen for 1 s each, and participants were instructed to remember the order of the letters shown. After the complete series was presented, participants were asked to recall the letters in their correct order by selecting them from a 4×4 grid that displayed both the presented letters and foils. As in the location span task, the number of to-be-remembered letters increased with each correct trial, and the task ended when the participant reported an incorrect sequence of letters for two trials in a row. The subject’s “letter span” was defined as the maximum number of letters remembered correctly.

Complex Working Memory Span: The automated operation span task (Unsworth, Heitz, Schrock, & Engle, 2005) was also included in the assessment battery. On each trial of this task, participants were shown a series of letters to hold in memory, presented for 1 s each and then immediately followed by a simple arithmetic equation (e.g., $(5 + 3) / 2 = 4$). Participants were asked to judge the veracity of each equation (true/false) before the next letter in the sequence was presented. In order to limit opportunities to engage in rote rehearsal of the letters, the presentation time for the math problems was tailored to each participant based on the speed with which they responded during a practice set of 15 math problems, completed prior to the final assessment task (for more details, see Unsworth et al., 2005). Upon completion of the interleaved letter-math problem sequence, participants were asked to recall the letters in their original order of presentation, by selecting them from a 4×4 grid of letters (as in the simple letter memory task). The length of the letter-math problem sequences ranged from 3 to 7, and participants completed 3 sequences at each length, in random order. A participant’s complex working memory span was computed as the total number of letters recalled in the correct position in a list across all letters presented in the task (75 total).

Cognitive Control

Neutral Go/No-Go: Participants were presented with pictures of automotive vehicles (SUV’s, two-door sports cars, and four-door sedans) and asked to click the mouse button as quickly as possible as each stimulus arrived, but to inhibit responding when an exemplar

from a pre-designated class of vehicles (e.g., SUV's) was shown (i.e. the No-Go stimulus class). By design, "Go" events occurred with higher frequency (2/3 of trials) than "No-Go" events. Vehicle stimuli were used in order to approximately match the relative visual complexity of the face stimuli used in an emotional Go/No-Go task (described below). Each successive stimulus in the task was presented for 500 ms, and trial accuracy and reaction times were recorded.

Participants completed a total of 4 task blocks, comprising 30 trials each, with a different pre-designated No-Go stimulus type in each block: Go = SUV, No-Go = 4-door sedan; Go = 4-door sedan, No-Go = SUV; Go = 2-door sports car, No-Go = 4-door sedan; Go = 4-door sedan, No-Go = 2-door sports car.

Emotional Go/No-Go: An emotional variant of the task paralleled the design of the neutral Go/No-Go, but used emotional face stimuli instead. Specifically, participants were presented with happy, angry, or neutral faces and were asked to click the mouse button every time a specific type of emotional face appeared on the screen (e.g., "click every time you see a happy face"). Participants completed 4 blocks of trials (Go = happy, No-Go = neutral; Go = neutral, No-Go = happy; Go = angry, No-Go = neutral; Go = neutral, No-Go = angry).

Neutral Stroop: In this traditional version of the Stroop task, participants saw the name of a color word (i.e., red, yellow, green, or blue) presented in a colored font (i.e., red, yellow, green, or blue), and were instructed to respond to the word by pressing a colored key that corresponded to the color of the font, ignoring the written word. Congruent trials consisted of written words and font colors that matched (e.g., "yellow" written in yellow font), while incongruent trials presented a written word and font color mismatch (e.g., "yellow" displayed in blue font). After a practice block, participants completed three rounds of 36 trials each. Stimuli were presented for 4 s or until a key was pressed. Half of the trials were congruent and half were incongruent, and trials were randomly intermixed within the three blocks.

Emotional Stroop: An emotional Stroop variant, involving emotion-related words overlaid onto emotionally expressive face images, was adapted from Preston and Stansfield (2008). In particular, each presentation of an angry, happy, or sad face was accompanied by an overlaid adjective that corresponded to one of the three emotion categories. Participants were instructed to respond to the emotion category of the word, while ignoring the expression shown in the picture of the emotional face. Responses were given using a keypad with three keys; marked "A" for angry, "H" for happy, and "S" for sad. For congruent trials, the emotional valence of the face and word matched (e.g., "joyful" overlaid on a happy face). Incongruent trials presented a mismatched face and adjective (e.g., "joyful" overlaid on a sad face). Half of the trials were congruent and half were incongruent within each task block. Each stimulus in the series was presented until a response was made, with no response deadline. After instruction and a brief practice period, participants completed one round of 144 experimental trials.

Findings from data acquired during only the pre-training assessment, based on individual differences in the emotional and neutral Stroop tasks, have been published previously

(Botdorf, Rosenbaum, Patrianakos, Steinberg, & Chein, 2016), without consideration for the effects of training. The present manuscript includes data from only the subset of participants who completed training and both the pre- and post-training assessments.

Risk Taking/Decision Making

Probabilistic Gambling Task: In a probabilistic gambling task (PGT; Smith, Chein, & Steinberg, 2014), participants were presented with a series of independent trials in which they chose to gamble, or not, based on a wheel divided into three pie-shaped sections of varying proportion, which represented the outcome probabilities. A green section indicated the participant's probability of winning 10 tokens, a red section indicated the probability of losing 10 tokens, and a gray section indicated the chance of neither winning nor losing tokens. All participants began the task with an endowment of 100 tokens. On each trial, participants were shown a given wheel and were asked to either play (spin the wheel to reveal the outcome) or to pass (move on to the next offer). Each wheel was presented for 2 s, and if participants did not respond in that time window the program automatically moved to the next trial (i.e. assumed a “pass”). After each trial, a feedback screen indicated whether the participant had won (+10 tokens), lost (-10 tokens), or attained a neutral outcome (0 tokens). Participants played one round of the PGT task, comprised of 42 wheels. Six different gain-to-loss probability ratios, ranging from 1.5 to 0.33, were used in the task, presented in random order. The neutral portion of the wheel was always fixed at either 50% or 10%, and the variably sized gain and loss sections completed the wheel. Risk taking was measured as the percentage of plays for each wheel type, and in following with our previous work using this task (see Smith et al., 2016), choice behavior for relatively “favorable” (higher odds of winning) and “unfavorable” (lower odds of winning) offers were treated separately in analyses. Participants who did not numerically decrease risk taking as the wheel favorability decreased were removed from analyses.

