THE EFFECTS OF WORKING MEMORY TRAINING ON CIGARETTE SMOKING

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ABSTRACT

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This research addresses how improving working memory capacity could assist daily smokers to reduce cigarette smoking. The relationship between working memory capacity and reducing cigarette smoking may be moderated by automaticity. Six participants, classified as daily smokers via carbon monoxide breath samples, were recruited from Texas State University–San Marcos and were randomly assigned to a treatment or control group. Measures of cigarette dependence, automaticity, and withdrawal were taken from each participant. The treatment and control groups were assigned to a difficult or easy level of working memory training, respectively. This study had a 100% attrition rate; therefore, only descriptive statistics were available. Past literature on the implications of improving working memory to reduce unhealthy habits is promising. If completion rates can be improved, this study deserves further investigation.

INTRODUCTION

Cigarette smoking has been identified as the leading cause of preventable mortality and premature mortality in the United States, and smoking is the leading cause of one in five deaths (Center for Disease Control, 2011). In 2010, the Center for Disease Control (CDC) estimated that 19.6% of adults smoke cigarettes. Despite these devastating statistics, smoking prevalence rates remain high because once an individual smokes regularly, it is unlikely that he or she will be able to quit easily because of the nicotine withdrawal syndrome (Heishman, Taylor, and Henningfield, 1994; Sherwood, 1993).

When attempting to achieve abstinence from smoking, conflicts can arise between automatic impulses and current goals (Strack and Deutsch, 2004; Kahneman, 2003). Beginning with the work of Tiffany (1990), dual-process models of addiction have proposed a distinction between at least two different types of processes. One set of processes is considered to be faster, more spontaneous, automatic, associative, or implicit, while the other set of cognitive processes is more controlled, reflective, deliberate, or executive in nature. In a study of impulsivity and nicotine dependence, Hogarth (2011) found that impulsivity confers a propensity for automatic control of drug-taking, in line with Tiffany (1990) and one of the more spontaneous and automatic sets of processes.

Recent research has expanded support for the view that multiple, cognitive–motivational processes play a role in substance use (Bechara and Damasio, 2002) as well as other behaviors (Kahneman, 2003). Strack and Deutsch (2004) indicate that long-term goals reside in a slow-acting, low-capacity, controlled reflective system. When automatic impulses and personal goals collide, maintaining goal-directed behavior requires that impulses be inhibited, and this ability to stop or override automatic impulses is referred to as executive control or executive functioning (McCabe, Roediger, McDaniel, Balota, and Hambrick, 2010).

Executive control refers to a collection of cognitive functions, such as planning, attention, memory, initiating appropriate actions, and inhibiting inappropriate actions (McCabe, Roediger, McDaniel, Balota, and Hambrick, 2010). These cognitive functions allow people to take goal-directed actions from the endless possibilities given to them by real-life situations (Baddeley and Della Salla, 1996; Baddeley, 1986; Norman and Shallice, 1986). Executive function deficits are also associated with a large number of substance use disorders, including alcohol and marijuana abuse (Sofuoglu, Sugarman, and Carroll, 2010; Verdejo-Garcia, Lawrence, and Clark, 2008).

In some recent dual-process models, spontaneous and executive processes may interact. One specific model of executive functioning that is relevant to this interplay is the executive attention view of working memory capacity (WMC), which has construct validity support across psychometric and neural domains (Kane and Engle, 2002). In this model, working memory maintains information (e.g., goals and behavioral options) in an active state, especially in the presence of interference.

Individual differences in WMC are associated with a range of complex cognitive tasks such as reading comprehension and reasoning (Kane and Engle, 2002) and are likely to influence decisions about substance use. Barrett, Tugade, and Engle (2004) suggested that the ability to control attentional resources (i.e., WMC) can moderate the effects of automatic cognitive processes. The automatic activation of associations by environmental cues occurs naturally among all persons, but those activated mental representations are more likely to influence behavior among individuals with lower WMC.

For those higher in WMC, more top-down, goal-directed attentional resources are available to (a) suppress the influence of associative tendencies when they interfere with other active goal states, (b) maintain long-term goals in the face of a stimulus, (c) draw on more knowledge concerning potential short- versus long-term outcomes, and (d) apply one of several cognitive processing strategies to resolve the goal conflict (Grenard, Ames, Wiers, Thush, Sussman, and Stacy, 2008; Wiers and Stacy, 2006; Stacy, Ames, and Knowlton, 2004).

