


Getting a Grip on Drinking Behavior: Training Working Memory to Reduce Alcohol Abuse

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Abstract

Alcohol abuse disrupts core executive functions, including working memory (WM)—the ability to maintain and manipulate goal-relevant information. When executive functions like WM are weakened, drinking behavior gets out of control and is guided more strongly by automatic impulses. This study investigated whether training WM restores control over drinking behavior. Forty-eight problem drinkers performed WM training tasks or control tasks during 25 sessions over at least 25 days. Before and after training, we measured WM and drinking behavior. Training WM improved WM and reduced alcohol intake for more than 1 month after the training. Further, the indirect effect of training on alcohol use through improved WM was moderated by participants' levels of automatic impulses: Increased WM reduced alcohol consumption in participants with relatively strong automatic preferences for alcohol. These findings are consistent with the theoretical framework and demonstrate that training WM may be an effective strategy to reduce alcohol use by increasing control over automatic impulses to drink alcohol.

Keywords

alcohol, cognition, executive functions, working memory

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Being presented with a delicious piece of chocolate cake when you are on a diet, desperately wanting a cigarette after a stressful day even though you have decided to give up smoking, and wanting to share a drink with your friends on the night before a big test may seem like very different situations, but they all have something important in common: a conflict between current goals and automatic impulses to behave in a certain way. Dual-process models of information processing, such as the reflective-impulsive model (Strack & Deutsch, 2004), propose that these conflicts reflect a tug-of-war between two qualitatively different processing systems. According to these models, automatic impulses originate from a fast-acting, high-capacity, associative *impulsive system* that appraises stimuli automatically in terms of affective and motivational significance and predisposes individuals to either approach or avoid certain stimuli. In contrast, long-term goals and personal standards reside in a slow-acting, low-capacity, controlled *reflective system* (Strack & Deutsch, 2004). Whenever conflict arises between automatic impulses and personal goals and standards, preserving goal-directed behavior requires that impulses be inhibited in favor of alternative behavioral options. This ability to stop or override automatic impulses is also referred to as executive control or executive functioning.

Executive control is an umbrella term that refers to a collection of cognitive functions—such as planning, attention, memory, initiating appropriate actions, and inhibiting inappropriate actions—that allow people to take goal-directed actions amid the endless possibilities afforded to them in real-life situations (Baddeley, 1986; Norman & Shallice, 1986). When executive functions are impaired, automatic impulses may not be suppressed, and maladaptive behavior may result. Indeed, executive-function deficits are associated with a large number of impulse-control disorders, including alcohol abuse (Verdejo-Garcia, Lawrence, & Clark, 2008).

Specifically, compared with people who do not abuse alcohol, chronic heavy users of alcohol often show lower levels of executive functioning, including lower levels of response inhibition (i.e., the capacity to inhibit prepotent responses when engaged in goal-directed action; Kamarajan et al., 2005; Noël, Bechara, Dan, Hanak, & Verbanck, 2007; Noël et al., 2005) and working memory (WM; i.e., the ability to maintain and manipulate goal-relevant information; Bechara & Martin

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2004; Goudriaan, Oosterlaan, de Beurs, & van den Brink, 2005). Although some of these deficits appear to result from heavy alcohol use (e.g., Fillmore & Vogel-Sprott, 2006), there is also evidence suggesting that problems with executive functions contribute to the development of alcohol abuse (e.g., Finn & Hall, 2004; Nigg et al., 2006). Further, research has shown that stronger automatic associations between alcohol and positive affect predict increased levels of alcohol consumption (e.g., Houben & Wiers, 2008a; Jajodia & Earleywine, 2003), especially when the levels of executive functions, such as response inhibition and WM, are reduced (e.g., Frieze & Hofmann, 2009; Frieze, Hofmann, & Wänke, 2008; Houben & Wiers, 2009; Thush et al., 2008). In line with dual-process models (Deutsch & Strack, 2006; Strack & Deutsch, 2004), these findings suggest that automatic impulses to drink alcohol cannot be properly regulated when executive functioning is low. Consequently, at low levels of executive functioning, drinking behavior is guided more strongly by impulses than by controlled processes, such as long-term goals.

