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Changing implicit attitudes toward smoking: results from a web-based approach-avoidance practice intervention

Jonathan T. Macy · Laurie Chassin · Clark C. Presson · Jeffrey W. Sherman

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Abstract Implicit attitudes have been shown to predict smoking behaviors. Therefore, an important goal is the development of interventions to change these attitudes. This study assessed the effects of a web-based intervention on implicit attitudes toward smoking and receptivity to smoking-related information. Smokers ($N = 284$) were recruited to a two-session web-based study. In the first session, baseline data were collected. Session two contained the intervention, which consisted of assignment to the experimental or control version of an approach-avoidance task and assignment to an anti-smoking or control public service announcement (PSA), and post-intervention measures. Among smokers with less education and with plans to quit, implicit attitudes were more negative for those who completed the approach-avoidance task. Smokers with more education who viewed the anti-smoking PSA and completed the approach-avoidance task spent more time reading smoking-related information. An approach-avoidance task is a potentially feasible strategy for changing implicit attitudes toward smoking and increasing receptivity to smoking-related information.

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Introduction

Although rates of cigarette smoking in the United States have declined dramatically since the middle of the twentieth century, progress has largely stalled in recent years so that about one in five adults are current smokers (Centers for Disease Control and Prevention, 2012), and cigarette smoking remains the leading cause of preventable death in the United States (Centers for Disease Control and Prevention, 2008). The progress in reducing smoking can be attributed to a range of interventions that have been implemented over the past 50 years. These interventions include educating consumers through the use of warning labels and mass media campaigns, treating nicotine dependence with drug therapies, increasing the cost of using tobacco through taxation or higher insurance premiums, and implementing policies that restrict the use, manufacture, or sale of tobacco products (Cummings, 2002).

Many of these interventions were designed to change consciously held explicit beliefs and attitudes about smoking. For example, research has demonstrated that mass media campaigns have been effective in changing explicit outcomes such as knowledge, beliefs, and quit intentions when campaign reach, intensity, and duration were sufficient and message type was appropriate for the target audience (Durkin et al., 2012). However, changing explicit cognitions alone is not sufficient to influence all smokers' behavior. Instead, studies of dual process models have shown that both conscious, controlled, reflective processes (such as explicit attitudes) and automatic

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associations that may be beyond conscious awareness (such as implicit attitudes) are important predictors of addictive behaviors like cigarette smoking (Wiers & Stacy, 2006). Explicit measures of attitudes, in which individuals directly report their evaluations of a target behavior by responding to survey questions, cannot detect attitudes that are outside of conscious awareness, and they may also underestimate positive attitudes for socially undesirable behaviors, such as smoking. In contrast, implicit attitudes, measured with a computer-based task that records reaction times to stimuli, reflect more automatic evaluative associations with smoking.

Prior studies, including our own, have examined the role of implicit attitudes measured with the Implicit Association Test (IAT; Greenwald et al., 1998) in predicting smoking behavior. Some previous work found that smokers had negative implicit attitudes toward smoking leading to questions about the relevance of the IAT for smoking behavior (Swanson et al., 2001). However, smokers have been found to have positive attitudes on the IAT when the IAT is personalized (De Houwer et al., 2006). Moreover, implicit attitudes measured on-line with the IAT have been shown to prospectively predict both smoking onset and smoking cessation over and above explicit measures (Chassin et al., 2010; Sherman et al., 2009). One study demonstrated that implicit attitudes were transmitted intergenerationally from parents to their adolescent children, and those implicit attitudes, in turn, predicted smoking onset 18 months later (Sherman et al., 2009). A second study showed that, among adult smokers, those with more negative implicit attitudes toward smoking at baseline were more likely to quit smoking 18 months later (Chassin et al., 2010).

Given the importance of implicit attitudes in predicting behavior, a potentially important public health goal is the development of interventions to change implicit attitudes. One strategy that has demonstrated some utility is approach-avoidance practice. It is based on theories of cognitive embodiment, which have demonstrated the effects of motor actions on attitudes (Neumann et al., 2003). Studies of early applications of this strategy showed that simple movements involving "pulling toward" and "pushing away" pictures of target objects affected both implicit attitudes and social behavior with regard to racism (Kawakami et al., 2007) and math among women (Kawakami et al., 2008). More recently, this intervention strategy has been successfully applied to an addictive behavior. Studies showed that approach-avoidance practice changed automatic cognitive biases among heavy drinkers (Wiers et al., 2010) and alcoholics (Eberl et al., 2013; Wiers et al., 2011). In the current study, we applied this same intervention strategy to the behavior of cigarette smoking and tested whether approach-avoidance practice changed smokers' implicit attitudes toward smoking. We accomplished this by randomly assigning study participants to complete a push–pull approach-avoidance task or a side-to-side control task, in which participants used a computer mouse to move pictures of cigarettes on the computer screen.

