Cue-Induced Smoking Urges Deplete Cigarette Smokers' Self-Control Resources

Martin S. Hagger, Eamonn Leaver, and Kerstin Esser,

Curtin University

Chung-Ming Leung,

University of Nottingham

Nina Te Pas,

Maastricht University

David Keatley, Derwin K.- C. Chan and Nikos L. D. Chatzisarantis,

Curtin University

Author Note

Martin S. Hagger, Eamonn Leaver, Kirsten Esser, David Keatley, Derwin K.- C. Chan, and Nikos L. D. Chatzisarantis, Health Psychology and Behavioural Medicine Research Group, School of Psychology and Speech Pathology, Perth, Australia; Chung-Ming Leung, School of Psychology, University of Nottingham, Nottingham, UK; Nina Te Pas, Department of Health Promotion, Maastricht University, The Netherlands.

Correspondence concerning this article should be addressed to Martin S. Hagger, Health Psychology and Behavioural Medicine Research Group, School of Psychology and Speech Pathology, Curtin University, GPO Box U1987, Perth, WA 6845, Australia, email: martin.hagger@curtin.edu.au

Abstract

Background. Exposure to smoking-related cues leads to increased urge-to-smoke in regular cigarette smokers and resisting these urges requires considerable self-control.

Purpose. Adopting a resource-depletion model, two studies tested the hypothesis that resisting smoking urges depletes self-control resources.

Methods. Adopting a within-participants randomized cross-over design, participants (Study 1, N = 19; Study 2, N = 32) were exposed to smoking-related (Study 1:smoking images; Study 2:cigarette cue-exposure task) and neutral (Study 1: neutral images; Study 2: drinking-straw task) cues with presentation order randomized. After each cue set, participants completed self-control tasks (Study 1: handgrip task; Study 2: handgrip and Stroop tasks), performance on which constituted dependent measures of self-control.

Results. Self-control task performance was significantly impaired when exposed to smoking-related cues compared to neutral cues. No significant presentation-order effects, or interaction effects between stimulus and presentation order, were found.

Conclusions. Findings corroborate our hypothesis that resisting smoking urges depletes cigarette smokers' self-control resources and suggests that self-control capacity is governed by a limited resource.

Key words: strength model, self-regulation, tobacco, smoking urge, dual-task procedure

Cue-Induced Smoking Urges Deplete Cigarette Smokers' Self-Control Resources

Cues that induce the urge to smoke are a major reason why cigarette smokers attempting to quit experience lapses [1, 2]. Smoking urges are heightened by exposure to environmental cues (e.g., observing others smoking or cigarettes) that trigger the urge to smoke through an interaction of conditioned responses and addictive substances in cigarettes (nicotine) [3, 4]. Without managing or reducing exposure to these cues, cigarette smokers attempting to curb their behavior will experience repeated urges and be forced to resist them [5]. Overcoming urges to smoke, therefore, requires considerable self-control with success dependent on the extent to which the cigarette smoker can control the urge to smoke [6, 7]. In the current investigation, we adopt a resource depletion model to test the hypothesis that smoking urges deplete a unitary, limited resource of self-control leaving cigarette smokers with reduced ability to perform subsequent acts of self-control. The research will add to current knowledge by examining the role of self-control resources in regular cigarette smokers' attempts to resist smoking urges when presented with cues to smoke.

Self-Control: A Resource Depletion Model

Self-control is required to overcome ingrained, highly-automatic habits and resist urges, temptations, and impulses. A prominent approach to the study of self-control conceptualizes self-control as a limited resource that enables people to exert control over their impulses and temptations, but only for a limited period after which self-control capacity is temporarily compromised leading to reduced performance on subsequent tasks or behaviors that require self-control [8, 9]. The state of diminished self-control resources is known as *ego-depletion*. The resource depletion model has received considerable empirical support in the literature in many domains of self-control supporting the notion that self-control is governed by a unitary source that generalizes to any task or behavior that requires self-control [10].