From these insights, one would expect that chronic heavy drinkers would profit from interventions that strengthen executive control. This possibility was examined in this study. There were two reasons for our focus on training WM as a way of strengthening executive control. First, WM can be improved via adaptive and extensive training procedures, and such training has been shown to be highly relevant for reducing clinical symptoms in a range of contexts (for a review, see Klingberg, 2010), including in children with attention-deficit hyperactivity disorder (ADHD; Beck, Hanson, Puffenberger, Benninger, & Benninger, 2010; Holmes et al., 2010), in children with reduced WM capacity (Holmes, Gathercole, & Dunning, 2009; Thorell, Lindqvist, Bergman, Bohlin, & Klingberg, 2009), and in aging populations (Borella, Carretti, Riboldi, & De Beni, 2010). Second, individual differences in WM correspond to fundamental differences in executive control (Engle, Tuholski, Laughlin, & Conway, 1999; Kane, Bleckley, Conway, & Engle, 2001), and WM training has been found to improve other executive functions as well (see Klingberg, 2010). In the study we report here, WM was trained using an adaptive training procedure similar to the one used by Klingberg (2010): Participants completed either WM training or control tasks for 25 consecutive sessions spread over at least 25 days. We expected that participants in the training condition would improve in WM and reduce their alcohol intake relative to participants in the control condition.

Method

Participants

Forty-eight heavy drinkers (25 females and 23 males; mean age = 44.33 years, $SD = 15.37$) were recruited via an advertisement asking for volunteers to participate in an online study on memory and drinking behavior. This advertisement was placed on various Web sites concerning alcohol abuse and problem

drinking. At the end of the advertisement, we provided the URL for the study. Potential participants who clicked on the URL were then screened with the Alcohol Use Disorders Identification Test (AUDIT; Saunders, Aasland, Babor, De la Fuente, & Grant, 1993). They were allowed to proceed with the study only if they scored 8 or higher (i.e., the cutoff score for hazardous drinking; Saunders et al., 1993). Participants in the final sample had an average AUDIT score of 17.19 ($SD = 5.77$, range = 8–31), indicating harmful problem drinking. With respect to education level, 6.3% of the participants had finished primary school, 56.3% had completed secondary school, and 37.5% had a college degree.

Materials and measures

WM training and control tasks. Participants in both the training and the control conditions completed three WM tasks: a visuospatial WM task, a backward digit span task, and a letter span task (adapted from Klingberg, Forssberg, & Westerberg, 2002). During the visuospatial WM task, several squares in a 4×4 grid on a computer screen changed color. Participants had to reproduce the sequence of changes by using a computer mouse to click, in order, on the squares that had changed color. During the backward digit span task, several numbers were presented on the computer screen one at a time, and participants had to reproduce this sequence in reverse order using either the computer mouse or the number keys on the keyboard. Finally, in the letter span task, several letters were presented one at a time in a circle on the computer screen. One of the positions in this circle was then indicated, and participants had to enter the corresponding letter using the keyboard. Each of the three tasks consisted of 30 trials.

In the training condition, the difficulty level of all three WM tasks was automatically adjusted on a trial-by-trial basis: Initially, each task involved sequences of three items. The length of the sequences then increased and decreased according to participants' performance. When participants correctly reproduced the sequences on two consecutive trials, one item was added to the sequence on the next trial. When participants were not able to correctly reproduce the sequences on two consecutive trials, the sequence in the next trial contained one item fewer. In the control condition, the difficulty level of the WM tasks was not adjusted, remaining at the initial, easy level throughout each task (i.e., three items in each sequence).