Importantly, the prior studies on implicit cognitions related to alcohol were conducted in controlled laboratory settings or in clinical settings, in which participants were presumably motivated to change their behavior and were also receiving conventional treatments. For greater public health impact, one important question is whether these types of interventions can be successfully delivered via the Internet to large numbers of individuals in the general population. Indeed, van Deursen et al. (2013) have published a study protocol describing their plan to test the efficacy of an online intervention for problem drinkers. The use of the Internet to deliver public health interventions has increased in recent years, and although there is potential for broad reach, available evidence suggests that participation by target audiences in such interventions has been low, and attrition has been high (Bennett & Glasgow, 2009). Therefore, one goal of this study was to test the feasibility of delivering a web-based approach-avoidance practice intervention to a community-based sample of mid-life adult smokers.

Another goal was to test whether viewing an anti-smoking public service announcement (PSA) increased the effect of the approach-avoidance intervention on changing smoking-related implicit attitudes. There is some limited evidence that anti-smoking PSAs might influence implicit attitudes toward smoking. For example, smokers' implicit attitudes were affected when they viewed a compelling anti-smoking PSA, but only when they had recently smoked (Rydell et al., 2012). A second study found that those who viewed several anti-smoking PSAs demonstrated more negative implicit attitudes toward smoking (Czyzewska & Ginsburg, 2007). Therefore, we expected that individuals who completed the approach-avoidance task and who viewed an anti-smoking PSA would demonstrate the largest change in implicit attitudes.

An additional goal of the study was to determine if the approach-avoidance practice and anti-smoking PSA intervention increased receptivity to other cessation-related interventions among a sample of smokers who may or may not be seeking treatment. This is important because most smokers do not actively seek treatment (Fiore et al., 2008). Therefore, the intervention tested in this study might either facilitate self-change or motivate treatment seeking. To test receptivity to other cessation-related interventions, as an additional implicit measure, we unobtrusively recorded the amount of time that participants spent reading smoking cessation information. In this study, reading time was

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treated as an implicit measure of a smoker's engagement with cessation-related information and thus an indirect measure of potential receptivity to information. A longer reading time would indicate greater time spent attending to and/or processing the information. An additional non-verbal, non-self-report outcome is important because indirect, non-verbal outcomes may be influenced differently than more explicit, self-reported outcomes (McConnell & Rydell, 2014). To further test this, we also assessed explicit outcomes. We asked participants whether they were interested in receiving further information, and we tested for changes in quitting plans.

The final goal of this study was to test whether educational attainment and plans to quit smoking moderated the effects of the intervention. Less educated individuals are more likely to smoke, more likely to be in social environments that encourage smoking, and harder to influence through public health media campaigns (Niederdeppe et al., 2008). Also, it is possible that smokers at varying levels of readiness to change behavior may respond differently to cessation interventions. Smokers with lower levels of educational attainment or without plans to quit may be especially hard to reach with traditional cessation interventions. Thus, it is important for public health to know whether a web-based intervention can influence the smoking-related outcomes of such groups.

Methods

Participants

Participants were adults recruited to a web-based study derived from a larger ongoing cohort-sequential study of the natural history of smoking (Chassin et al., 2000). Between 1980 and 1983, all consenting 6th to 12th graders in a Midwestern US school system completed annual surveys. Follow-up surveys were conducted in 1987, 1993, 1999, 2005, and 2009. Additional information about the sample, data collection procedures, representativeness, and attrition bias has been published elsewhere (Chassin et al., 2000, 2008, 2010; Rose et al., 1996).