Stoplight Task: The Stoplight task (Chein et al., 2011; Steinberg et al., 2008) is a driving simulation game in which participants must make their way down a straight road as quickly as possible. Along the way, participants encountered a series of intersections (32 in the present implementation). At each intersection, a traffic signal turned yellow (with variable timing) as the participant approached the stoplight, and the player needed to decide whether to continue through the light or to stop (by pressing the spacebar on the keyboard). If a participant stopped, he or she needed to wait 3 seconds for the light to cycle from yellow to red to green. If the participant decided to run the light, he or she could proceed un-delayed through the intersection (and thus reach the end of the course more quickly), but this choice also incurred a risk of crashing into another car. A crash resulted in a 6-second delay in resuming the game. The probability of a crash at each intersection was varied to make the outcomes impossible to predict. Risk taking in this task was indexed as the proportion of intersections on which the participant chose to “run” the light and thus risk crashing.

Delay Discounting: In this task, participants chose between \$1000 at a delay of variable duration and a smaller but immediate reward. Six delay intervals were tested in separate blocks (1 week, 1 month, 6 months, 1 year, 5 years, and 15 years). Within each block, the immediate offer was initialized randomly at either \$200, \$500, or \$800, and the amount of

the immediate offer was then titrated according to participants' choices until the program determined an "indifference point" for that delay interval – a dollar amount reflecting the subjectively discounted value of the delayed \$1000 reward. There were no time constraints to responding in this task. For each participant, a mean indifference point and individual discounting rate (k) was determined (see O'Brien, Albert, Chein, & Steinberg, 2011 for more details). Similar results were obtained using each metric of inter-temporal preference, and only results based on participants' average indifference points are reported below.

Post-Training Assessment and Peer Manipulation

After the conclusion of the 4-week training protocol, participants returned to the laboratory to complete a post-training assessment, which consisted of the same tasks administered at pre-training. The mean number of days between the pre- and post-training assessments was 40.38. All tasks were presented to the participants in the same order in which they were encountered during pre-training. However, to assess vulnerability to peer influences on risk taking behavior, participants additionally played each of the risk-taking/decision-making tasks (PGT, Stoplight, and Delay Discounting) twice; once alone and once while under the belief that they were being observed by an anonymous peer. The order of the peer observation was counterbalanced across participants.

Several steps were taken to implement the peer context manipulation. First, when participants arrived for the post-training session, they were asked to complete a sign-in sheet where they saw that another participant of the same gender (John for males, Jess for females; henceforth referred to as the "peer") was already signed in. The participant was told that the peer was participating in another experiment, but that they may interact later in the study. Then, before completion of the risk-taking tasks, participants were told that the peer would be observing their choices via a closed-circuit computer system, and that the peer's role was to predict participants' choices based on a limited amount of information that was provided through a brief exchange conducted prior to testing. Over a two-way radio, the participants first heard a short introduction from the peer ("Hey, my name is John [Jess, for female participants], I'm [participant's age] years old. My favorite color is blue, and I was born in Philadelphia."). Subsequently, the participants gave their own introduction. Unbeknownst to the participants, the peer was not a real observer, and the exchange between the participant and peer used a prerecorded audio file. At the start of each successive task round, the experimenter reminded the participant and (non-existent) peer that the predictions should be made, and played the peer's prerecorded response over the two-way radio (e.g., "OK, I'm ready now"; "I'm good, go ahead"). Further details of the peer interaction and manipulation are described in Weigard, Chein, Albert, Smith, and Steinberg (2014).

Importantly, because the peer manipulation involves deception and we hoped to make the manipulation as salient and believable as possible, we decided to administer this manipulation only at post-training, where we expected the effect to be largest. While we therefore do not have data regarding susceptibility to the peer manipulation at pre-training, scores on the Resistance to Peer Influence scale (Steinberg & Monahan, 2007) indicated that self-reported history of peer susceptibility did not significantly differ across the WMT and ACT groups at pre-training ($t(52) = .21, p = .834$) or post-training ($t(47) = .15, p = .880$).

Training

Participants were randomly assigned to either the working memory training (WMT) group or to an active control training (ACT) group. Regardless of the assignment, participants were asked to complete 40 minutes of training for each training day, 5 days per week, for 4 weeks. They were also instructed to email daily training results to the experimenter upon completion of each training session. Researchers responded to verify receipt of the files, and tracked the number of sessions completed. If participants failed to email results for two successive training days, researchers followed up via email and phone to discuss the continuation of training.

Working Memory Training

Participants in the working memory training group completed 20 sessions of an adaptive working memory training protocol, which included both a complex working memory span (CWMS; based on Chein & Morrison, 2010) and an n -back (based on Jaeggi, Buschkuhl, Shah, & Jonides, 2014) component. Each component of training lasted for about 20 minutes (for a total training session length of 40 minutes). The order of the training tasks was counterbalanced between participants (i.e., half of participants always completed CWMS followed by n -back, while the other half completed n -back first).