Compared with people who do not abuse alcohol, chronic heavy users of alcohol show lower levels of executive functioning, including lower levels of response inhibition (Noel, Bechara, Dan, Hanak, and Verbanck, 2007; Noel et al., 2005) and working memory (Goudriann, Oosterlaan, de Beurs, and van der Brink, 2005; Bechara and Martin, 2004). As in the case of alcohol abusers, chronic cigarette smoking, abrupt withdrawal, and acute smoking or nicotine administration can affect performance on tests of working memory, although the results have been inconsistent (Heishman, Henningfield, and

Singleton, 2002; Rezvani and Levin, 2001; Pritchard and Robinson, 1998; Heishman, Snyder, and Henningfield, 1993).

Some studies have shown that heavy smokers have lower WMC. Grenard, Ames, Wiers, Thush, Sussman, and Stacy (2008) also found that drug- related associations are stronger predictors of cigarette use among those with lower WMC than those with higher WMC. These findings are consistent with dual-process theories and with the hypothesis that higher WMC moderates the effects of spontaneous drug-related associations (Barrett, Tugade, and Engle, 2004; Stacy, Ames, and Knowlton, 2004). In line with dual-process models (Duetsch and Strack, 2006; Strack and Duetsch, 2004), these findings suggest that automatic impulses to smoke cannot be properly regulated when executive functioning is low, and also that smoking behavior is guided more strongly by impulses than by controlled processes.

From these conclusions, one would expect that heavy smokers could benefit from interventions that strengthen executive control. This possibility will be examined in this study. Training working memory as a way of improving executive control is focused on for two reasons. First, working memory can be improved via adaptive and extensive training procedures (Jaeggi, Buschkuehl, Jonides, and Shah, 2011; Jaeggi, Studer-Luethi, Buschkuehl, Su, Jonides, and Perrig, 2010; Feiyue, Qinqin, Liying, and Lifang, 2009; Jaeggi, Buschkuel, and Perrig, 2008). Second, individual differences in WM correspond to fundamental differences in executive control (Kane, Bleckley, Conway, and Engle, 2001; Engle, Tuholski, Laughlin, and Conway, 1999), and WM training has been found to improve other executive functions as well (Klingberg, 2010).

Both cigarette and alcohol use appear to be maladaptive and overly automatic (Orbell and Verplanken, 2010). In other words, in those with either alcohol abuse/dependence or nicotine dependence, alcohol or cigarette use is outside of deliberative decision making processes. WMC training could increase the ability of a substance user to increase deliberative control over substance use, aiding the process of abstinence. For alcohol use, this was found by Houben, Wiers, and Jansen (2011). The researchers conducted a study that examined alcohol abuse and working memory training. The researchers indicated that alcohol abuse disrupts core executive functions, including working memory, and they proposed that when executive functions like working memory are weakened, drinking behavior becomes out of control and is guided more strongly by automatic impulses. They found that training working memory reduced alcohol use by increasing control over automatic impulses through increased working memory.

Based on these findings, the present study investigates cigarette smoking and working memory training. Participants will be randomly assigned to a working memory training control or treatment group. The participants will perform working memory capacity training four about four weeks. Measures of daily cigarette smoking will be taken in order to determine if working memory capacity training will decrease cigarette smoking. Dual process theories of addiction state that impairments of executive functions lead to maladaptive behavior, such as nicotine abuse, because automatic impulses can no longer be effectively suppressed (Tiffany, 1990). Therefore, it is hypothesized that participants with the strongest automatic impulses to smoke cigarettes should benefit the most from working memory training because strengthening an executive function like working memory should increase their control over automatic impulses.

METHOD

Participants

A total of six participants (3 males, 3 females Mean age = 21.3, age range: 18-26) were recruited from five psychology courses at Texas State University-San Marcos from January to April of 2012. Each course had a total student enrollment of about four hundred students. All of the six participants who gave written consent to participate dropped out prematurely after about one week, stating that the time commitment was too cumbersome.

Materials and Procedures

This research entailed components of a repeated measures mixed group design. The participants were randomly assigned to the treatment or control group. The study was expected to last about four weeks, with an initial meeting between each participant and the principal investigator, a second meeting two weeks after starting the working memory training, and a final meeting after four weeks of working memory training. However, all of the participants declined further participation after about one week. Upon arriving to the initial session, the participants were provided with a consent form that described the nature of the study, including the tasks to be performed, the absence of anticipated risk, the right of the participants to discontinue the study at any time without penalty, and the availability of an alternative activity (critique of a psychological research article) that will provide credit equal to that of participating in the study.