The model is typically tested using an experimental dual-task paradigm in which participants engage in two consecutive tasks. Participants complete one of two tasks, randomly assigned: a task that requires self-control (ego-depletion condition) or a version of the task that does

not (control condition). All participants then complete a second task that requires self-control from a different domain to that of the first task. The extent to which performance on the second task is diminished in participants in the ego-depletion condition relative to the control condition provides support for the resource depletion effect.

Self-Control Resource Depletion and Addictive Behaviors

The resource depletion model of self-control has been applied to people attempting to reduce their use of everyday addictive substances such as cigarettes and alcohol [e.g., 11, 12, 13]. Cues that prompt these addictive behaviors require individuals to exert self-control to overcome the conditioned response. According to the resource depletion model, resisting the urge and suppressing the conditioned response will deplete self-control resources leaving the individual in an ego-depleted state [14]. Cigarette smoking is a prime example of such a behavior as it is a highly automatized, conditioned habit and attempts by regular cigarette smokers to quit or curb their smoking behavior, particularly in the face of smoking cues, requires self-control to resist the well-conditioned response to smoke [15-17]. Similarly, research applying the resource-depletion model in addictive behaviors, including cigarette smoking and alcohol consumption, has implicated self-control resources in the process of resisting the urges to engage in these behaviors [11-13].

Overview of Current Research and Hypotheses

The present research builds on studies applying the limited resource model to addictive behaviors and aimed to test the hypothesis that resisting the urge to smoke leads to increased self-control resource depletion in regular cigarette smokers. The research makes a unique contribution to the literature by demonstrating that self-control is implicated in resisting smoking urges and leads to short-term depletion of self-control resources. While previous research has shown that self-control depletion leads regular cigarette smokers to smoke more, the current research will add to knowledge by demonstrating that cues inducing the urge to smoke in cigarette smokers leads to reduced self-control in other domains. This will provide an indication that smokers attempting to curb their cigarette use might encounter difficulties when approaching self-control tasks in other domains.

Method

Design. Two studies adopting two-factor within-participants randomized cross-over designs were conducted. In each study participants were exposed to a set of smoking-related (Study 1: smoking-related images; Study 2: cigarette cue-exposure task) or neutral (Study 1: neutral images; Study 2: neutral 'object-rating' task) cues. The smoking-related cues (smoking images and cigarette cue-exposure) were designed to induce the urge to smoke consistent with previous studies [18-20]. The order of presentation of the cue sets was randomized. Following exposure to the first cue set, participants completed a handgrip strength task (both studies) and modified incongruent version of the Stroop color-naming task (Study 2 only). Performance on the baseline-adjusted handgrip task (both studies) and Stroop task (Study 2 only) a served as dependent measures of self-control capacity. After a brief break, participants were presented with the remaining cue set followed by the handgrip and Stroop tasks once more. The study protocol received approval from the Curtin University Human Research Ethics Committee.

Participants. Participants (Study 1: N = 19, 12 males, 7 females, *M* age = 23.47, *SE* = 0.69[1]; Study 2: N = 32, 13 males, 19 females; *M* age = 20.13, *SE* = .25) were recruited through notices advertising the study posted on undergraduate notice boards throughout Curtin University and in emails circulated to the undergraduate student body. The notices informed participants that they had to be regular cigarette smokers, defined as smoking at least 10 cigarettes per day, to be eligible to participate. Participants volunteering to participate in the study were invited to visit the laboratory and asked to refrain from smoking for 1 hour prior to attendance. Participants completed an initial questionnaire that included their demographic details, self-reported average number of cigarettes smoked per day to ensure they met the selection criterion of smoking at least 10 cigarettes per day, and the Tobacco Dependence Screener [21]. Participants received a payment of $10 in advance for their participation. All participants reported smoking at least 10 cigarettes per day (Study 1: *M* =

[1]We omitted the data of one participant from the original sample (N = 20) as the data were incomplete as she opted to withdraw from the experiment early.

14.95 cigarettes smoked per day, *SE* = 1.21, range = 10-30; Study 2: *M* = 14.34 cigarettes per day, *SE* = 0.68, range = 10-25) and scores on the Tobacco Dependence Screener (Study 1: *M* = 7.35, *SE* = 1.08, range 3-10; Study 2: *M* = 7.31, *SE* = 0.40, range = 3-10) exceeded published norms [21]. Data on socioeconomic status and ethnicity were not collected.