The n -back training task followed the procedures of Jaeggi et al. (2014). In this verbal auditory n -back task, participants heard a series of letters (e.g. B, F, D, G) and were instructed to press the 'A' key if they heard a letter that was presented n letters prior. The task began at $n = 1$ and was adaptive to the participant's performance.

The CWMS training task was modified from the spatial working memory training protocol used in Chein & Morrison (2010). In the task, participants were asked to remember the location of a series of highlighted squares presented sequentially on a 4×4 grid. Interleaved with each square presentation, participants were shown two shapes side-by-side and were asked to determine if the shapes were rotated versions of the same shape, or different shapes (i.e. they performed a series of mental rotation judgments). Once the sequence of location-rotation judgment pairs was completed, participants were asked to recall the location of the highlighted squares by clicking them sequentially on a blank grid. At the initiation of training, the location load was set to 2 items with a single interleaved rotation judgment, and the task was adaptive such that the level of difficulty/load (i.e. number of locations and number of intervening rotation judgments) was adjusted based on performance.

Active Control Training—A comparison group of subjects was assigned to an active control training (ACT) group. These participants completed online trivia quizzes (on the website funtrivia.com) for twenty 40-minute sessions (for additional methods see Richmond, Morrison, Chein, & Olson, 2011). Participants were asked to complete as many quizzes as they could at normal pace in the 40-minute period. To mirror the two separate training tasks used in the WMT group, ACT participants were instructed to complete quizzes from two different categories on the trivia site during each session. Moreover, to parallel the adaptive nature of the WMT condition, at the initiation of training participants were asked to complete only “easy” quizzes (as indicated on the website) and received instructions

throughout the training period to modify the level of quiz difficulty. Researchers had access to, and monitored, the participants' online training accounts to ensure that participants were completing the training as instructed.

Analysis

All analyses were run in SPSS Version 24, and used a two-tailed alpha level of .05. Outliers were defined as those data falling more than twice the interquartile range from the experimental group's mean for any given task, and were excluded from analyses based on that task. Because outliers were removed on a task-by-task basis, the sample size in each analysis varied. The number of participants included from each group for each analysis is listed in the appropriate table. Additionally, due to a computer error, pre-training data from one WMT participant were missing.

The data that support these findings are available from the corresponding author upon reasonable request.

Results

Participants who completed vs. dropped out of training

To understand whether the participants who dropped out and those who finished training differed meaningfully, we ran a series of *t*-tests on task performance at pre-training as a function of whether the participant ultimately finished training. Participants who dropped out performed significantly worse than those who finished on the neutral Go/No-Go task ($t(85.42) = 2.57, p = .012$; corrected for violating homogeneity of variances). The two groups did not significantly differ on any other measures ($p > .05$).

WMT vs. ACT Pre-training performance

WMT and ACT participants who completed training did not significantly differ in performance on any of the near- or intermediate-transfer measures at pre-training ($p > .05$; means provided in Table 3). Among the decision making/risk taking tasks, WMT participants took significantly more risks at pre-training in the PGT for unfavorable offers ($M_{\text{WMT}} = .16; M_{\text{ACT}} = .06; t(25.28) = 2.48, p = .020$; corrected for violating homogeneity of variances).

Near Transfer

Performance on each simple span task was assessed to determine potential near transfer effects of the training paradigm. We first entered location span scores for the WMT and ACT groups into a repeated-measures ANOVA treating assessment time (pre, post) as a within-subjects factor. The assessment time (pre, post) $\times$ condition (WMT, ACT) interaction was significant ($F(1, 56) = 4.08, p = .048$). Based on within-group pairwise contrasts, this interaction was driven by increased location span performance in the WMT group from pre- to post-training (mean improvement = .80 locations, $p = .001$), that was not observed in the active control group (mean improvement = .21 locations, $p = .272$).

A similar, though non-significant, pattern was obtained for the letter span task. A repeated-measures ANOVA indicated a highly significant main effect of assessment time ($F(1, 54) = 16.55, p < .001$), but a non-significant interaction between assessment time and condition ($F(1, 54) = .55, p = .461$). Pairwise comparisons showed that both groups significantly improved in letter memory from pre- to post-training, with a somewhat more sizable improvement being observed in the WMT group (WMT: mean improvement = 1.12 letters, $p = .002$; ACT: mean improvement = 0.77 letters, $p = .016$).

For the operation span task, which involved letter memory interleaved with a processing task (judging the accuracy of math equations), the assessment time by training condition interaction was again not significant ($F(1, 32) = .50, p = .485$) using a standard threshold of 85% accuracy on the math judgments for data inclusion (see e.g., Unsworth et al, 2005). Since this cutoff forced us to exclude a fairly large number of participants, we also repeated the analysis using a less stringent 60% threshold. At this lower threshold, a marginal main effect of assessment time was observed ($F(1, 53) = 3.66, p = .061$), but the interaction of training condition with assessment time was still non-significant ($F(1, 53) = 1.32, p = .255$).

Intermediate Transfer: Cognitive Control

To evaluate performance on the neutral and emotional Go/No-Go tasks, we computed d' for each task at pre- and post-training using a log-linear method (Hautus, 1995). For the neutral version of the task, we did not find a significant interaction between training condition and assessment time ($F(1, 56) < .01, p = .997$), but there was a marginally significant main effect of assessment time ($F(1, 56) = 3.22, p = .078$).

