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How Persistent Is the Effect of Smoking Urges on Cognitive Performance?

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Several studies have provided empirical support for S. T. Tiffany's (1990) hypothesis that drug urges interfere with cognitive performance. The authors examined the persistence of this effect. Results from an experiment involving 48 smokers and 46 nonsmokers, using a paradigm developed by R. A. Zwaan and T. P. Truitt (1998), suggest that the effect of smoking urges in cognitive performance dissipates over time. The implications of this finding for cognitive theories of drug urges and for future research on the effects of smoking urges are discussed.

Smokers are often confined to smoke-free environments, for example, classrooms and office buildings, in which they are to perform complex cognitive tasks. Given that smokers are unable to respond to their smoking urges in such environments, there is the potential of a conflict between the urge to smoke and the task at hand. Indeed, researchers have hypothesized that smoking urges have a detrimental effect on cognitive performance (see, e.g., Tiffany, 1990). There is initial evidence for this hypothesis in the literature. For example, both Sayette and Hufford (1994) and Cepeda-Benito and Tiffany (1996) have shown that smoking urges bring about increases in simple tone-reaction times relative to a no-urge condition. More recently, Zwaan and Truitt (1998) showed that smoking urges interfere with higher cognitive processes, in this case, language comprehension. In Tiffany's theory, findings such as these are explained by assuming that smokers have smoking-related action schemata stored in long-term memory. These scripts can be activated by external cues, such as the smell of smoke, or by internal cues, such as thoughts about smoking. Urges and cravings are thought to occur when the drug-use action schema is activated but its implementation is impeded by external conditions, for instance, when the smoker is confined to a smoke-free environment. More specifically, addicts are hypothesized to use conscious processing resources to inhibit the drug-use action plan. As a consequence, they should have fewer conscious resources available for other tasks they are engaged in at the time.

Although the cited studies have shown that smoking urges elicited by in vivo cues or by imagery scripts may have deleterious effects on cognitive performance, little is known about the time course of these effects. Three patterns are theoretically possible: The urge effect may (a) remain constant, (b) dissipate, or (c) increase over time. The prediction that smoking urges have a continuous effect on cognitive performance can be derived from Tiffany's model, in which cognitive performance in the presence of a smoking urge is likened to dual-task performance (Tiffany, 1990, p. 160). That is, the smoking urge functions like a secondary task, drawing on resources needed for the main task.

The prediction that the effect of smoking urges dissipates over time would be borne out either by decay of the urge itself (e.g., if it is not supported by a continuously present urge cue) or by a coping mechanism that allows the smokers to minimize or eliminate the interference from the urge by adapting their cognitive strategies for performing the primary task.

The prediction that the urge effect increases over time can be derived from Wegner's (1994) theory of ironic memory processes. Wegner and colleagues have shown that the active suppression of information can have ironic effects such that the information that is actively being suppressed actually gains more in activation (Wegner, 1989, 1992; Wegner, Quillian, & Houston, 1996; Wegner, Schneider, Carter, & White, 1987). Thus, according to this prediction, the cognitive performance of smokers exposed to the urge script should become increasingly worse. This effect might be enhanced if the inability to implement the smoking-action plan renders smokers increasingly frustrated. This would presumably generate more task-irrelevant thoughts, thereby adding to the deleterious effect of the urge itself.

Thus, there are three classes of hypotheses that make different predictions about the time course of the urge effect. According to the first class, the effect remains constant. According to the second class, it dissipates. And according to the third class, it increases. The main goal of this study was to distinguish empirically among the three classes of predictions by examining the time course of the urge effect on cognitive performance.

A second goal of this study was to provide a conceptual replication of Zwaan and Truitt (1998). They obtained an urge effect in smokers (but not nonsmokers) on sentence

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comprehension accuracy. However, they also found that smokers were generally faster in reading the stimulus sentences than nonsmokers. Although this pattern was orthogonal to the pattern in the accuracy data and thus did not compromise Zwaan and Truitt's conclusions, we used an experimenter-paced presentation paradigm in the present study such that encoding time was controlled for in all participants. In all other respects, our procedure and materials were like those of Zwaan and Truitt, with the small exception that we used only two categories of stimulus items: sentences with no semantic cue and sentences with two semantic cues. Zwaan and Truitt also used sentences that had only one cue. However, they found that performance on them was highly similar to that of the two-cue sentences and therefore collapsed across the one-cue and two-cue sentences. In our present set of stimulus items, half the stimulus sentences had no semantic cues, the difficult sentences, and the other half had two, the easy sentences. Examples of each category are given in the Method section. The prediction, as in Zwaan and Truitt, was that the smoking urge effect should be particularly strong for the difficult sentences, given that they require more processing resources for adequate comprehension.