Implicit Association Test. To assess automatic impulses to drink alcohol, we measured automatic (or implicit) preferences for alcohol using the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998; see also Houben & Wiers, 2009). The IAT is a reaction time task that requires participants to sort stimuli in four categories using just two response keys. In this experiment, participants sorted word stimuli into two target categories, "alcohol" (i.e., *wine, beer, pint, vodka, whiskey*, and [Bacardi] *breezer*) and "soft drink" (i.e., *Coca-Cola, Fanta, orange soda, sparkling water, juice*,

and *cassis* [black currant juice]), and two attribute categories, “pleasant” (i.e., *talkative, excited, cheerful, happy, funny, and lively*) and “unpleasant” (i.e., *nauseous, listless, awful, miserable, sad, and annoying*). Items representing the four categories were presented on a computer screen one at a time, and participants had to categorize them as quickly as possible. Each stimulus remained on the screen until a correct response was given. Feedback was presented in red type beneath the stimulus after an incorrect response (i.e., “wrong”).

The IAT consisted of seven blocks. In the first block (24 trials), participants classified pleasant and unpleasant stimuli with response keys on the left and right. In the second block (24 trials), participants classified alcohol stimuli and soft-drink stimuli using the same response keys as in the first block. In the third and fourth blocks (24 and 48 trials, respectively), words representing all four categories were presented. For half the participants, alcohol stimuli were assigned to the same key as pleasant stimuli, and soft-drink stimuli were assigned to the same key as unpleasant stimuli. For the remaining participants, this mapping was reversed so that alcohol and unpleasant stimuli had to be categorized with one response key, and soft-drink and pleasant stimuli with the other. The fifth, sixth, and seventh blocks were identical to the second, third, and fourth blocks, respectively, except that the assignment of response keys for the alcohol and soft-drink stimuli was reversed. Assignment of the pleasant and unpleasant categories to the response keys was counterbalanced across participants. The difference in participants’ classification speed between the two combined sorting conditions (i.e., Blocks 3 and 4 vs. Blocks 6 and 7) reflects the strength of implicit preferences for alcohol. IAT effects were calculated with the D600 algorithm (Greenwald, Nosek, & Banaji, 2003); higher scores indicate faster performance when alcohol was paired with pleasant stimuli (and soft drinks were paired with unpleasant stimuli) than when alcohol was paired with unpleasant stimuli (and soft drinks were paired with pleasant stimuli). Thus, higher scores indicate stronger implicit preferences for alcohol.

WM capacity. WM capacity was measured using the same tasks that were used during WM training. However, the assessment versions of the three tasks ended when participants were unable to reproduce a sequence on two consecutive trials. The outcome measure for each task was the length of the longest sequences that participants correctly reproduced on two consecutive trials.

Alcohol use. Alcohol use was measured with the Time-Line Follow-Back questionnaire (TLFB; Sobell & Sobell, 1990). Participants were asked to indicate how many alcoholic beverages they consumed each day of the previous week.

Procedure

Participants completed the study via the Internet. All potential participants first had to give their consent and register. Upon

registration, they were given a unique participant number for data storage and chose a login name that provided access to the various sessions. All participants were then screened for problem drinking with the AUDIT. Participants who passed the screening were randomly assigned to either the training condition ($n = 20$; 11 females and 9 males) or the control condition ($n = 28$; 14 females and 14 males).

Participants in both conditions completed 28 sessions via the Internet: During the first session (pretest), they completed the WM capacity tasks, the IAT, and the TLFB in that order (for a recent validation of this Internet-based assessment of alcohol-related outcome measures and for a discussion of the advantages and disadvantages of online research, see Houben & Wiers, 2008b). In the following 25 sessions, participants completed the WM training or control tasks, according to their condition; all three WM tasks were included in each session. Participants were given 2 days to complete each training or control session. If they did not complete a session in time, it was marked as missed, and participants moved on to the next session. In total, participants could miss up to 5 training or control sessions. Hence, the total number of training or control sessions varied between 20 and 25. Participants also completed the WM capacity tasks and the TLFB 1 week after the last training or control session (posttest, Session 27) and 1 month after the posttest (follow-up, Session 28). At the completion of the study, participants received a €50 gift certificate as remuneration for their participation.