In the emotional Go/No-Go task, there was no significant effect of training condition ($F(1, 57) = 1.64, p = .205$) or assessment time ($F(1, 57) = 1.15, p = .288$) on d' performance, suggesting that neither group improved significantly from pre- to post-training on the emotional Go/No-Go. However, simple pairwise contrasts showed that both WMT and ACT participants increased in performance (but not significantly) from pre- to post-training ($M_{\text{WMT}} = .18, p = .247$; $M_{\text{ACT}} = .18, p = .168$).

Performance on the neutral and emotional Stroop tasks was indexed by the magnitude of the Stroop effect (incongruent RTs – congruent RTs), with a lower score indicating a smaller effect of interference from incongruent stimuli, and thus better performance. Interestingly, there was a marginally significant assessment time by training group interaction for the neutral Stroop task ($F(1, 56) = 3.69, p = .060$), though the interaction was directionally inconsistent with the hypothesis that WMT would yield stronger improvements. Specifically, pairwise comparisons showed that the interaction effect was driven by relative improvements in the ACT group (improvement of 20.12 ms, $p = .062$) that were not observed for WMT participants.

In the emotional Stroop task, there was a significant main effect of assessment time ($F(1, 53) = 6.26, p = .015$), such that both groups showed a smaller interference effect at post-training relative to pre-training, but the training group by assessment time interaction again did not approach significance ($F(1, 53) = .62, p = .435$).

Far Transfer: Risk Taking/Decision Making

Performance on the PGT, Stoplight, and Delay Discounting tasks was assessed to determine if a training benefit might extend to such tasks, especially when tested under the affective challenge of a peer observation. As described in the methods section, at post-training, participants completed the tasks once alone and again while being observed by an anonymous peer audience (in counterbalanced order). Results are summarized in Table 4 and Figures 1 and 2.

For all three assessment tasks we first conducted a repeated-measures ANOVA, again treating training condition (WMT, ACT) as a between subjects factor and assessment time (pre, post) as a within subjects factor, considering only performance in the alone condition at post-training. No significant interactive effects with training condition were observed (all p s $> .05$). However, on the Stoplight task, there was a main effect of assessment time, such that both groups of participants took significantly fewer risks at post-training than they had at pre-training ($F(1, 53) = 5.02, p = .029$). Meanwhile, the reverse pattern was observed on the PGT, for which there was a significant assessment time by wheel type interaction ($F(1, 47) = 7.81, p = .007$), with participants in both groups taking more risks at post-training in the alone condition than at pre-training.

We next conducted analyses exploring differences in adolescents' vulnerability to peer influence following WMT relative to ACT. For the PGT, proportion of plays at post-training was entered into a training condition (WMT, ACT) $\times$ social context (observed, unobserved) $\times$ wheel type (favorable, unfavorable) repeated-measures ANOVA. This analysis produced a significant three-way interaction ($F(1,49) = 5.62, p = .022$). Simple main effects contrasts indicated that participants in the WMT group took fewer risks when they were observed by peers than when they were unobserved, specifically when presented with unfavorable (i.e. risky) gambles ($M = -0.16; p < .001$; Figure 1). In contrast, the ACT group did not show differences in risk taking based on social context for either the favorable or unfavorable wheels (p s $> .3$; Figure 1).

To analyze performance on the Stoplight task, we conducted a repeated-measures ANOVA on the proportion of lights run in the peer vs. the alone contexts, as a function of training condition. Similar to the PGT results, there was a significant social context by training group interaction ($F(1,54) = 4.09, p = .048$). Again, this interaction was driven by a significant decrease in risk taking for the WMT participants in the peer context ($M = .14$) relative to the alone context ($M = .20; p = .046$; Figure 2), an effect not seen in the ACT participants ($p = .494$).

Last, we explored whether the training groups differed in their impulsive decision making in the presence of peers, as indexed by Delay Discounting. We computed the mean indifference point for each participant, and entered these values into a repeated-measures ANOVA. Results were directionally consistent with those from the PGT and Stoplight in indicating less impulsive decision making among the WMT group under peer observation. Namely, WMT participants exhibited a numerically higher average indifference value in the presence of peers ($M = 570.51$) relative to when they were alone ($M = 538.29$). However, the effect was not significant for the social context (observed, unobserved) $\times$ condition (WMT, ACT)

interaction ($F(1,56) = 1.10, p = .299$) or for the pairwise comparison of performance across social contexts within the WMT group ($p = .315$).

Discussion

The present study assessed the effectiveness of a working memory training (WMT) paradigm in a typically developing mid-adolescent sample that was recruited from an urban community. The design included tasks to index varying degrees of potential transfer (near, intermediate and far). Guided by the dual systems model of adolescent risk taking (Steinberg, 2008), which suggests that heightened risk taking during this phase of life is partially a function of limited self-regulatory skills, we tested whether an increase in cognitive control, and a concomitant decrease in risk taking (especially in the presence of peers) might emerge as a result of targeted WMT. Results provided some support for key hypotheses, but also included several outcomes that are more difficult to explain within this framework.

Encouragingly, we found a significant increase in location memory in association with WMT, but not in ACT, along with an increase in letter memory that was numerically, but not significantly, larger in the WMT than the ACT group. These results provide some indication that among adolescents, as with adults included in prior studies, WMT training may generalize to performance benefits on near transfer tasks similar to those included in the training protocol. More crucially, and consistent with our framework, we also found that, during the post-training assessment, those in the WMT group took fewer risks under peer observation, relative to when they were alone. This pattern of results was evident on both the PGT and the Stoplight task, and a directionally similar (though non-significant) outcome was observed for choice impulsivity as indexed by Delay Discounting.