Working memory capacity was assessed during the initial meeting using the digit span and arithmetic subtests of the Wechsler Adult Intelligence Test-IV (WAIS-IV). If any participants had completed the study, working memory capacity would also have been assessed during the final meeting, using counter-balancing to neutralize practice effects. Smoking questionnaires and demographic questions were administered during the initial meeting, and they would have also been administered during the second and final meetings (Wisconsin Inventory of Smoking Dependence Motives (Brief WISDM); Minnesota Nicotine Withdrawal Scale (MNWS) and the Questionnaire on Smoking Urges-Brief (QSU-B)).

The QSU-brief is a nicotine craving survey that measures (1) a desire and intention to smoke with smoking anticipated as pleasurable, and (2) an anticipation of relief from negative affect and nicotine withdrawal, with an urgent desire to smoke (Cox, Tiffany, and Christen, 2001). The two factors of the QSU-brief have strong internal consistency, with Cronbach's alpha levels of 0.97 for both (Cox, Tiffany, and Christen, 2001). The MNWS measures nicotine withdrawal symptoms and has a Cronbach's alpha of 0.80 (Toll, O'Malley, McKee, Salovey, and Krishnan-Sarin, 2007).

The Brief WISDM is a survey that measures nicotine dependence in terms of distinct motivations for smoking, and it contains an automaticity that has a Cronbach's alpha level of 0.88 (Shenassa, Graham, Burdzovic, and Buka, 2009). Scores on the automaticity scale were used to test for a moderation relationship between working memory capacity and the change in the number of cigarettes smoked daily.

The participants were also asked to give the principal investigator a breath sample during the initial meeting, and would also have been asked during the second and final meetings, in order to measure levels of carbon monoxide (CO) as a result of smoking. Abstinence from smoking was defined as having a level of 7ppm and below, and daily smoking was defined as having a value of 10ppm and above. All of the participants had a CO level of above 10 ppm (Mean level = 12.3, standard deviation = 1.5), classifying them as daily smokers.

The participants were instructed to complete at their own discretion daily working memory capacity training via Brain Workshop (http://brainworkshop.sourceforge.net/). Research has shown that optimal benefits of this working memory training program should be achieved by performing the training for about twenty sessions per day five days a week for at least four weeks (Jaeggi, Buschkuel, and Perrig, 2008). Based on these findings, all participants were asked to complete twenty sessions of the working memory training program five days per week for four weeks. All participants brought a personal laptop to the initial session in order for the principal investigator to install the Brain Workshop software. If any of the participants were not able to bring a personal laptop, they would have been provided detailed instructions on how to install the software on their own.

Brain Workshop is a free open-source version of a computerized dual n-back brain training exercise, which is designed to increase working memory capacity (Jaeggi, Buschkuel, and Perrig, 2008). The dual n-back task involves remembering a sequence of spoken letters and visual squares positions on a three by three grid concurrently and identifying when a letter or square position matches the one that appeared n trials earlier. For example, if in dual 2-back, the participant would need to remember the letter or square position from 2 trials back.

The Brain Workshop program has two modes that can be set during instillation of the software. This allows for each participant's sessions to be in manual mode or the dual-n-back mode. The manual mode, which was the control group mode, prevents the n-back level from being adjusted automatically based on the participants' performance. The dual-n-back mode, which was the treatment group mode, uses an adaptive level-changing model which will increase or decrease the n-back level depending on the participants' performance.

When a score of 80% or greater is achieved during the course of the session, the n-back level increases, thus the difficulty level of the working memory training increases. For example, if the participant achieved a score above 80% at a 2-back level, the n-back would then increase to 3-back, forcing the participants to remember three trials back instead of the two. If a participant achieves a score of 50% to 79% during the course of the session, the n-back level is maintained until the participant increases their score to 80% or greater. If a participant achieves a score of below 50% during the training session, the n-back level is decreased, allowing the participant to master easier levels first. The intention of this adaptive level-changing model is to ensure each participant is playing at their ideal level, and this model has been shown by research to be the most effective at increasing working memory capacity (Jaeggi, Buschkuel, and Perrig, 2008). Statistics are generated by Brain Workshop after each completed session. In order to ensure completion of the daily training, the participants sent the principal investigator daily emails of these statistics and the number of cigarettes smoked daily. All of the data were kept on password-encrypted files on the principal investigator's computer to ensure confidentiality.