The Present Study

In the present study, we used the same paradigm as was used by Zwaan and Truitt (1998). For the manipulation of smoking urge, participants were presented with one of two imagery scripts developed by Maude-Griffin and Tiffany (1996; also used by Zwaan & Truitt, 1998): a script with smoking content, intended to elicit a smoking urge in smokers, and a script that did not contain smoking-related information. Both scripts had a positive emotional valence. As in Zwaan and Truitt, we did not directly assess urge by way of rating scales. Our main reason for this was our concern that having to rate one's urge to smoke may have the highly undesirable side effect of eliciting a smoking urge, thus creating a confound in our design. That is, to determine whether or not he or she experiences the urge to smoke, a smoker may retrieve memory representations of earlier situations in which he or she experienced a smoking urge. Similar to an urge script, such an evoked memory might trigger a smoking urge.

In a recent study of similar design (Madden & Zwaan, 2000), smokers provided retrospective urge ratings. That is, they provided these ratings after they had been exposed to the imagery scripts and several cognitive tasks so that the rating task could not affect performance on the cognitive tasks. The retrospective urge ratings pertained to several points during the experiment. Of particular relevance here is the finding that the smokers who were exposed to the urge script provided significantly higher retrospective urge ratings than those exposed to the neutral script for the time right after the presentation of the script, whereas the two groups provided equivalent retrospective urge ratings for the time before the presentation of the script. Thus, although retrospective urge ratings are somewhat indirect, they provide support for the idea that presentation of the urge script leads to a greater smoking urge than presentation of the neutral script.

After the presentation of the imagery scripts, all participants performed a sentence comprehension task very similar to the one used by Zwaan and Truitt (1998). The sentences were counterbalanced so that they could be segregated into four blocks on the basis of presentation order. This allowed us to assess the participants' comprehension performance over time.

In view of the theoretical considerations outlined above, we generated the following set of predictions:

(1) Smoking urges affect comprehension accuracy. This should result in a significant two-way interaction between smoking status and script (urge vs. neutral). This interaction would suggest that there is a detrimental effect of the urge script, relative to the neutral script, on cognitive performance in the smokers but not in the nonsmokers, whose performance should be unaffected by script content. A significant interaction would provide a conceptual replication of Zwaan and Truitt (1998).

(2) We considered three alternative predictions regarding the time course of the urge effect: (a) Smoking urges function as a concurrent memory load and therefore should not vary as a function of trial block. This leads to the prediction that block should not interact with script in smokers. A more powerful version of this prediction is that the urge effect should be significant both in the first and in the last trial block. This prediction was tested as well. (b) The urge effect dissipates over time because either the memory representation of the stimulus that gave rise to the urge decays or participants learn to cope with the urge. (c) The urge effect increases over time because of ironic memory processes (see, e.g., Wegner, 1989).

Method

Participants

Ninety-six undergraduate students (48 male, 48 female, with 24 smokers and 24 nonsmokers in each gender group) enrolled at Florida State University participated in the experiment. They received partial course credit as compensation. Analyses, described in more detail later, revealed that 4 participants (2 smokers, male and female, and 2 nonsmokers) had exceedingly long response times. The 2 smokers could be replaced because more had been run than were scheduled. However, the 2 nonsmokers were not replaced. Thus, the analyses reported below were based on 48 smokers and 46 nonsmokers.

Materials and Design

The materials were the same as in Zwaan and Truitt (1998), with the exception that the sentences in which one semantic cue was provided were changed to either two semantic cues or no semantic cues so that half of the experimental sentences contained no semantic cues (the difficult sentences) and half contained two cues (the easy sentences). An example of an easy sentence is "The robber that the fireman rescued stole the jewelry." An example of a difficult sentence is "The robber that the fireman applauded watched the program." The easy sentences are relatively easy to comprehend because semantic information helps the comprehender determine who did what in the situation described by the sentence. Robbers typically steal things, and firemen typically rescue people. Thus, both semantic and syntactic (word order) cues are at the comprehender's disposal. In the difficult sentences, on the other hand, determination of who did what can be based on syntactic analysis only as the semantics provide no helpful information.