However, a less encouraging result emerged from the cognitive control assessments. We found no evidence of any benefit from WMT to performance on either a Go/No-Go task or a Stroop task, under neutral or emotionally valenced conditions. The absence of transfer to these tasks is somewhat inconsistent with findings from prior WMT studies (see e.g., Chein & Morrison, 2010), and more importantly, presents a challenge for interpretation of the overall findings. Specifically, we hypothesized that heightened cognitive control would account for decreased risk taking following WMT. While the WMT group improved on the emotional Go/No-Go, and the ACT group did not, this comparison did not reach significance. Further, and contrary to our expectation, only the ACT group exhibited a significant pre- to post-training improvement on the neutral Stroop task, whereas the WMT group did not show a significant improvement on this task. Additionally, on the emotional Stroop and neutral Go/No-Go tasks, analysis of assessment time suggested that both groups showed similar improvements from pre- to post-training. While we had anticipated that the use of emotionally salient stimuli in these cognitive control tasks might amplify training benefits, the two training groups showed a similar degree of improvement on the emotional Stroop task, and no significant improvements in emotional Go/No-Go performance. Thus, the findings from these intermediate transfer measures call into question the notion that the reduced vulnerability to peers observed in the risk-taking measures resulted specifically from the enhancement of cognitive control. It is therefore clear that the present data are not

adequate to render specific support for the dual systems-driven hypothesis that increases in cognitive control explain lower risk taking in the presence of peers. However, the direction of the results hints that with a larger group of WMT trained participants, the increase in emotional Go/No-Go performance would have likely reached significance.

Further, while these cognitive control tasks have been widely used in the developmental literature, and past studies using these measures have lent support to the dual systems model (e.g. Aïte et al., 2016; Botdorf et al., 2016; Somerville, Hare, & Casey, 2012), the individual tasks may have only limited sensitivity to measure-specific aspects of cognitive control and training. In this regard, it is noteworthy that SDs for performance on the Stroop tasks were quite large, and that the test-retest reliability for the cognitive control measures within this sample was relatively low. It is also worth pointing out that, although performance on the emotional Stroop was not significantly different at pre-training between the WMT and ACT groups, WMT participants on average performed well on the emotional Stroop task (i.e., the mean interference effect was quite low) both pre- and post-training. Therefore, it is possible that ceiling effects prevented the task from indexing the effects of training. If measurement error or ceiling effects explain the lack of transfer, a different cognitive control task (or a version of the same task with different parameters, e.g., a more stringent RT limit or different balance between congruent/Go and incongruent/NoGo trials) might have been more effective at detecting a training-related change. Therefore, changes in cognitive control not detected with these tasks could still be responsible for the WMT group's lower risk taking in the presence of peers.

It is also critical to point out that we chose only to implement the peer manipulation at post training. We were concerned that including this manipulation at the pre-training session could have altered participants' expectations about the purpose of training. Such altered expectations about the training and decision making tasks had the potential to change the demand characteristics of the tasks, rendering the manipulation less believable or less salient at post-training. As a result of this decision, we did not obtain baseline risk taking levels in the peer condition. Results from the Resistance to Peer Influence (RPI; Steinberg & Monahan, 2007) scale, which indicated no differences between ACT and WMT participants at pre-training, provide some confirmation that the two groups should have reacted similarly to the peer manipulation at baseline. However, we should be cautious in interpreting reduced risk taking under peer observation in the WMT group at post-test as the specific consequence of training, since we do not know for certain whether WMT participants would not have taken fewer risks in the peer condition at pre-training.

Another important caveat concerns the high participant attrition rate. Despite our best efforts to motivate and maintain continuous contact with participants, and to reach out to those individuals who were slow in completing and logging their training efforts, almost half of the initially recruited participant sample ultimately dropped out of the study. This high rate of attrition resulted in a considerably smaller than anticipated final sample. Accordingly, it is likely that some of the non-significant results reported in this study would have been more suitably powered, and thus reached statistical significance, in a larger sample.

To make a broader point, we believe our experiences in managing the sample in this study underscore how difficult it can be to execute a training intervention of this type in a sample of community youth. Adolescence is a difficult period for an at-home training paradigm like the one we attempted to implement and test. By this age, most adolescents experience (and demand) an increase in autonomy, and their commitment to research participation comes without the benefit of parental monitoring. Such expected autonomy was obvious in our sample, as evidenced by the fact that very few of our participants' parents were involved in the study beyond the point of signing the consent form (e.g., only a handful escorted their children to the assessment sessions, and few made direct contact with the study team). As mentioned in the introduction, most previous studies of WMT in adolescents have been carried out in teens with ADHD or known executive functioning disorders. In such contexts, parents may be more motivated to engage with their teens and to monitor their continued involvement in an intervention. Moreover, while some participants indicated that they were dropping out of training in order to have adequate time to complete homework or attend tutoring (and we thought it would be unethical to encourage further involvement in the training study when school work may have been compromised), others seemed to simply lose track of their commitment to the study. If such cases are interpreted as an expected manifestation of the limited self-regulatory capacity possessed by these individuals, it is quite possible that those who might have benefitted most from the training were also the ones who were most likely to drop out. This interpretation is supported by poorer initial Go/No-Go performance among those who eventually dropped out compared to those who completed the study. Thus, while we specifically sought out the cohort used in this study in order to impart greater generalizability to the work, it seems likely that a more extended and well-resourced effort, and perhaps one that also engages participants' parents, would yield a more adequate assessment of the potential value of this training approach in a normative community sample.