Results

Differences at baseline

There were no significant differences in participants’ age, $F < 1$, or education level, $\chi^2(2, N = 48) = 1.07$, between the training and control conditions, whereas there was a marginally significant difference in AUDIT scores, with participants in the training condition scoring slightly higher than those in the control condition, $F(1, 46) = 2.96, p = .09$ (see Table 1). IAT scores at baseline did not differ significantly between participants in the two conditions ($F < 1$; see Table 1). Overall, participants performed better on the IAT when alcohol was paired with unpleasant stimuli than when alcohol was paired with pleasant stimuli, $t(43) = -4.44, p < .001$, a pattern indicating stronger negative implicit associations with alcohol than with soft drinks.

Manipulation check

Participants in the training condition completed an average of 24.50 training sessions ($SD = 0.69$), and participants in the control condition completed an average of 24.11 training sessions ($SD = 1.40$). In the control condition, the difficulty of the WM tasks always remained on the easiest level, with only three to-be-remembered items in each sequence. Consequently, the observed WM span of participants in the control

Table 1. Mean Age, Mean AUDIT and IAT Scores, and Education Level of Participants in the Training and Control Conditions

Variable	Condition	
	Training	Control
Education level	Primary school: <i>n</i> = 2; secondary school: <i>n</i> = 10; college: <i>n</i> = 8	Primary school: <i>n</i> = 1; secondary school: <i>n</i> = 17; college: <i>n</i> = 10
Age (years)	<i>M</i> = 46.5 (14.93)	<i>M</i> = 42.79 (15.77)
AUDIT score	<i>M</i> = 18.85 (5.54)	<i>M</i> = 16.00 (5.74)
IAT score	<i>M</i> = -0.33 (0.39)	<i>M</i> = -0.31 (0.55)

Note: Standard deviations are given in parentheses. AUDIT = Alcohol Use Disorders Identification Test (Saunders, Aasland, Babor, De la Fuente, & Grant, 1993); IAT = Implicit Association Test.

condition remained at the same level over the course of the training period (see Fig. 1). In contrast, in the training condition, the tasks were adjusted adaptively to participants' performance. As shown in Figure 1, the WM performance of participants in the training condition increased steadily during the training period.

Training effects

WM capacity. Scores on the three WM capacity tasks were averaged for each session and analyzed using a 3 (time: pretest, posttest, or follow-up) × 2 (condition: training or control) mixed analysis of covariance (ANCOVA) with AUDIT score as a covariate. Results showed significant effects of time, $F(2, 90) = 3.99, p = .02, \eta_p^2 = .08$; condition, $F(1, 45) = 11.09, p < .01, \eta_p^2 = .20$; and AUDIT score, $F(1, 45) = 6.23, p = .02,$

$\eta_p^2 = .12$. Although the interaction between AUDIT score and time was not significant ($F < 1.5$), the crucial interaction between time and condition was significant, $F(2, 90) = 12.84, p < .001, \eta_p^2 = .22$; WM capacity changed differently in the two conditions. Contrasts revealed a significant interaction between time and condition in the comparison of WM capacity at pretest and posttest, $F(1, 45) = 16.59, p < .001, \eta_p^2 = .27$, and in the comparison of WM capacity at pretest and follow-up, $F(1, 45) = 17.32, p < .001, \eta_p^2 = .28$. As shown in Figure 2, WM capacity increased more from pretest to posttest for participants in the training condition than for those in the control condition, and this improvement in WM capacity was still present at follow-up, 1 month later.