RESULTS

Data from the initial meeting with each participant are listed in Table 1 and Table 2. The mean age of the participants was 21.3 years with a standard deviation of 3.1, and fifty percent of the participants were male. Fifty percent were of Caucasian descent; Thirty-three percent were of Hispanic descent, and seventeen percent were of Asian descent. The average years of education were 14.5 years with a standard deviation of 0.6. The average initial carbon monoxide level was 12.3 ppm with a standard deviation of 1.5, classifying all of the participants as heavy smokers. The average score on the Brief WISDM automaticity scale was 4.4 with a standard deviation of 1.4, and the average score on the QSU-brief was 3.5 with a standard deviation of 1.4. The average score on the MNWS was 1.3 with a standard deviation of 1.1.

The average Digit Span subtest scaled score was 8.0 with a standard deviation of 0.9, and the average Arithmetic subtest scaled score was 9.8 with a standard deviation of 2.6. The average Working Memory composite score was 94.0 with a standard deviation of 8.7.

A one-way between-subjects analysis of variance (ANOVA) would have been used to compare the pre- and post-test means between the two treatment groups on the measures of working memory capacity and the change in number of daily cigarettes smoked. The average Working Memory Index scores pre- and post-training and the average of the change in the number of cigarettes smoked pre- and post-training would have been used in the ANOVA.

An average score on the automaticity scale of the Brief WISDM would have been calculated for each participant. A hierarchical multiple regression analysis would have been run using the automaticity scores to test for the moderation relationship of automaticity between working memory capacity and the change in the number of cigarettes smoked daily.

Table 1
Characteristics of Participants

	Smokers (n=6)
Age	21.3 (3.1)
% male	50%
Years of education	14.5 (0.6)
Race	
Caucasian (Non-Hispanic)	50%
Hispanic	33%
Asian	17%
CO level in ppm	12.3 (1.5)
Brief WISDM – Automaticity Scale	4.4 (1.4)
QSU – Brief	3.5 (1.4)
MNWS	1.3 (1.1)

Values in parentheses represent standard deviation.

Table 2
Mean Working Memory Index Scores of Participants

	Smokers (n=6)
Digit Span subtest scaled score	8.0 (0.9)
Arithmetic subtest scaled score	9.8 (2.6)
Working Memory Index score	94.0 (8.7)

Values in parentheses represent standard deviation.

DISCUSSION

This study investigated the effects of WM training on WMC and smoking behavior in a sample of daily smokers. All of the participants did not complete the study; therefore, the following interpretations are anticipatory only.

It was expected that training WM would significantly improve WMC and lead to a significant decrease in smoking. It was further expected that improving WM via training would reduce smoking by restoring control over automatic impulses, given that previous research has demonstrated that reduced executive functions, including WM, cause drinking behavior to become driven by automatic impulses to a larger extent (Houben and Wiers, 2009). Since both cigarette and alcohol use appear to be maladaptive and overly automatic, it was assumed that reduced executive functions, including WM, could also cause smoking behavior to become driven by automatic impulses (Orbell and Verplanken, 2010).

It was anticipated that the data would show this conditional mediation effect: The indirect effect of WM training on cigarette smoking through WMC would be moderated by the strength of automaticity for cigarette smoking. Increased WMC should have reduced cigarette smoking to a greater extent among participants who had the strongest automatic impulses to smoke than among the participants who did not have strong automatic impulses to smoke. In other words, the participants who had the strongest automaticity to smoke would benefit the most from the WM training.

Based on this reasoning, the two participants with the highest scores on the automaticity scale of the Brief-WISDM, 5.2 and 6.6, should have benefited the most from the WM training. These two participants should have increased their WMC via the WM training, thus reducing the number of cigarettes smoked to a greater extent than the other four participants.

These findings would have implied that procedures that strengthen executive functions, such as WM, may be a useful supplement to existing interventions for cigarette smoking. Training executive functions as part of an intervention may provide nicotine-dependent patients with a stronger ability to resist temptation and to control their smoking habits.

This study does have limitations. Monetary payment was not available for this study; therefore, this study had a zero percent completion rate, and it was probably not realistic and feasible as a Master's level thesis. Because all of the participants dropped out due to the extensive time commitment, it is recommended that future researchers provide monetary payment to the participants for participation and completion. Also, the study would have relied on self-report measures of the amount of cigarettes smoked, and the possibility of participant bias could have confounded the results.

In conclusion, the anticipated training effects would have suggested that WM training might be useful as an intervention tool for individuals with impulse-control disorders resulting from deficits in executive functioning. Previous literature on the implications of improving working memory, which may potentially allow for more control over automatic impulses, is promising. If a low attrition rate can be maintained using the recommendations listed above, this study should be further examined.

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