The challenges we encountered in implementing a training study within this community adolescent cohort, and the mixed evidentiary support that we obtained for our mechanistic framework (e.g., modest evidence of near transfer and no evidence of selective transfer to measures of cognitive control), give us pause in rendering any strong conclusions from the findings. Nevertheless, in light of some promising findings relating to participants' suppression of risk behavior under peer observation following WMT, we remain hopeful that an intervention targeting the still immature self-regulatory abilities of adolescents might yet prove to be a fruitful approach toward mitigating the costly risk behaviors that are so common in this age group.

Acknowledgments

This work was supported by an R21 from the National Institute on Drug Abuse (DA031436) awarded to JMC and LS. We would also like to thank Drs. Susanne Jaeggi and Martin Buschkuhl for the use of their *n*-back task.

References Cited

Aïte A, Cassotti M, Linzarini A, Osmont A, Houdé O, Borst G. Adolescents' inhibitory control: keep it cool or lose control. *Developmental Science*. 2016 Jan.:1–9.

- Albert D, Chein JM, Steinberg L. The Teenage Brain: Peer Influences on Adolescent Decision Making. *Current Directions in Psychological Science*. 2013; 22(2):114–120. [PubMed: 25544805]
- Au J, Sheehan E, Tsai N, Duncan GJ, Buschkuehl M, Jaeggi SM. Improving fluid intelligence with training on working memory: a meta-analysis. *Psychonomic Bulletin & Review*. 2015; 22:366–377. [PubMed: 25102926]
- Bickel WK, Yi R, Landes RD, Hill PF, Baxter C. Remember the future: Working memory training decreases delay discounting among stimulant addicts. *Biological Psychiatry*. 2011; 69(3):260–265. [PubMed: 20965498]
- Borella E, Carretti B, Riboldi F, De Beni R. Working memory training in older adults: evidence of transfer and maintenance effects. *Psychology and Aging*. 2010; 25(4):767. [PubMed: 20973604]
- Botdorf M, Rosenbaum GM, Patrianakos J, Steinberg L, Chein JM. Adolescent risk-taking is predicted by individual differences in cognitive control over emotional, but not non-emotional, response conflict. *Cognition and Emotion*. 2016; 9931(April):1–8.
- Burnett S, Bault N, Coricelli G, Blakemore SJ. Adolescents' heightened risk-seeking in a probabilistic gambling task. *Cognitive Development*. 2010; 25(2010):183–196. [PubMed: 20689728]
- Casey BJ, Galvan A, Somerville LH. Beyond simple models of adolescence to an integrated circuit-based account: A commentary. *Developmental Cognitive Neuroscience*. 2016; 17:128–130. [PubMed: 26739434]
- Chein J. Peers and Adolescent Risk Taking. *Emerging Trends in the Social and Behavioral Sciences* Edited. 2015:1–13.
- Chein J, Albert D, O'Brien L, Uckert K, Steinberg L. Peers increase adolescent risk taking by enhancing activity in the brain's reward circuitry. *Developmental Science*. 2011; 14(2):F1–10. [PubMed: 21499511]
- Chein J, Morrison A. Expanding the mind's workspace: training and transfer effects with a complex working memory span task. *Psychonomic Bulletin & Review*. 2010; 17(2):193–199. [PubMed: 20382919]
- Clayton R, Cattarello A, Johnstone B. The Effectiveness of Drug Abuse Resistance Education (Project. *Preventative Medicine*. 1996; 31825:307–318.
- de Water E, Cillessen AHN, Scheres A. Distinct age-related differences in temporal discounting and risk taking in adolescents and young adults. *Child Development*. 2014; 85(5):1881–1897. <http://doi.org/10.1111/cdev.12245>. [PubMed: 24749521]
- Defoe IN, Dubas JS, Figner B, Van Aken MAG. A Meta-analysis on Age Differences in Risky Decision Making : Adolescents versus Children and Adults. *Psychological Bulletin*. 2015; 141(1): 29.
- Ennett ST, Tobler NS, Ringwalt CL, Flewelling RL. How effective is drug abuse resistance education? A meta-analysis of project DARE outcome evaluations. *American Journal of Public Health*. 1994; 84(9):1394–1401. [PubMed: 8092361]
- Figner B, Mackinlay RJ, Wilkening F, Weber EU. Affective and deliberative processes in risky choice: age differences in risk taking in the Columbia Card Task. *Journal of Experimental Psychology Learning, Memory, and Cognition*. 2009; 35(3):709–30.
- Gardner M, Steinberg L. Peer influence on risk taking, risk preference, and risky decision making in adolescence and adulthood: an experimental study. *Developmental Psychology*. 2005; 41(4):625–35. [PubMed: 16060809]
- Hautus MJ. Corrections for extreme proportions and their biasing effects on estimated values of d' *Behavior Research Methods, Instruments, & Computers*. 1995; 27(1):46–51.
- Jaeggi SM, Buschkuehl M, Shah P, Jonides J. The role of individual differences in cognitive training and transfer. *Memory & Cognition*. 2014; 42(3):464–480. [PubMed: 24081919]
- Kann L, Kinchen S, Shanklin SL, Flint KH, Kawkins J, Harris WA, et al. Zaza S. Youth risk behavior surveillance--United States, 2011. *Morbidity and Mortality Weekly Report Surveillance Summaries* (Washington, DC: 2002). 2012; 61(4):1–168.
- Karbach J, Verhaeghen P. Making working memory work: a meta-analysis of executive-control and working memory training in older adults. *Psychological Science*. 2014; 25(11):2027–37. [PubMed: 25298292]