In the most recent follow-up of the larger cohort study, all participants who reported current (at least monthly) cigarette smoking were invited to a web-based study. Of the 1042 total participants invited, 444 (42.6 %) completed the baseline session. There was no difference between those who participated and those who did not in terms of age, $t(862) = 1.54$; $p = .12$, or gender, $\chi^2(1, n = 1{,}042) = .60$; $p = .44$. However, those who participated had higher educational attainment, $\chi^2(1, n = 1{,}019) = 4.77$; $p = .03$, than those who did not participate. Of the 444 participants, 33 were eliminated from these analyses due to missing data on implicit attitude, educational attainment, or plans to quit smoking. An additional 19 participants were eliminated due to making too many errors (more than 40 % errors in any one of the critical blocks or more than 30 % errors overall) on the IAT. Finally, 7 were eliminated due to poor quality control. Participants were flagged as having poor quality control data when they reported that they were distracted three-fourths or more of the time or that they paid no attention to the questions and responses during the session.

This resulted in an eligible baseline sample of 385. Of these, 318 (82.6 %) completed the follow-up session and were thus eligible for inclusion in the current analyses. Those who were lost to follow-up did not significantly differ from those who were retained in terms of gender, $\chi^2(1, n = 386) = .03$; $p = .86$, age, $t(384) = 1.75$; $p = .08$, baseline implicit attitude toward smoking, $t(384) = 1.06$; $p = .29$, educational attainment, $\chi^2(1, n = 382) = 2.00$; $p = .16$, or plans to quit smoking, $\chi^2(1, n = 382) = .11$; $p = .74$. Of those retained, five were eliminated due to missing data on session two variables of interest, two were eliminated because of making too many errors (more than 40 % errors in any one of the critical blocks or more than 30 % errors overall) on the session two IAT, three were eliminated because of their responses to quality control items in session two (being distracted three-fourths or more of the time or paying no attention to the questions and their responses), and, to control for the influence of current smoking behavior on the effect of the intervention, 24 were eliminated because they reported that they were no longer smoking at session two. This yielded a final sample size of 284. In terms of sample characteristics, 48 % were male; 50 % had some college education or higher; 97 % were non-Hispanic white; their mean age was 44 (range = 40–50); 95 % were daily smokers; and the average amount smoked per day was 15–20 cigarettes.

Procedure

The research protocol was approved by the Institutional Review Board at Indiana University, and informed consent was obtained for participation in the research. Participants were informed that the study was concerned with beliefs and attitudes about smoking and reactions to cigarette-related stimuli. Data were obtained from two web-based sessions. During the baseline session, participants reported demographic characteristics, answered questions about their smoking-related behaviors and attitudes, and completed an IAT to measure their implicit attitude toward smoking. One month after the baseline session, participants received an email invitation to complete the follow-up

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session. The median time interval between sessions was 3 months.

The follow-up session contained the intervention, which consisted of two parts and was pilot-tested with a separate online sample. The first part of the intervention was random assignment to one of two versions of a practice task: (1) the experimental version of the task that involved pushing images of cigarettes away and pulling images of geometric shapes toward the participant on the computer screen with the computer mouse and (2) the control version of the task that involved moving images of cigarettes to the left and right and moving images of geometric shapes to the left and right on the computer screen with the computer mouse. The cigarette pictures were color drawings of cigarettes, some lit and some unlit, by themselves or with matches, and the shape pictures were red images on a tan background that included a circle, diamond, heart, hexagon, plus, and star. The pictures were selected to be similar to but sufficiently distinct from the pictures used in the IAT. The task consisted of four blocks of 24 trials each. Participants assigned to the push–pull version were instructed to use the mouse to push away images of cigarettes and pull towards them images of shapes. Pushing a cigarette picture away caused the picture to shrink in size, whereas pulling a shape picture closer caused the picture to increase in size. Participants assigned to the side-to-side control version were instructed to use the mouse to move the cigarette and shape images to the left and right sides of the screen. In this version, the picture size did not change when moved to the left or to the right. The second part of the intervention was random assignment to one of three 30-s PSAs (one anti-smoking and two controls). The anti-smoking PSA used a Venus flytrap plant analogy to depict the phenomenon of being trapped by nicotine addiction (used with permission from the Florida Department of Health), one control PSA showed a cartoon fish dying as a result of exposure to a water contaminant (used with permission from Yoshua Ewaldo), and the second control PSA showed a man describing steps to successfully grow Venus flytrap plants (used with permission from Expert Village). Because the two control PSA conditions did not differ in their effects, they were collapsed into one control group for the analyses presented here. After completing both parts of the intervention, participants again completed an IAT and answered questions about their smoking-related attitudes and behaviors. Participants were then instructed to read a short passage related to smoking and asked to rate the information on a scale from "very boring" to "very interesting." The amount of time spent reading the material was unobtrusively recorded, but participants were not told that they would be timed. Finally, participants were asked if they were interested in receiving additional information about smoking.