Procedure. Participants were shown into a laboratory and provided with a cover story to mask the true purpose of the study. Participants in Study 1 were informed that they were participating in a study on image perceptions and that they would be asked to watch and rate two sets of images on a computer monitor. Participants in Study 2 were informed that they were participating in a study examining evaluations of different brands of everyday objects and that they would be asked to interact with, and provide ratings of, cigarettes and drinking straws. As a part of the cover story to mask the link between the experimental tasks, participants were informed that they would be asked to complete an additional task (Study 1: "a handgrip strength task"; Study 2: "a handgrip strength task and a computerized color-naming task") to provide another researcher with pilot data for an unrelated study. They were told that it was convenient to include these measures in order to provide a natural break between the other tasks. Participants were also informed that they were to abstain from smoking at all times during the study, but that if they needed to smoke the experimenter would accompany them to a smoking area.

After signing a consent form, participants were asked to engage in a handgrip task using a commercially-available, spring-loaded handgrip apparatus of the type used in previous studies to measure self-control capacity [e.g., 9]. Participants were asked to squeeze the handles of the apparatus together using their dominant hand with sufficient force to hold a coin between the handles for as long as possible. The experimenter measured the time the participants were able to hold the coin between the handles using a stopwatch, the fallen coin indicating when timing should cease. Performance on the handgrip task constituted a dependent measure of self-control performance for both studies and the initial task was designed to provide a baseline measure to control for individual differences in grip strength.

Participants were then exposed to the first cue-exposure set. In Study 1, the cue set comprised either 30 smoking-related images (photographs of hands holding cigarettes and people smoking) designed to induce the urge to smoke or 30 neutral images (photographs of hands holding items of stationary and people without cigarettes). The images were derived from the International Smoking Images Series [22] and have been previously validated as a means to induce the urge to smoke [23]. Images were presented in series on a cathode ray tube screen for 3s controlled by the Eprime experimental software. Participants were required to depress a button on the keyboard to acknowledge that they were focusing their attention on the images. In between each image exposure, a black fixation cross on a white background was presented for a randomly-determined period of 8, 10, or 12s. The entire image sequence lasted approximately 5.50 minutes.

In Study 2, the cue set comprised an adapted form of a cue-exposure task developed to evoke the urge to smoke in previous studies on smoking [17, 24, 25], with a neutral alternative equivalent in format and information load. In an ostensible object-rating task, participants were presented with three piles of cigarettes or drinking straws and asked to perform several brief actions involving each set of objects and rate them accordingly. Participants were seated at a desk and three piles of the objects (commercially-available cigarettes or drinking straws) were placed on separate paper plates in front of them, labelled 'Brand A', 'Brand B' and 'Brand C' respectively[2]. Alongside each pile was an instruction sheet and a rating questionnaire. Participants were asked to follow the instructions on the sheet closely for each pile starting with Brand A. The instructions asked participants to lift, hold, feel, roll, smell, and manipulate one of the objects from each pile in their dominant hand several times[3]. Thereafter they were instructed to rate the objects according to their weight and feel on the brief questionnaire. They were then asked to move on to the second 'brand' until they had completed all three piles. During the task, the experimenter sat at an adjacent desk away from the participant and pretended to work. Instead, the experimenter covertly observed the

[2]In reality, the cigarettes in each pile were from the same brand and therefore identical in order to control for brand preference.

[3]The protocols for the cigarette and drinking-straw evaluation (cue-exposure) tasks are available from the first author on request.

participant to ensure that they engaged in the task and that they spent a maximum of 5 minutes on each pile. If the participant spent too long on any one pile, they were politely asked to move on.