Drinking behavior. Weekly alcohol use was analyzed using a 3 (time: pretest, posttest, or follow-up) × 2 (condition: training

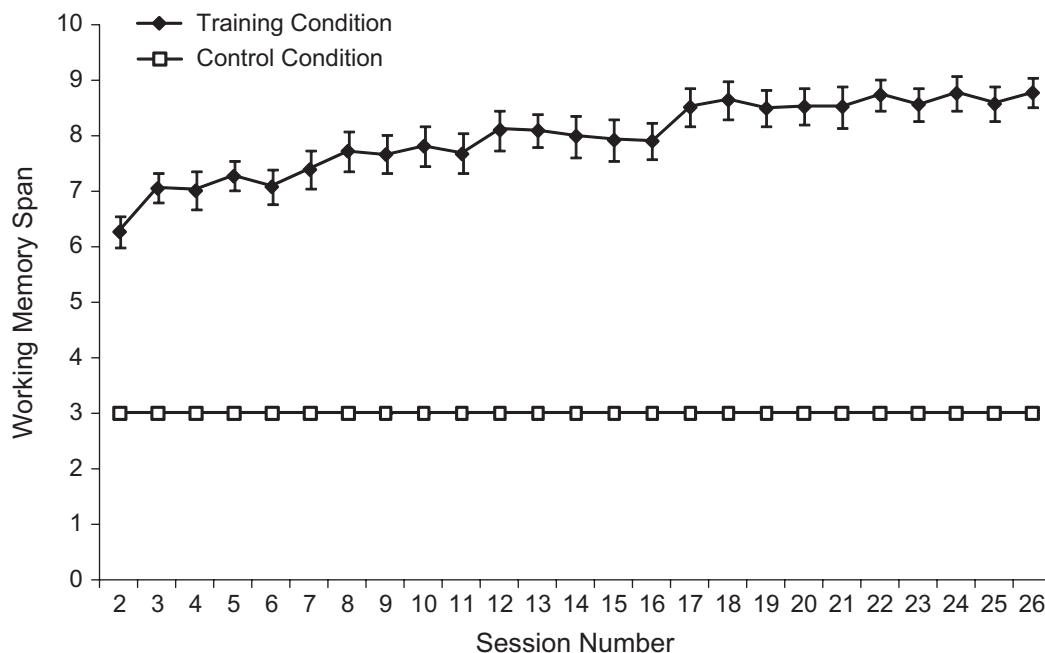


Fig. 1. Mean working memory span of participants in the training and control conditions at the end of each training or control session. For each session, working memory span was averaged across the three working memory tasks. Error bars represent standard errors of the mean.

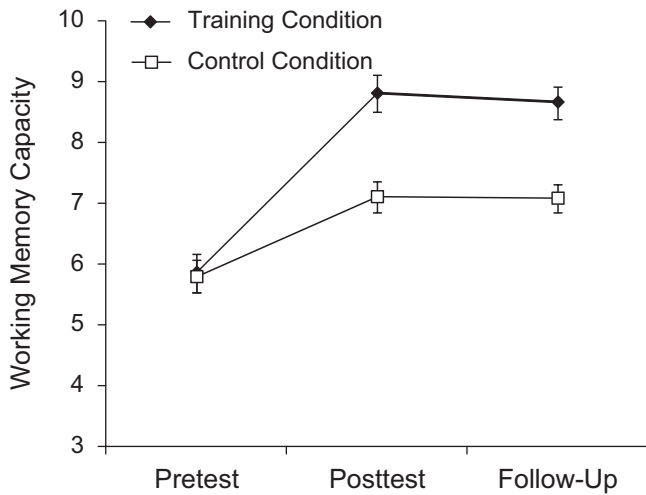


Fig. 2. Estimated marginal means for the working memory tasks at pretest, posttest, and follow-up, separately for participants in the training and control conditions. Error bars represent standard errors of the mean.