Participants were paid $15 for completing the baseline session and $20 for completing the follow-up session and were entered into drawings for additional cash prizes of $100–$500.

Measures

Educational attainment. Participants reported the highest level of education that they completed. For analyses, educational attainment was dichotomized into no college (e.g., less than high school, high school diploma or GED, or vocational or technical school; 50 %) versus some college or higher (e.g., community college, bachelor's degree, or graduate degree; 50 %).

Plans to quit. At both sessions, participants reported their plans to quit within the next 12 months. Response options were, "Yes," "Not sure, I've given it some thought but I have not made any definite plans," "I have not thought about quitting," and "No, I have given it some thought but I have no plans to quit within the next 12 months." Participants who answered "yes" were categorized as planning to quit, and those who chose any other response option were categorized as not planning to quit. At baseline, 27 % of participants reported having plans to quit; post intervention, 24 % of participants reported having plans to quit.

Implicit attitude toward smoking. At both sessions, participants completed an implicit measure of attitude toward smoking using an attitudinal IAT (Implicit Association Test; Greenwald et al., 1998), which was administered online through Project Implicit's Virtual Laboratory (Nosek et al., 2005). There were eight pictures that showed a scene related to smoking (someone holding a burning a cigarette (three pictures), a burning cigarette in an ashtray (two pictures), someone lighting a cigarette, cigarettes lying on a table, and cigarettes and a lighter lying on a table) and eight pictures of geometric shapes (rectangle, parallelogram, triangle, pentagon, trapezoid, square, oval, and octagon). These were different pictures than those used in the approach-avoidance practice intervention. As positive and negative stimuli, we used eight adjectives with a positive meaning (excellent, fabulous, friendly, great, nice, pleasant, terrific, and wonderful) and eight adjectives with a negative meaning (awful, disgusting, dreadful, horrible, nasty, rotten, stupid, and ugly). All stimuli were presented in the center of a black screen with words displayed in green letters. The words smoking, shape, good, and bad were used for labels. The smoking and shape labels were displayed in white letters, and the good and bad labels in green letters. Participants responded by pressing the letter e (left) or the letter i (right) on the keyboard.

This version of the IAT is a dual categorization task. Participants saw the four types of stimuli: smoking pictures,

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shape pictures, positive words, and negative. There were five phases to the IAT during which the labels of the stimuli assigned to the e (left) and i (right) keys were continuously displayed on the screen. The first phase was a practice phase consisting of 20 trials of good and bad words displayed in random order. Participants were instructed to match the words to the good or bad label by pressing either the e or i key. In the second phase, also consisting of 20 trials, the smoking and shape pictures were presented in random order, and participants were instructed to match the pictures to the smoking or shape label by pressing either the e or i key. The third phase contained the SMOKING + BAD task and consisted of three blocks, one of 20 trials and two of 40 trials, during which pictures and words were displayed in random order, and participants responded by pressing the appropriate key. The fourth and fifth phases were identical to the second and third, except that the response assignment for the smoking and shape pictures were reversed (e.g., the letter e instead of i), there were 40 trials in the fourth phase as opposed to 20 trials in the second phase, and the fifth phase contained the SMOKING + GOOD task. For each trial, the stimulus was displayed until the participant pressed the e or i key. If the response was correct, the next stimulus appeared. If the response was incorrect, a red X was displayed on the screen until the participant pressed the correct key. Phases three and five were used to measure implicit attitude toward smoking. To the extent that reaction times are slower during phase five when smoking pictures are paired with positive words than phase three when smoking pictures are paired with negative words, participants have more negative implicit attitudes toward smoking.

We calculated an IAT *D* score for each participant using a standard scoring algorithm (Greenwald et al., 2003). As noted above, participants were flagged who made more than 40 % errors in any one of the critical blocks or more than 30 % errors overall. Trial latencies greater than 10,000 ms or less than 400 ms were eliminated, and error latencies were replaced with the block mean plus 600 ms. The mean IAT score was .68 (SD = .32, range −1.04 to 1.40) at baseline and .70 (SD = .30, range −.41 to 1.35) at post-intervention. A higher value indicated a more negative attitude toward smoking.

Time spent reading anti-smoking information. At session two only, participants were presented with material about smoking cessation to read. The amount of time spent reading the material was recorded. Participants who read for less than 30 s (i.e., clicked through without doing any reading) were excluded from analyses ($n = 35$).