Following the first cue exposure period, participants completed the brief version of the Questionnaire of Smoking Urges [18] and the Brief Mood Introspection Scale [26]. They then engaged in the handgrip task and the time spent on the task recorded. As an additional measure of self-control capacity, participants in Study 2 also completed the Stroop color-naming tasks. We adopted an incongruent version of the Stroop color-naming task. In this task, participants were presented with a series of color-words printed in colored ink so that the meaning of the word and ink color conflicted (e.g., the word "blue" written in green ink). Participants were required to name the color of the ink and not read the word. This task has been acknowledged as one that requires self-control resources as participants have to suppress the impulse to read the word rather than name the color [27]. The words were presented in a random order on a cathode ray tube screen controlled by Eprime experimental software. Responses were made using keys corresponding to three colors (red, green, and blue) on the computer keyboard. Participants received an initial set of 10 practice trials followed by a short break and then received 90 experimental trials, randomly presented. Response latencies were recorded with slower responses indicative of greater self-control resource depletion.

After a five-minute break, during which participants were asked to sit quietly, participants were presented with the second cue set followed by the Brief Mood Introspection Scale and Questionnaire of Smoking Urges scale for a second time. Participants then engaged in the handgrip task (both studies) and the incongruent Stroop color-naming task (Study 2 only) for a final time. Finally, the experimenter administered a funnel debrief procedure in which participants were probed for a suspected link between the cue-exposure procedure and the handgrip (both studies) and Stroop color-naming (Study 2 only) tasks prior to receiving a full debrief after which they were thanked and dismissed. None of the participants reported noticing a link between the cue-exposure sets and the dependent self-control tasks.

Results

Responses to image exposure. Cronbach alpha (α) reliability coefficients for smoking (Study 1: positive affect α = .77, negative affect α = .70; Study 2: positive affect α = .81, negative affect α = .82) and neutral (Study 1: positive affect α = .88; negative affect α = .63; Study 2: positive affect α = .75, negative affect α = .76) cue sets for the subscales of the Brief Mood Introspection Scale and the smoking (Study 1: α = .89; Study 2: α =.85) and neutral (Study 1: α = .91; Study 2: α = .88) cue sets for the Questionnaire of Smoking Urges scale were adequate, although the alpha for negative affect subscale under the neutral cue set in Study 1 was a little on the low side. Participants reported significantly higher urge to smoke for scores on the Questionnaire of Smoking Urges scale when they were exposed to the smoking-related (Study 1: *M* = 30.53, *SE* = 2.59; Study 2: *M* = 42.44, *SE* = 1.60) compared to when they were exposed to the neutral (Study 1: *M* = 26.63, *SE* = 2.57; Study 2: *M* = 28.59, *SE* = 1.66) cue set (Study 1: $t(18) = 2.83$, $p = .011$, $d = 1.29$; Study 2: $t(31) = 15.98$, $p < .001$, $d = 5.65$[4]). There were no significant differences in scores on the positive and negative affect subscales of the Brief Mood Introspection Scale across the smoking and neutral cue sets.

Self-control. We conducted a two-way mixed-model ANOVA on baseline-adjusted[5] handgrip task duration with cue set (smoking-related vs. neutral) as a within-participants factor and order of presentation as a between-participants factor. Results are displayed in Figure 1. Participants spent significantly less time on the handgrip task when exposed to the smoking-related (Study 1: *M* = -33.18, SE = 15.34; Study 2: *M* = -13.64, *SE* = 2.69) than when they were exposed to the neutral

[4]We also tested for differences across smoking and neutral cue exposure on critical single items from the brief Questionnaire of Smoking Urges scale shown to have equal sensitivity to abstinence and reliability to the full scale. Specifically, we found significant differences on item 5 "All I want right now is a cigarette" (Study 1: smoking image exposure *M* = 2.58, *SE* = 0.30, neutral image exposure *M* = 2.00, *SE* = 0.24, $t(18) = 3.64$, $p = .002$, $d = 1.67$; Study 2: smoking cue exposure *M* = 3.41, *SE* = 0.28, neutral cue exposure, *M* = 2.13, *SE* = 0.18, $t(31) = 5.57$, $p < .001$, $d = 1.97$) and item 6 "I have an urge for a cigarette" (Study 1: smoking image exposure *M* = 3.68, *SE* = 0.45, neutral image exposure, *M* = 3.11, *SE* = 0.41, $t(18) = 2.25$, $p = .037$, $d = 1.03$; Study 2: smoking cue exposure *M* = 4.63, *SE* = 0.26, neutral cue exposure, *M* = 3.00, *SE* = 0.28, $t(31) = 7.59$, $p < .001$, $d = 2.68$).