A smoking questionnaire was also designed to assess some of the relevant smoking-related habits of the participants. All participants were asked to classify themselves as regular smokers or nonsmokers and to state their gender. Furthermore, smokers were asked to state how many cigarettes they smoked per day, how long they had smoked 10 or more cigarettes per day (a precondition for experimental participation was that smokers had to smoke at least 10 cigarettes a day), and finally, how long after waking in the morning they smoked their first cigarette. Nonsmokers were asked if they had ever tried smoking, if they ever smoked socially, and when, if ever, was the last time they had smoked a cigarette. Social smokers were excluded from the analyses.

Finally, a computerized version of the Daneman and Carpenter (1980) reading span task was used in the current experiment. In this task, participants are required to read increasingly longer sequences of sentences and to recall the final word of all the sentences in each sequence. From each set, they are subsequently presented with two of the sentences from which words have been replaced with blanks. Their task is to fill in the blanks. This cloze task discourages participants from merely memorizing the last words while ignoring the sentences. All participants were tested using the Psyscope software (Cohen, MacWhinney, Flatt, & Provost, 1993). The experiment was run on a Macintosh Quadra.

The study used a 2 (smoking status) × 2 (script) × 2 (sentence difficulty) × 4 (block) design. The first two factors were between subjects and the last two within. The materials were presented on four different lists, with list counterbalanced with the between-subjects factors. The list factor was included to systematically exclude item variance (Pollatsek & Well, 1995) but was not analyzed because of its lack of theoretical interest. Reading span was used as a covariate to control for individual differences in working-memory span.

Procedure

The procedure was very similar to that used by Zwaan and Truitt (1998) with the exception that sentence presentation was experimenter rather than subject paced. Each sentence appeared on the screen for an amount of time equal to the number of words in the sentence times 300 ms. To control as much as possible for time of day, all participants were tested between noon and 6 p.m. Each smoker smoked a cigarette away from the laboratory area immediately before entering the laboratory.

Upon reentering the lab, participants filled out a smoking questionnaire. Next, they performed a computerized version of the Daneman and Carpenter (1980) reading span task. After finishing the reading span task, all participants listened through headphones to the computer-presented urge or neutral script. They then read the sentences and answered comprehension questions for half of them. Each sentence was presented individually on the computer screen. When presented with a question, participants pressed one of two keys, labeled "yes" and "no," to respond to the question. The computer recorded the accuracy and latencies of the participants' responses to the comprehension questions. The comprehension task took about 8 min. Subsequent to the comprehension task, the participants recalled the script they had listened to by typing it directly into the computer. This task was used primarily for exploratory purposes. After having completed this task, the participants were debriefed about the purposes of the experiment.

Results

Descriptives

Table 1 shows the background information and individual differences data segregated by smoking status and script. As indicated earlier, 4 participants had extremely long response latencies on the comprehension task (with averages of more than 6 s on at least one block). Because more smokers had been run than were scheduled, the 2 smokers could be replaced. However, because we had no replacements for the nonsmokers, the 2 nonsmokers were not replaced. The demographic data show that the smokers tended to be light to intermediate smokers and that the subgroups of smokers are comparable in terms of smoking background. Analyses of variance supported these conclusions. None of the background variables showed a significant effect of script or a significant interaction between these two variables. A composite measure of reading span (described below) was used as a covariate in the analyses reported below.

Figure 1 shows the accuracy scores for the smokers in the urge condition and those in the neutral condition per block.

Comprehension Accuracy

We performed a 2 (smoking status) × 2 (script) × 2 (sentence difficulty) × 4 (block) analysis of covariance (ANCOVA), with reading span (operationalized as the sum

Table 1
Descriptive Statistics for Comprehension Accuracy, Reading Span, and Smoking Habits by Smoking Status and Script Condition

Status & script condition	Accuracy easy	Accuracy hard	% recall read span	% fill-in read span	Cigarettes per day	Years smoking	Minutes until 1st cigarette of day
Smokers							
Urge script	0.86 (0.13)	0.78 (0.11)	0.77 (0.12)	0.46 (0.15)	16.7 (6.3)	2.0 (1.2)	71.8 (82.5)
Neutral script	0.90 (0.09)	0.85 (0.10)	0.80 (0.08)	0.45 (0.16)	16.0 (7.7)	1.6 (1.2)	61.1 (64.9)
Nonsmokers							
Urge script	0.89 (0.09)	0.84 (0.15)	0.82 (0.08)	0.46 (0.20)	NA	NA	NA
Neutral script	0.88 (0.10)	0.80 (0.12)	0.82 (0.10)	0.50 (0.17)	NA	NA	NA

Note. Values in parentheses are standard deviations. NA = not applicable.