Interest in receiving additional anti-smoking information. At session two only, participants were asked if they were "interested in receiving a link to a good web site with information about smoking." Response options were "Yes, a good website with ideas about prevention," "Yes, a good website with ideas about quitting," "Yes, both of the above," and "No, neither of the above." For analyses, responses were dichotomized into any yes response (37 %) versus no (63 %).

Quality control items. At both sessions, participants responded to two items that were used to evaluate the quality of the data provided. The first item was, "While you were working on this study how often did things happen to distract you?" (see Table 1 for response options). Participants who reported that there were distracted ¾ of the time or always were considered to have poor quality data and were excluded from analyses. The second item was, "How much attention did you pay to the questions and your responses?" (see Table 1 for response options). Those who responded "none" were excluded.

Data analyses

To assess the effect of the approach-avoidance practice plus anti-smoking PSA intervention on implicit attitudes toward smoking, analysis of covariance (ANCOVA) was conducted with post-intervention implicit attitude toward smoking as the outcome variable, educational attainment (high, low), plans to quit (yes, no), approach-avoidance practice task (push–pull, side-to-side control), and PSA (anti-smoking, control) as between subjects factors, and baseline implicit attitude toward smoking as a covariate. Analysis of variance (ANOVA) was used to assess the effect of the intervention on the amount of time spent reading information about smoking cessation. In this model, between subjects factors were educational attainment (high, low), plans to quit (yes, no), approach-avoidance practice task (push–pull, side-to-side control), and PSA (anti-smoking, control). Finally, logistic regression was used to test the effect of the intervention on interest in receiving additional anti-smoking information and on plans to quit among the current smokers who reported no plans to quit at baseline.

Results

In terms of the feasibility of delivering this intervention via the Internet to a community-based sample of mid-life adult smokers, 42.6 % of those invited completed the baseline session, and 82.6 % of these participants were retained for the second session. Table 1 displays the results of the quality control items at both the baseline and the follow-up sessions. Overall, of those who completed the baseline session, 13 % had unusable data because they did not answer key questions, made too many errors on the IAT, reported that they were distracted or interrupted ¾ of the

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Table 1 Results from self-reported quality control items at baseline and follow-up sessions

Response	Proportion at baseline session (%)	Proportion at follow-up session (%)
Item: "While you were working on this study how often did things happen to distract you?"		
"Never"	55.9	60.4
"Once or twice I got distracted or interrupted"	38.3	35.3
"About 1/4 of the time I was distracted or interrupted"	3.1	2.1
"About 1/2 of the time I was distracted or interrupted"	.7	1.1
"About 3/4 of the time I was distracted or interrupted"	1.0[a]	.7[a]
"Always—Something was always distracting or interrupting me"	1.0[a]	.4[a]
Item: "How much attention did you pay to the questions and your responses?"		
"A lot"	83.8	89.4
"Some"	13.1	7.8
"A little"	2.8	2.8
"None"	.3[a]	.0[a]

[a] Excluded from analyses

time or always, or reported that they paid no attention to the questions and their responses during the session. Similarly, at the follow-up session, 11 % of participants had unusable data for these reasons.

In the ANCOVA that assessed the effect of the approach-avoidance practice plus anti-smoking PSA intervention on implicit attitudes toward smoking, a significant main effect of the approach-avoidance practice task, $F(1, 267) = 14.70$, $p = .0002$, partial $\eta^2 = .05$, indicated that implicit attitudes toward smoking were significantly more negative for those who completed the push–pull approach-avoidance task (adjusted M = .79, se = .03) compared to those who completed the side-to-side control task (adjusted M = .63, se = .03). However, this main effect was qualified by two interactions. First, an approach-avoidance practice task by education level interaction, $F(1, 267) = 4.83$, $p = .029$, partial $\eta^2 = .02$, indicated that the effect of the task differed by educational attainment. As illustrated in Fig. 1, for those with no college education, implicit attitudes toward smoking were more negative for participants who completed the push–pull task (adjusted M = .83, se = .04) compared to participants who completed the side-to-side control task (adjusted M = .58, se = .05). The difference in the means between the push–pull and side-to-side conditions was statistically significant, $F(1, 267) = 14.54$, $p = .0002$, partial $\eta^2 = .05$. For those with some college education or higher, there was no difference in implicit attitudes between participants who completed the push–pull task (adjusted M = .75, se = .04) compared to participants who completed the side-to-side control task (adjusted M = .68, se = .03), $F(1, 267) = 1.81$, $p = .18$, partial $\eta^2 = .007$.