[5]We adjusted the time participants spent on the handgrip task after exposure to each image set for baseline strength by subtracting baseline handgrip duration from handgrip task duration after each image set. The more negative the scores, the greater the level of self-control resource depletion

(Study 1: M = -16.03, SE = 17.68; Study 2: M = -2.47, SE = 2.36) cue sets (Study 1: $F(1,17) = 6.83$, $p = .018$, $\eta_p^2 = .29$; Study 2: $F(1,30) = 14.76$, $p < .001$, $\eta_p^2 = .33$). There was neither a significant main effect for order of presentation (Study 1: $F(1,17) = 0.04$, $p = .949$, $\eta_p^2 = .00$; Study 2: $F(1,30) = 0.56$, $p = .815$, $\eta_p^2 = .00$) nor a significant cue-exposure task x presentation order interaction effect (Study 1: $F(1,17) = 1.18$, $p = .291$, $\eta_p^2 = .06$; Study 2: $F(1,30) = 0.33$, $p = .568$, $\eta_p^2 = .01$). For the analysis of the Stroop color-naming task data in Study 2, we conducted an identical analysis with response latency as the dependent variable. Response latencies were significantly greater when participants were exposed to smoking-related (M = 654.78, SE = 14.14) than when they were exposed to neutral (M = 590.70, SE = 11.14) cue sets, $F(1,30) = 72.76$, $p < .001$, $\eta_p^2 = .71$. There was no significant main effects for order of presentation ($F(1,30) = 0.14$, $p = .715$, $\eta_p^2 = .01$) or a significant cue-exposure task x order of presentation interaction effect ($F(1,30) = 3.02$, $p = .092$, $\eta_p^2 = .09$)[6].

Discussion

The present findings are unique in that they provide the first indication that cues that stimulate the urge to smoke lead to decrements in self-control resources in regular cigarette smokers. This is entirely consistent with theory on addictive behaviors, and health behavior in general, which suggests that self-control is a key factor determining individuals' ability to overcome well-learned habits, impulses, urges, and temptations [7, 14, 28]. Cigarette smoking is a particularly relevant behavior in this regard as it is maintained through strong conditioned responses to addictive chemicals in cigarettes (nicotine) and social cues paired with smoking initiation. Our results suggest that resisting urges to smoke leads to reduced self-control in other domains, a fact that has been implied in research that shows abstinence leads to reduced performance on tasks that require self-control in domains such as vigilance and cognitive functioning [29, 30].

[6]We repeated the ANOVAs with Tobacco Dependence Screener scores as a covariate to control for tobacco dependence. The pattern of findings was identical to the analyses with Tobacco Dependence Screener scores excluded and there were no significant main or interaction effects for Tobacco Dependence Screener scores on the handgrip (both studies) and Stroop (Study 2) dependent variables. We therefore report the ANOVA results with the Tobacco Dependence Screener scores excluded.

Our results are also consistent with previous research examining the role of self-control resource depletion on health-related behaviors adopting the resource depletion model. For example, Muraven and Shmueli [11] used a similar cue-exposure task to that used in Study 2 to show that regular alcohol drinkers had diminished performance on self-control tasks after exposure to a cue to drink (sniffing alcohol) compared to when they were exposed to a neutral cue (sniffing water). Muraven and Shmueli's findings, along with current results, suggest that resisting cues for conditioned addictive behaviors consumes a unitary self-control resource which is finite and common to behaviors that require individuals to overcome temptations and urges. This is consistent with a key premise of Baumeister et al.'s [8] and Muraven et al.'s [9] limited resource model that self-control capacity is generalizable to numerous behavioral domains.