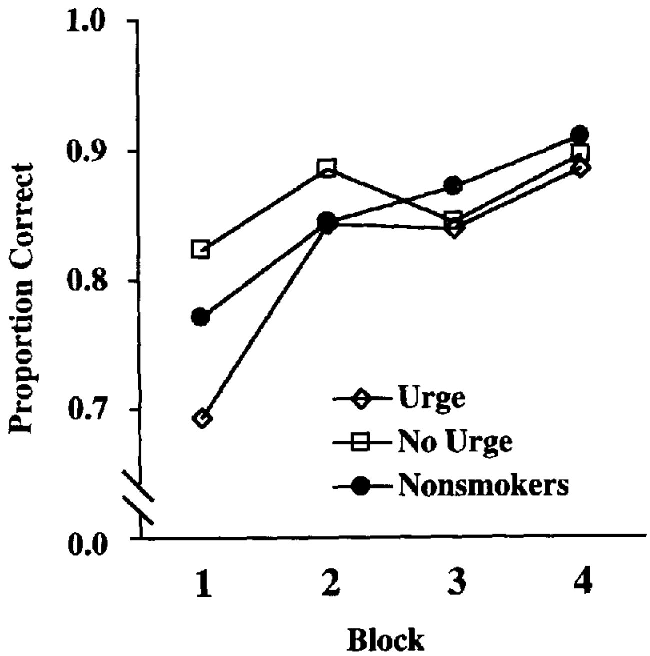

Figure 1. Comprehension accuracy by block for smokers in the urge script and neutral script conditions and for nonsmokers.

of the normalized proportion correct scores on the final-word recall and cloze completion components of the reading span task) as the covariate. In preliminary analyses, list and gender were included in the initial design, but because they did not participate in any of the relevant interactions, they were not further included. We discuss the results as they pertain to our hypotheses.

As Figure 1 suggests, exposure to the urge script decreased comprehension accuracy in the smokers but not in the nonsmokers. This interaction was significant, $F(1, 89) = 6.13$, $p < .05$. Follow-up analyses using the error term from the omnibus analysis showed that this interaction was associated with a significant detrimental effect of script on the smokers, $F(1, 45) = 5.87$, $p < .01$, whereas there was no significant effect of script on the nonsmokers, $F(1, 43) = 1.29$. There was a significant three-way interaction between smoking status, script, and block, $F(3, 267) = 5.07$, $p < .005$. Within the smokers, the interaction between script and block was marginally significant, $F(3, 135) = 2.22$, $p < .09$. Simple-effects analyses revealed that the effect of script in the smokers was significant on the first block, $F(1, 45) = 8.14$, $p < .01$, but reduced to nonsignificance on the later blocks, all $Fs < 1.75$.

The predicted three-way interaction between smoking status, script, and sentence difficulty was not significant, $F(1, 86) = 2.00$, nor was the four-way interaction that also included block, $F(3, 258) = 1.89$.

The only two significant main effects were those of sentence difficulty and block. As expected, the more difficult sentences yielded generally lower comprehension accuracy than the easier sentences, $F(1, 86) = 24.61$, $p < .001$. Furthermore, participants became more accurate over time, $F(3, 264) = 16.33$, $p < .001$. None of the other main effects were significant.

Response Latencies

In our analysis, we considered all response latencies, including those pertaining to incorrect responses (see Figure 2). Analyses of response latencies for only the correct items yielded a similar pattern of results but were deemed less useful because there were a few empty cells, namely, when all of a participant's responses in a given block for a category of items were incorrect. Response latencies more than two standard deviations from a participant's block average were considered outliers and removed from the analysis. This involved less than 5% of the data.

As in the analyses of response accuracy, we performed a 2 (smoking status) × 2 (script) × 2 (sentence difficulty) × 4 (block) ANCOVA on response latencies, again with our measure of reading span as the covariate. In a preliminary analysis, list and gender were included as between-subjects factors in the design as well, but because they did not participate in any of the relevant interactions, they were omitted in the analyses reported here.