Second, an approach-avoidance practice task by plans to quit interaction, $F(1, 267) = 4.54$, $p = .034$, partial $\eta^2 = .02$, demonstrated that the effect of the task depended on having plans to quit smoking. Figure 2 show that for smokers with plans to quit, implicit attitudes toward smoking were more negative for those who completed the push–pull task (adjusted M = .87, se = .05) compared to those who completed the side-to-side control task (adjusted M = .62, se = .05). The difference in the means between the push–pull and side-to-side conditions was statistically significant, $F(1, 267) = 11.42$, $p = .001$, partial $\eta^2 = .04$. For those with no plans to quit, there was no difference in implicit attitudes between participants who completed the push–pull task (adjusted M = .71, se = .03) compared to participants who completed the side-to-side control task (adjusted M = .64, se = .03), $F(1, 267) = 3.23$, $p = .07$, partial $\eta^2 = .01$.

For the reading time outcome, a three-way educational attainment by approach-avoidance practice task by PSA interaction was detected, $F(1, 227) = 4.30$, $p = .039$, partial $\eta^2 = .02$. This interaction, displayed graphically in Fig. 3, indicated that for smokers with at least some college education who viewed the anti-smoking PSA, the amount of time spent reading cessation information was greater for those who completed the push–pull task (adjusted M = 136.42 s, se = 9.76) compared to those who completed the side-to-side control task (adjusted M = 121.18 s, se = 14.39). This mean difference was marginally statistically significant, $F(1, 227) = 3.14$, $p = .078$, partial $\eta^2 = .01$. There were no mean differences in any of the other groups (all p values >.16).

There were no effects of the intervention on expressed interest in receiving additional anti-smoking information or on post-intervention plans to quit smoking. Those with baseline plans to quit smoking had greater odds of reporting interest in receiving anti-smoking information (adjusted OR = 2.62, 95 % CI = 1.46, 4.73, $p = .001$).

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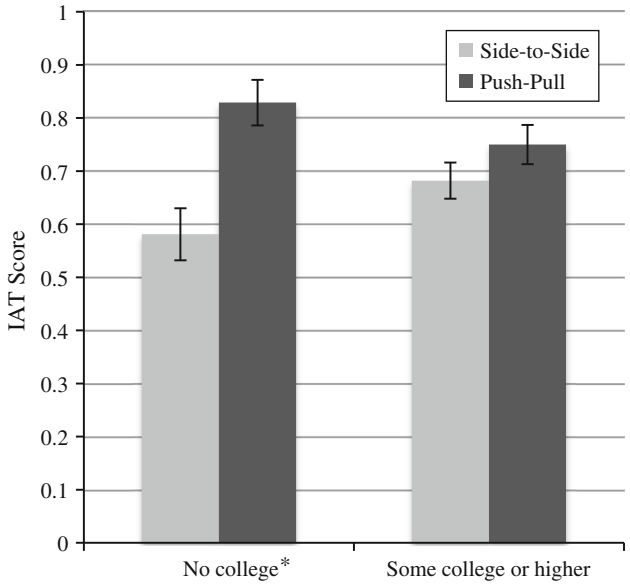

Fig. 1 Implicit attitude toward smoking (IAT score) for those who completed the push–pull approach-avoidance task versus the side-to-side control task by educational attainment, after controlling for baseline implicit attitude toward smoking. A higher value reflects a more negative implicit attitude toward smoking. *Mean difference $p = .0002$