- Kun Y. Impact of computerized cognitive training on working memory, fluid intelligence, science achievement (Doctoral Dissertation). 2007
- Melby-Lervåg M, Hulme C. Is working memory training effective? A meta-analytic review. *Developmental Psychology*. 2013; 49(2):270–291. [PubMed: 22612437]
- Melby-Lervåg M, Redick T, Hulme C. Working Memory Training Does Not Improve Performance on Measures of Intelligence or Other Measures of “Far Transfer”: Evidence from a Meta-Analytic Review. *Perspectives on Psychological Science*. 2016; 11(4):512–534. [PubMed: 27474138]
- Mitchell SH, Schoel C, Stevens AA. Mechanisms underlying heightened risk taking in adolescents as compared with adults. *Psychonomic Bulletin & Review*. 2008; 15(2):272–277. [PubMed: 18488639]
- Morrison AB, Chein JM. Does working memory training work? The promise and challenges of enhancing cognition by training working memory. *Psychonomic Bulletin & Review*. 2011; 18(1): 46–60. [PubMed: 21327348]
- O'Brien L, Albert D, Chein J, Steinberg L. Adolescents Prefer More Immediate Rewards When in the Presence of their Peers. *Journal of Research on Adolescence*. 2011; 21(4):747–753.
- Paulsen DJ, Carter RM, Platt ML, Huettel SA, Brannon EM. Neurocognitive Development of Risk Aversion from Early Childhood to Adulthood. *Frontiers in Human Neuroscience*. 2012; 5(January):1–17.
- Preston SD, Stansfield RB. I know how you feel: task-irrelevant facial expressions are spontaneously processed at a semantic level. *Cognitive, Affective & Behavioral Neuroscience*. 2008; 8(1):54–64.
- Pugin F, Metz AJ, Stauffer M, Wolf M, Jenni OG, Huber R. Working memory training shows immediate and long-term effects on cognitive performance in children and adolescents. *F1000Research*. 2014; (0):1–10. [PubMed: 24715972]
- Richmond LL, Morrison AB, Chein JM, Olson IR. Working memory training and transfer in older adults. *Psychology and Aging*. 2011; 26(4):813–822. [PubMed: 21707176]
- Romer D, Betancourt LM, Brodsky NL, Giannetta JM. Does Adolescent Risk Taking Imply Weak Executive Function? A Prospective Study of Relations between Working Memory Performance, Impulsivity, and Risk Taking in Early Adolescence. *Developmental Science*. 2012; 14(5):1119–1133.
- Sala G, Gobet F. Working Memory Training in Typically Developing Children: A Meta-Analysis of the Available Evidence. *Developmental Psychology*. 2017
- Salminen T, Strobach T, Schubert T. On the impacts of working memory training on executive functioning. *Frontiers in Human Neuroscience*. 2012; 6:1–14. [PubMed: 22279433]
- Shavelson, R., Yuan, K., Alonzo, A. On the impact of computerized cognitive training on working memory and fluid intelligence. In: Berliner, DC., Kuppermintz, H., editors. *Contributions of educational psychology to changing institutions, environments, and people*. New York, NY: Routledge; 2008. p. 1-11.
- Shipstead Z, Redick TS, Engle RW. Is working memory training effective? *Psychological Bulletin*. 2012; 138(4):628–654. [PubMed: 22409508]
- Shulman EP, Smith AR, Silva K, Icenogle G, Duell N, Chein J, Steinberg L. The dual systems model: Review, reappraisal, and reaffirmation. *Developmental Cognitive Neuroscience*. 2016; 17(2015): 103–117. [PubMed: 26774291]
- Simons-Morton B, Lerner N, Singer J. The observed effects of teenage passengers on the risky driving behavior of teenage drivers. *Accident Analysis and Prevention*. 2005; 37(6):973–982. [PubMed: 15921652]
- Simons-Morton B, Ouimet MC, Zhang Z, Klauer S, Lee SE, Wang J, et al. Dingus TA. The Effect of Passengers and Risk-Taking Friends on Risky Driving and Crashes/Near Crashes Among Novice Teenagers. *Journal of Adolescent Health*. 2011; 49(6):587–593. [PubMed: 22098768]
- Smith AR, Chein J, Steinberg L. Peers increase adolescent risk taking even when the probabilities of negative outcomes are known. *Developmental Psychology*. 2014; 50:1564–8. [PubMed: 24447118]
- Somerville LH, Hare T, Casey B. Frontostriatal maturation predicts cognitive control failure to appetitive cues in adolescents. *Journal of Cognitive Neuroscience*. 2012; 23(9):2123–2134.
- Steinberg L. A Social Neuroscience Perspective on Adolescent Risk-Taking. *Developmental Review*. 2008; 28(1):78–106. [PubMed: 18509515]

- Steinberg L, Albert D, Cauffman E, Banich M, Graham S, Woolard J. Age differences in sensation seeking and impulsivity as indexed by behavior and self-report: evidence for a dual systems model. *Developmental Psychology*. 2008; 44(6):1764–78. [PubMed: 18999337]
- Steinberg L, Monahan KC. Age Differences in Resistance to Peer Influence. *Developmental Psychology*. 2007; 43(6):1531–1543. [PubMed: 18020830]
- Unsworth N, Heitz RP, Schrock JC, Engle RW. An automated version of the operation span task. *Behavior Research Methods*. 2005; 37(3):498–505. [PubMed: 16405146]
- Weicker J, Villringer A, Thöne-Otto A. Can impaired working memory functioning be improved by training? A meta-analysis with a special focus on brain injured patients. *Neuropsychology*. 2015; 30(2):1–23.
- Weigard A, Chein J, Albert D, Smith A, Steinberg L. Effects of anonymous peer observation on adolescents' preference for immediate rewards. *Developmental Science*. 2014; 17(1):71–8. [PubMed: 24341973]
- West SL, O'Neal KK. Project D.A.R.E. outcome effectiveness revisited. *American Journal of Public Health*. 2004; 94(6):1027–1029. [PubMed: 15249310]
- Wysong E, Wright DW. A Decade of DARE: Efficacy, Politics and Drug Education. *Sociological Focus*. 1995; 28(3):283–311.
- Zimring, FE. *American Youth Violence*. Oxford University Press; 2000.