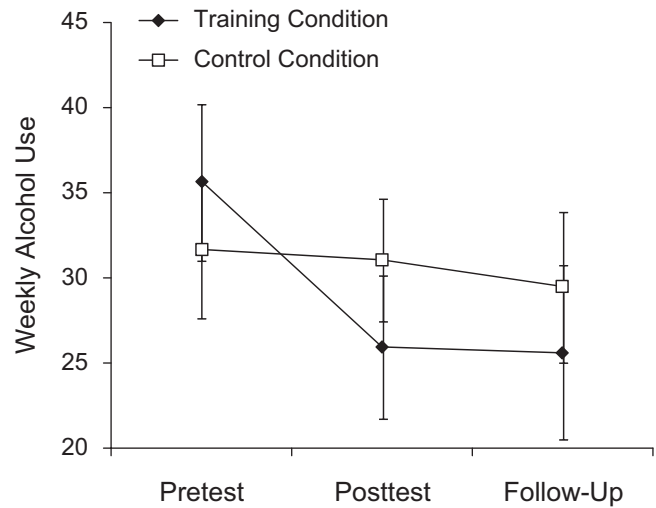


Fig. 3. Estimated marginal means for weekly alcohol use (number of alcoholic drinks per week) at pretest, posttest, and follow-up, separately for participants in the training and control conditions. Error bars represent standard errors of the mean.

or control) mixed ANCOVA with AUDIT score as a covariate. One influential outlier in the control condition (a participant with pretest alcohol use > 2.5 *SD* above the mean) was removed from the analyses, which were performed with 47 participants. The main effects of time and condition on alcohol use were not significant (both F s < 1.5). The effect of AUDIT score was significant, $F(1, 44) = 33.90, p < .001, \eta_p^2 = .44$, but there was no significant interaction between time and AUDIT score ($F < 1$). It is important to note that the interaction between time and condition was significant, $F(2, 88) = 3.27, p = .04, \eta_p^2 = .07$. Further, there was a significant interaction between time and condition for the contrast comparing pretest and posttest alcohol use, $F(1, 44) = 6.60, p = .01, \eta_p^2 = .16$, and a marginally significant interaction between time and condition for the contrast comparing pretest and follow-up alcohol use, $F(1, 44) = 3.69, p = .06, \eta_p^2 = .08$. Thus, the reduction in alcohol use at posttest was larger for participants in the training condition than for participants in the control condition, and this effect was still marginally significant at follow-up (see Fig. 3).

Mediation analysis

Next, we tested whether the training-induced improvements in WM capacity mediated the reduction in alcohol use at posttest. Dual-process accounts of alcohol abuse state that impairments of executive functions lead to maladaptive behavior, such as alcohol abuse, because automatic impulses can no longer be effectively suppressed. Therefore, participants with the strongest automatic impulses to drink alcohol should have benefited the most from training because strengthening an executive function (WM) should have increased their control over automatic impulses. Hence, we did not expect that WM improvement in itself would mediate the effect of training on drinking

behavior, but rather we expected that this mediation would be conditional on the strength of automatic impulses. The presence of such a conditional mediation effect (also referred to as moderated mediation) was examined following the recommendations of Preacher, Rucker, and Hayes (2007). These analyses were performed with 44 participants, after 4 participants with missing data on the IAT were excluded (because of technical difficulties, IAT data were not collected for those 4 participants).

In order to test whether the indirect effect of training on drinking behavior depended on participants' automatic impulses (i.e., IAT score), we estimated coefficients independently in two regression analyses (using mean-centered variables). In both regression analyses, AUDIT score, WM capacity at pretest, and alcohol use at pretest were used as covariates. First, WM capacity at posttest was regressed on condition (the mediator-variable model). Condition significantly predicted WM capacity at posttest: Participants in the training condition had a higher WM capacity at posttest than did participants in the control condition (see Table 2). Subsequently, log-transformed drinking behavior at posttest was regressed on condition, WM capacity at posttest, IAT score, and the interaction between WM capacity at posttest and IAT score. This model (the dependent-variable model) explained 70% of the behavioral variance in alcohol use, with alcohol use being significantly predicted by the Posttest WM Capacity \times IAT Score interaction, but not by condition (see Table 2). This significant interaction effect in the absence of a significant condition effect supports the idea of moderated mediation (see Fig. 4 for a schematic of the moderated-mediation model).