There were no significant interactions involving smoking status and script, all $Fs < 1.55$. Participants generally responded more quickly toward the end of the experiment, as evidenced by a significant block effect, $F(3, 267) = 41.10$, $p < .001$.

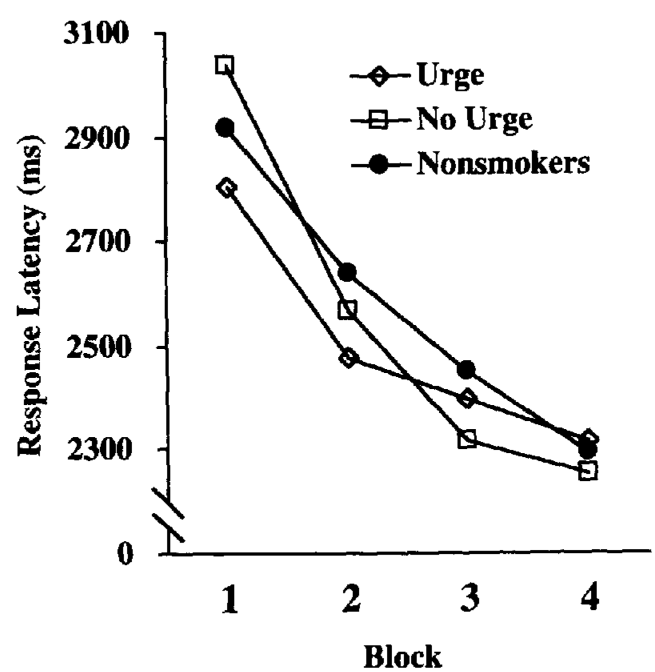

Figure 2. Comprehension latencies by block for smokers in the urge script and neutral script conditions and for nonsmokers.

Discussion

Effect of Smoking Urges on Cognitive Performance

Our results replicate and extend those of Zwaan and Truitt (1998), who found deleterious effects of smoking urges on language comprehension performance. Our results extend these results in that they show that the urge effect occurs also when the presentation rate of the stimulus sentences is experimenter controlled, rather than subject paced, as it was in Zwaan and Truitt. More generally, this finding is also consistent with earlier findings by Sayette and Hufford (1994) and Cepeda-Benito and Tiffany (1996). It is interesting to compare the different tasks that have been used so far to demonstrate the effect of smoking urges on cognitive performance. Sayette and Hufford and Cepeda-Benito and Tiffany both used simple reaction times to a probe. It would seem that these latter findings are consistent with the idea that smoking urges interfere with attentional processes, rather than with working-memory operations, given that responding to simple probes does not require working-memory operations.

The findings of Zwaan and Truitt (1998), on the other hand, are prima facie highly consistent with Just and Carpenter's (1992) capacity view of working memory. According to this view, people have a limited capacity to briefly store and manipulate information in memory. Furthermore, there are individual differences in working-memory capacity. As a consequence, additional tasks that require working-memory resources may interfere with cognitive performance on the primary task as they deplete the available resources required for that task, and people with less working-memory capacity should experience more detrimental effects from a secondary task than people with more capacity. Furthermore, to the extent that the primary task requires more resources, it should be more affected by a secondary task.

Given the assumption that activities to inhibit the smoking-action plan function as a secondary task, the findings of Zwaan and Truitt (1998) can be explained by the capacity view. Exposure to an urge cue had a detrimental effect on comprehension accuracy in smokers, and this effect was particularly strong (a) in smokers with low working-memory capacity and (b) for the sentences that were the most resource demanding. Our current findings are also largely consistent with this view, although we did not obtain a significant interaction between sentence difficulty, smoking status, and script, which would have provided more statistical support.

Although the capacity view can explain the findings of Zwaan and Truitt (1998) and our current findings rather well, its apparent inability to provide a straightforward explanation for the findings reported by Sayette and Hufford (1994) and by Cepeda-Benito and Tiffany (1996) is problematic. Furthermore, the capacity view has recently come under fire in the memory literature. Consider, for instance, Ericsson and Kintsch's (1995) theory that individual differences in memory performance can be attributed to differences in (encoding) skill. According to this view, a secondary task does not lead to detrimental effects because it uses up working memory resources but because it draws attentional resources away from the encoding and processing of stimulus information. The more skilled people become at performing a task, the more effectively they can encode information and the less disruptive the effect of a secondary task is. It would seem that such a view provides a potent alternate account of our findings. Attempts to inhibit the smoking urge drew away attentional resources (presumably intermittently, rather than continuously) from accurately encoding the sentences, leading to a decrement in comprehension accuracy.