Figure 1.

Peer effect (risk taking in peer – alone context) by training group social context and wheel type in the Probabilistic Gambling Task (PGT). WMT = Working Memory Training; ACT = Active Control Training. *** $p < .001$

Figure 2.

Peer effect in the stoplight task (lights run in peer – alone social context). WMT = Working Memory Training; ACT = Active Control Training. * $p < .05$

Table 1

Test-retest reliability of cognitive measures

	Location Span	Letter Span	Complex Span	Neutral GNG	Emotional GNG	Neutral Stroop	Emotional Stroop
Correlation	.732	.089	.719	.479	.596	.433	.215
Significance	<.001	.513	<.001	<.001	<.001	.001	.115
N	58	56	34	57	59	58	55

Note. GNG = Go/No-Go.

Table 2

Correlations (Ns) across tasks at pre- and post-training

	Letter Span	Complex Span	Neutral GNG	Emotional GNG	Neutral Stroop	Emotional Stroop
Location Span	.198 (.53)	.282 (.34)	-.091 (.52)	.205 (.54)	-.034 (.53)	-.203 (.51)
Letter Span		.209 (.34)	.145 (.51)	.127 (.53)	-.088 (.52)	.093 (.50)
Complex Span			-.013 (.33)	-.044 (.34)	-.131 (.33)	-.182 (.33)
Pre-Training				.303* (.52)	-.042 (.51)	-.085 (.49)
Emotional GNG					-.099 (.53)	-.292* (.51)
Neutral Stroop						.056 (.50)
Location Span	.346* (.53)	.18 (.35)	-.011 (.52)	.063 (.54)	.023 (.53)	-.13 (.51)
Letter Span		.409* (.35)	-.008 (.51)	.212 (.53)	.087 (.52)	-.124 (.50)
Complex Span			-.04 (.34)	.389* (.35)	-.197 (.34)	.055 (.34)
Post-Training				.262 (.53)	-.054 (.52)	.242 (.50)
Neutral GNG					-.334* (.54)	-.09 (.52)
Emotional GNG						
Neutral Stroop						-.004 (.51)

Note. GNG = Go/No-Go.

* $p < .05$.

Table 3
Task performance at pre- and post-training by training condition

Task Index	WMT					ACT		
	N	Mean (SD)	Pre-training	Mean (SD)	Post-Training	Post - Pre- Training (Significance)	Mean (SD)	Post-Training (Significance)
Location Span # <i>Locations remembered</i>	25	6.84 (1.62)		7.64 (1.50)		0.80 ($p = .001$)	6.67 (1.38)	6.88 (1.60)
Letter Span # Letters <i>remembered</i>	25	6.36 (1.22)		7.48 (1.61)		1.12 ($p = .002$)	6.39 (0.95)	7.16 (1.32)
Complex Span Total <i>Letters remembered</i>	15	55.93 (15.66)		55.00 (16.56)		-0.93 ($p = .748$)	49.53 (13.53)	51.32 (13.71)
Neutral GNG d'	24	2.07 (0.39)		2.25 (0.87)		0.18 ($p = .247$)	2.09 (0.66)	2.27 (0.81)
Emotional GNG d'	25	2.07 (0.48)		2.23 (0.80)		0.17 ($p = .127$)	2.16 (0.46)	2.15 (0.54)
Neutral Stroop <i>Interference effect, ms</i>	24	67.40 (50.47)		78.80 (75.18)		11.40 ($p = .368$)	74.85 (57.39)	54.74 (52.08)
Emotional Stroop <i>Interference effect, ms</i>	24	22.68 (78.99)		4.05 (60.97)		-18.62 ($p = .259$)	49.66 (65.95)	13.93 (44.48)
PGT Favorable Risk Rate	23	.76 (.16)					.72 (.20)	
PGT Unfavorable Risk Rate	23	.16 (.20)					.06 (.06)	
Stoplight Risk Rate	24	.26 (.12)					.25 (.12)	
Delay Discounting Mean <i>Indiff Pt.</i>	25	482.59 (192.65)					506.22 (179.91)	

Note. Post-training means for risk-taking and decision-making tasks are listed in Table 4 by social condition. GNG = Go/No-Go, PGT = Probabilistic Gambling Task.

Table 4

Peer effects in PGT, Stoplight, and Delay Discounting at post-training.

Task	WMT				ACT			
	N	Mean (SD) Alone	Mean (SD) Peer	Peer Effect (Significance)	N	Mean (SD) Alone	Mean (SD) Peer	Peer Effect (Significance)
PGT Favorable Risk Rate	20	.77 (.17)	.76 (.16)	-.01 ($p = .702$)	31	.71 (.18)	.71 (.18)	<.01 ($p = .903$)
PGT Unfavorable Risk Rate	20	.24 (.24)	.07 (.10)	-.16 ($p < .001$)	31	.13 (.18)	.09 (.15)	-.03 ($p = .331$)
Stoplight Risk Rate	22	.20 (.15)	.14 (.09)	-.06 ($p = .046$)	34	.21 (.17)	.23 (.19)	.02 ($p = .494$)
Delay Discounting Mean Indiff Pt.	24	538.29 (262.00)	570.51 (248.29)	32.22 ($p = .315$)	34	524.67 (253.72)	513.33 (241.64)	-11.33 ($p = .673$)