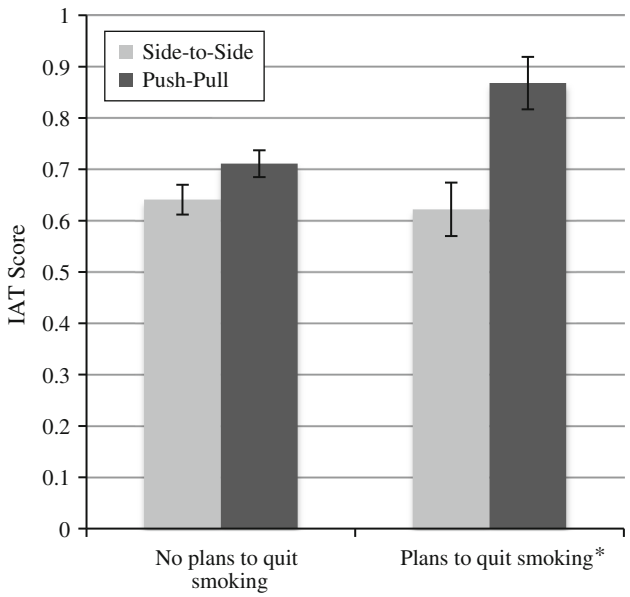

Fig. 2 Implicit attitude toward smoking (IAT score) for those who completed the push–pull approach-avoidance task versus the side-to-side control task by plans to quit smoking, after controlling for baseline implicit attitude toward smoking. A higher value reflects a more negative implicit attitude toward smoking. *Mean difference $p = .001$

Discussion

The current study had multiple goals. One goal was to assess the feasibility of delivering a web-based intervention

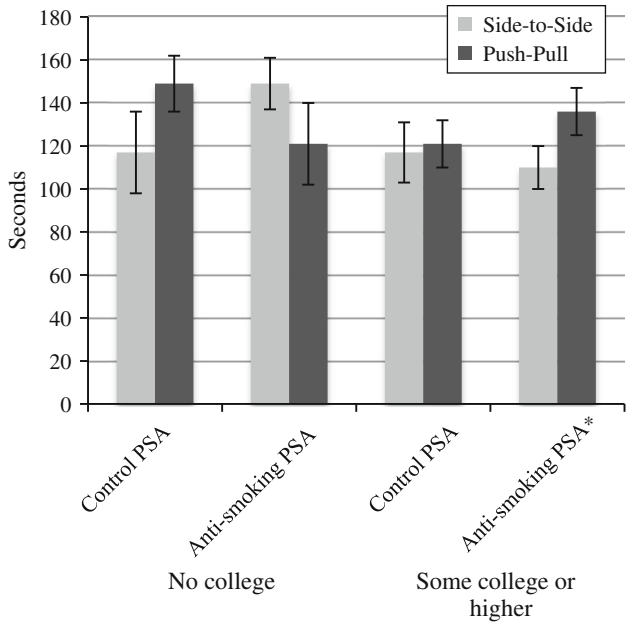

Fig. 3 Amount of time spent reading anti-smoking information (in seconds) for those who completed the push–pull approach-avoidance task versus the side-to-side control task by educational attainment and PSA viewed. *Mean difference $p = .078$

designed to change implicit attitudes toward smoking and increase receptivity to cessation-related information to a community-based sample of mid-life adult smokers. The results suggest that this approach is potentially viable. Specifically, unlike in prior studies of the approach-avoidance practice task that took place in supervised laboratory or clinical settings (Eberl et al., 2013; Kawakami et al., 2007, 2008; Wiers et al., 2010, 2011), the participants in this study completed the two-session study on their own with no direct oversight or assistance. Moreover, this study was conducted using a general sample of smokers as opposed to only those seeking treatment, so the sample better represents the population of smokers. A relatively low proportion of participants had unusable data due to missing data, problems completing the IAT, or self-reported distractions or lack of attention paid during the sessions. This has important implications for public health interventions that seek to reach large numbers of individuals. Considering that 20 % of US adults smoke cigarettes (Centers for Disease Control and Prevention, 2012), there is a need for inexpensive interventions that can be widely disseminated. A review of public health interventions delivered via the Internet (Bennett & Glasgow, 2009) found lower participation rates than the 43 % participation rate in this study. Thus, although utilization rates of web-based interventions have been low to date, this study's relative success in the recruitment of smokers not necessarily seeking treatment and the ability to reach large populations with the Internet suggest that web-based smoking cessation interventions have potential utility.

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In addition to investigating the feasibility of this web-based approach with a general sample of smokers, we were also interested in testing the effect of the intervention on implicit attitudes toward smoking and whether the effects were moderated by characteristics of the smokers. The results suggest that the approach-avoidance practice task may be able to make some smokers' implicit attitudes toward smoking more negative. First, the intervention may be able to make implicit attitudes toward smoking more negative for smokers with low levels of educational attainment. Importantly, this is the group that is of highest risk for heavy smoking and smoking-related morbidity and mortality (Hiscock et al., 2012). It is also a group that has been reported to be difficult to influence through traditional interventions such as media campaigns that target explicit outcomes (Niederdeppe et al., 2008), so that this is potentially a particularly important outcome. Second, smokers who reported having plans to quit smoking at baseline and completed the push–pull practice task were found to have more negative implicit attitudes toward smoking at follow-up. This is consistent with a study that found that a web-based intervention among smoking parents in a pediatric clinic was found to be effective in increasing motivation to quit only for those who were already contemplating behavior change (Gillaspy et al., 2013). Thus, effects of web-based smoking cessation interventions may be stronger among smokers who have at least some interest in changing their behavior.