The Time Course of the Urge Effect

Our current results extend those of earlier studies in that they suggest that the effect of smoking urges on cognitive performance is relatively short-lived. Exposure to the urge script led to a statistically significant 13% decrease in comprehension accuracy in smokers during the first trial block, but this difference was reduced to a statistically nonsignificant 1% in the fourth block. In the introduction, we alluded to two potential explanations of this pattern. According to one hypothesis, the urge simply decays over time, perhaps because the urge cue is presented only temporarily, rather than continuously. An alternative explanation is that smokers develop strategies to work around the smoking urge, that is, they adapt their task performance so that the effect of the smoking urge is minimized. A third, and perhaps related, explanation focuses on the primary task. Given that the smokers in the urge condition showed rapid improvement on the task, their performance became less and less susceptible to urge interference. Both the capacity view of working memory (Just & Carpenter, 1992) and the skill-based view (Ericsson & Kintsch, 1995) generate this explanation. According to the capacity view, the comprehension task's working memory demands became increasingly smaller, making comprehension increasingly impervious to the memory demands of the smoking urge. In terms of the skill-based view, task improvement would be interpreted to be the result of more efficient, that is, faster, encoding processes, which should be less likely to be disrupted by intermittent attentional competition than slower encoding processes.

Although our present data do not allow us to distinguish between these explanations, they do allow us to rule out other predictions regarding the urge effect. It is clearly not the case that the smoking urge prevents people from learning a task. The smokers in the urge condition showed a significant increase in comprehension accuracy, as well as a decrease in response latencies, much like the other participants. Second, it is clear that the urge effect does not increase over time.

Conclusions

Our results provide further support for the hypothesis, derived from Tiffany's (1990) cognitive model of drug urges and drug-use behavior, that drug urges interfere with cognitive performance. Our finding that this interference effect is rather short-lived provides a new challenge to cognitive theories of drug urges. An important and logical next question to address is whether the dissipation of the urge effect is due to a decay of the urge itself or whether, as is predicted by current theories of working memory, improved performance on the primary task eliminates the urge effect. We are currently examining this question.

References

Cepeda-Benito, A., & Tiffany, S. T. (1996). The use of a dual-task procedure for the assessment of cognitive effort associated with cigarette craving. *Psychopharmacology, 127,* 155–163.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). Psyscope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments and Computers, 25,* 257–271.

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior, 19,* 415–466.

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review, 102,* 211–245.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review, 99,* 122–149.

Madden, C. J., & Zwaan, R. A. (2000). *The impact of smoking urges on working memory performance.* Manuscript in preparation.

Maude-Griffin, P., & Tiffany, S. T. (1996). Production of smoking urges through imagery: The impact of affect and smoking abstinence. *Experimental and Clinical Psychopharmacology, 4,* 198–208.

Pollatsek, A., & Well, A. (1995). On the use of counterbalanced designs in cognitive research: A suggestion for a better and more powerful analysis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 785–794.

Sayette, M. A., & Hufford, M. R. (1994). Effects of cue exposure and deprivation on cognitive resources in smokers. *Journal of Abnormal Psychology, 103,* 812–818.

Tiffany, S. T. (1990). A cognitive model of drug urges and drug-use behavior: Role of automatic and nonautomatic processes. *Psychological Review, 97,* 147–168.

Wegner, D. M. (1989). *White bears and other unwanted thoughts.* New York: Viking Press.

Wegner, D. M. (1992). You can't always think what you want: Problems in the suppression of unwanted thoughts. In M. Zanna (Ed.), *Advances in experimental social psychology* (Vol. 25, pp. 193–225). San Diego, CA: Academic Press.

Wegner, D. M. (1994). Ironic processes of mental control. *Psychological Review, 101,* 34–52.

Wegner, D. M., Quillian, F., & Houston, C. E. (1996). Memories out of order: Thought suppression and the disturbance of sequence memory. *Journal of Personality and Social Psychology, 71,* 680–691.

Wegner, D. M., Schneider, D. J., Carter, S., III, & White, L. (1987). Paradoxical effects of thought suppression. *Journal of Personality and Social Psychology, 68,* 782–792.

Zwaan, R. A., & Truitt, T. P. (1998). Smoking urges affect language processing. *Experimental and Clinical Psychopharmacology, 6,* 325–330.

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