We further examined this interaction effect by plotting the simple regression slopes of alcohol use on WM capacity at posttest at low (1 *SD* below the mean IAT score) and high (1 *SD* above the mean IAT score) levels of automatic

Table 2. Mediation Analyses of the Indirect Effects of Training on Alcohol Use

Variable	<i>b</i>	<i>SE</i>	<i>t</i>	<i>p</i>
Mediator-variable model				
AUDIT score	-0.01	0.04	-0.31	.759
WM at pretest	0.50	0.14	3.60	.001
Alcohol use at pretest	0.00	0.01	0.32	.753
Condition	-1.66	0.38	-4.42	< .001
Dependent-variable model				
AUDIT score	0.05	0.02	2.92	.006
WM at pretest	0.06	0.07	0.94	.352
Alcohol use at pretest	0.02	0.01	5.06	< .001
Condition	0.15	0.19	0.78	.439
WM at posttest	-0.06	0.07	-0.95	.347
IAT score	-0.11	0.17	-0.64	.525
Posttest WM × IAT Score	-0.24	0.12	-2.11	.042

Note: The mediator-variable model (*df* = 39) regressed posttest working memory (WM) capacity on training condition. The dependent-variable model (*df* = 36) regressed posttest alcohol use on condition and the interaction of automatic impulses (Implicit Association Test, or IAT, score) and posttest WM capacity, with the latter two variables included as simultaneous predictors in the model. AUDIT = Alcohol Use Disorders Identification Test (Saunders, Aasland, Babor, De la Fuente, & Grant, 1993).

preferences for alcohol, and testing whether these simple slopes differed significantly from zero (Cohen, Cohen, West, & Aiken, 2003). The simple-slopes analysis confirmed that alcohol use at posttest decreased significantly with increased WM capacity for participants with high IAT scores, $\beta = -0.31$, $t(36) = -2.25$, $p = .03$. In contrast, for participants with low IAT scores, WM capacity at posttest was unrelated to alcohol use at posttest, $\beta = 0.09$, $t(36) = .56$. Given the overall significant interaction between WM capacity at posttest and automatic impulses, we conducted Sobel tests of the hypothesis that WM capacity at posttest mediated the relationship between

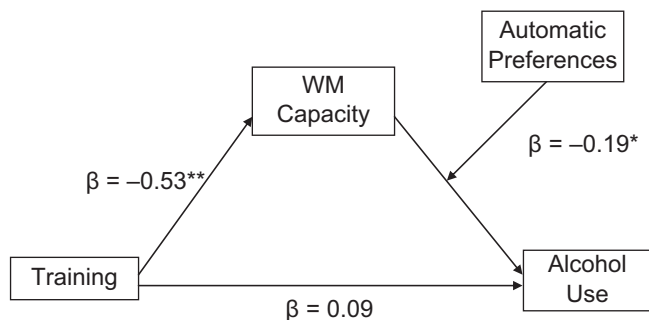


Fig. 4. Parameter estimates for the model of automatic impulses as a moderator of the indirect effect of training on alcohol use through working memory (WM) capacity. Participants completed 25 training or control sessions that included three WM tasks. Posttest WM capacity was the working memory span averaged across the three WM tasks. Automatic preferences for alcohol were measured by the Implicit Association Test. The number of alcoholic drinks consumed per week was measured with the Time-Line Follow-Back questionnaire (Sobell & Sobell, 1990). Asterisks indicate significant parameters (* $p < .05$, ** $p < .01$).

condition and alcohol use at posttest only when automatic preferences for alcohol were high. WM capacity at posttest indeed mediated the effect of condition on alcohol use at posttest for participants with strong automatic impulses to drink alcohol (1 *SD* above the mean IAT score), but not for participants with weak automatic impulses to drink alcohol (1 *SD* below the mean IAT score; see Table 3). Thus, increasing WM capacity via training predicted a reduction in alcohol use especially for participants with high automatic preferences for alcohol.