In terms of the other outcomes, we identified an effect of the combination of the approach-avoidance practice task and anti-smoking PSA on the amount of time smokers spent reading information about smoking, but the effect was limited to participants with at least some college education. There were no significant effects for participants with lower levels of educational attainment, and their pattern of means was difficult to interpret. Among individuals with lower levels of education, reading time may be influenced not only by their interest in receiving the information but also by their literacy, which may result in reading too fast or too slow. Thus, reading time may be a better measure of interest and engagement for those with higher levels of education than for less educated individuals.

There were no significant effects of the intervention on the explicit outcomes of reported interest in receiving additional information about smoking cessation and plans to quit. There are two possible explanations for these null findings. First, it is possible that one session of the approach-avoidance practice task is not sufficient to change these outcomes. Although a single-session laboratory study showed effects on behavioral indicators of racial attitudes (Kawakami et al., 2007), changing actions related to an addictive behavior like cigarette smoking may require additional intervention. Second, this sample was comprised of individuals at different levels of motivation to change their behavior. In contrast, the Wiers et al. (2011) and Eberl et al. (2013) studies, which showed both effects on automatic cognitive biases and behavioral outcomes related to alcohol use, utilized multiple sessions of approach-avoidance practice in combination with cognitive behavior therapy and was conducted with individuals in alcohol treatment. Moreover, the proposed online intervention to reduce alcohol use among problem drinkers will utilize 12 sessions (van Deursen et al., 2013). Thus, in order to achieve similar outcomes for smoking, it is possible that multiple sessions and/or additional interventions are required. It is also possible that smokers enrolled in cessation programs would experience better outcomes, so that this intervention may be most useful as a component of broader smoking cessation programs.

In this study, the effect of the anti-smoking PSA was limited to increasing time spent reading anti-smoking information among smokers with at least some college education. Again, it is likely that one viewing of a PSA was not sufficient to influence the other outcomes. Only two studies have measured the effect of viewing an anti-smoking PSA on implicit attitudes toward smoking (Czyzewska & Ginsburg, 2007; Rydell et al., 2012), and one of them used multiple PSAs, and the other found effects only when smokers had just smoked a cigarette. Moreover, research has shown that media interventions were successful when they achieved high levels of exposure to media messages, and this led to in changes in smoking-related outcomes such as intentions and behaviors (Hornick, 2002). A review of mass media campaigns designed to promote smoking cessation among adults reported that both high reach and frequency are needed to influence adult smoking, probably due to the addictive nature of cigarette smoking (Durkin et al., 2012).

There are limitations to this study that should be considered. First, the participation and retention analyses suggest the need for caution in generalizing the findings to general community samples. In addition, the community from which this sample was chosen is predominantly white and well-educated. Also because of the racial and ethnic homogeneity of the sample and its community, it was not possible to test for differing effects of the intervention based on race and ethnicity. Finally, it is possible that findings may differ for intermittent smokers than for regular daily smokers, but the very small number of non-daily smokers in this sample made it unfeasible to test for this moderating influence.

Despite these limitations, this study demonstrated the potential usefulness of a web-based application of an approach-avoidance practice task that has been shown to be successful in changing implicit measures and related

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behaviors in other domains (Eberl et al., 2013; Kawakami et al., 2007, 2008; Wiers et al., 2010, 2011). Results suggest that it is feasible to utilize this intervention strategy to reach large target audiences, an important public health objective for reducing smoking. Effects were limited to implicit outcomes (i.e., implicit attitudes toward smoking and time spent reading anti-smoking information) in the analyses presented here, but future applications of this strategy that involve more intervention sessions and include individuals who are motivated to change their smoking behavior may result in meaningful changes in explicit outcomes as well and subsequent behavior change that ultimately leads to cessation.

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Conflict of interest Jonathan T. Macy, Laurie Chassin, Clark C. Presson, and Jeffrey W. Sherman declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

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