Discussion

This study investigated the effects of WM training on WM capacity and drinking behavior in a sample of problem drinkers. As expected, training WM significantly improved WM, and these training effects were still present more than 1 month after training. Moreover, the training not only improved WM, but also led to a significant behavioral change. Specifically, alcohol use was reduced by almost 10 glasses per week from pretest to posttest in the training condition, and this reduction in alcohol intake was still evident 1 month later, at follow-up. Further, we expected that improving WM via training would reduce drinking by restoring control over automatic impulses, given that previous research demonstrated that reduced executive functions, including WM, cause drinking behavior to become driven by automatic impulses to a larger extent (e.g., Houben & Wiers, 2009; Thush et al., 2008). Our findings showed exactly this conditional mediation effect: The indirect effect of WM training on alcohol use through WM capacity was moderated by the strength of automatic preferences for alcohol. Specifically, increased WM capacity reduced alcohol use to a greater extent among participants who experienced strong automatic impulses to consume alcohol than among participants who did not experience strong automatic impulses to drink alcohol. In other words, participants with strong impulses to drink alcohol profited the most from the WM training.

Thus, training WM reduced alcohol use by increasing control over automatic impulses through increased WM. These findings imply that procedures that strengthen executive functions, such as the WM training tested here, may be a useful supplement to existing interventions for problem drinking, especially because alcohol abuse is associated with

Table 3. Indirect Effect of Condition on Alcohol Use at Posttest at Different Levels of Automatic Impulses to Drink Alcohol

IAT score	Indirect effect	<i>SE</i>	<i>z</i>	<i>p</i>
Low (1 <i>SD</i> below the mean: -0.48)	-0.09	0.16	-0.54	.590
Mean (0.00)	0.11	0.12	0.91	.363
High (1 <i>SD</i> above the mean: 0.48)	0.30	0.15	1.97	.049

Note: IAT = Implicit Association Test.

deterioration of inhibitory abilities (Goldstein & Volkow, 2002; Noël et al., 2007). Training executive functions as part of an intervention may provide alcohol-dependent patients with a stronger ability to resist temptation and to control their drinking habits.

However, some limitations to these findings should be noted. This study was conducted via the Internet, a medium that has some important benefits but also some disadvantages. Although alcohol-related outcome measures, such as the IAT and the TLFB, were validated for Web-based research in a previous study (Houben & Wiers, 2008b), conducting research via the Internet diminishes experimenter control compared with the control possible in laboratory-based research using a standard testing environment and standardized testing procedures. Precisely because participants completed the study in their own homes, their anonymity was ensured, and they never came into contact with an experimenter, a context that reduced potential demand artifacts and experimenter effects. However, this procedure also precluded the possibility of testing the breath and urine for alcohol or other drugs during the study or performing a diagnostic interview to assess alcohol dependence. Consequently, it is unclear how many of the participants met the criteria for alcohol dependence, and therefore it is unclear how the present findings generalize to clinical samples. We therefore hope that these initial findings will stimulate future research in clinical samples to further investigate the potential clinical significance of WM training for reducing alcohol abuse.

In addition, because of the restrictions that are associated with Internet-based research, we measured the effect of the training on self-reported alcohol use only. Therefore, these findings need to be replicated in studies using outcome measures of actual drinking behavior to further examine the value of WM training for reducing alcohol use. Finally, training effects were still present more than 1 month after the training. Even though this result appears highly relevant, it remains unclear whether the training caused long-term improvements in WM and drinking behavior. Future research should examine the effect of training on alcohol consumption over a longer period of time.

In conclusion, the observed training effects suggest that WM training might be useful as an intervention tool for individuals with impulse-control disorders resulting from deficits in executive functioning. Whereas this study demonstrated that WM training reduces drinking behavior, previous studies have demonstrated beneficial effects of WM training in other impulse-control disorders, such as ADHD (see Klingberg, 2010). Future challenges will be to explore the value of WM training for treating other impulse-control disorders, such as binge eating, overeating, and drug abuse, and to test the efficacy of the training in clinical samples of alcohol abusers.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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