Practical Implications

The current research has implications for the management of smoking cessation and interventions to help regular cigarette smokers quit. Our results indicate that the depletion of self-control resources in cigarette smokers exposed to smoking cues leads to reduced capacity to perform actions requiring self-control in other domains. A practical example in a health-related context would be a cigarette smoker attempting to quit while also having the need to change their behavior to manage another long-term condition such as obesity. If the smoker's self-control resources become compromised as a result of resisting the urge to smoking then it may lead to impaired capacity to control other behaviors such as eating. Practitioners should be wary of the role that self-control resource depletion plays when implementing interventions to change multiple health behaviors simultaneously. Confining intervention efforts to changing health-related behaviors in series (i.e., one at a time) rather than in parallel may avoid potential interference from compromised self-control capacity and lead to most success [28].

Other means available to health practitioners to bolster self-control resources to optimize cigarette smokers' capacity to resist smoking urges brought about by cue exposure include

pharmacological interventions such as nicotine replacement therapy to manage the strength of smoking urges [24], training or practice on self-control tasks [31], and nutritional interventions to boost self-control [32]. Behavioral interventions that aim to reduce the salience of, or help manage, the cues that induce the urge to smoke in addictive behaviors have been shown to be particularly efficacious in maintaining abstinence. For example, imagery may play a role in promoting self-regulation by reducing the salience of cues [33] or promoting increased motivation and self-efficacy toward behaviors to help cope with cues to smoke [34].

Conclusion, Strengths, and Limitations

The present study provides preliminary evidence that a unitary, generalized self-control resource is implicated in regular cigarette smokers' responses to smoking-related cues and the subsequent impairment of performance on self-control tasks. Strengths of the research include (1) the adoption of a within-participants experimental design; (2) the use of previously-validated (neutral and smoking images) and innovative (cue-exposure paradigm) cue sets to manipulate the urge to smoke, and (3) the adoption of behavioral dependent measures of self-control capacity.

A number of limitations of the current research should be acknowledged. First, we did not administer baseline measures of Stroop interference in Study 2. To some extent, our within-participants design served to control for individual variations in response tendencies on interference tasks like the Stroop. We also included practice trials to eliminate practice effects. However, a control for baseline Stroop interference is the most reliable way to control for individual-differences in response tendencies and Stroop results should, therefore, be interpreted with caution.

Second, we did not include a baseline measure of smoking urges meaning that we cannot compare smoking urge levels after exposure to either neutral or smoking-related cues with urge levels in the absence of either cue. This is also a limitation of previous studies examining the role of self-control in the addiction literature [11]. Research has demonstrated that regular cigarette smokers report significant elevations in self-reported smoking urges when exposed to smoking-

related cues in laboratory contexts, similar to those administered in the current study, relative to both baseline and neutral cues and these have been shown to be no different to responses to *in vivo* smoking cues, such as being confronted with a lit cigarette [35], and extended periods of abstinence [19]. We are therefore confident that, despite lack of a baseline measure, the smoking-related cues in our studies were successful in bringing about changes in cigarette smoking urges consistent with those induced in ecologically-valid contexts and by abstinence.

Third, we did not include a measure of nicotine withdrawal, pharmacologically or by self-report, or salivary cotinine to confirm the extent to which participants were experiencing cigarette withdrawal or had been affected by their abstinence. This means we cannot unequivocally rule out the possibility that the early symptoms of withdrawal may have interacted with the effects of the cues in terms of their performance on the self-control tasks. One assumption that could be made is that the level of abstinence would have been relatively consistent for all participants given that we instructed them not to smoke in the hour preceding the study. Nevertheless, this does, however, present a caveat to the current findings, and future research may assist in directly addressing this issue by including nicotine withdrawal and salivary cotinine measures as covariates or, better still, formally varying the length of abstinence or withdrawal period as an independent variable as has been done in other experimental studies of smoking urges [e.g., 19].

Finally, the present research was conducted on relatively small samples of undergraduate students. Although the effect sizes were such that both studies were adequately powered, the homogeneity and small samples serve place limits on the generalisability of the present findings to the wider population. Replication in larger, non-student samples is warranted.

Conflict of Interest Statement

The authors have no conflict of interest.

References

1. Borland R: Slip-ups and relapse in attempts to quit smoking. *Addictive Behaviors.* 1990, *15:*235-245.

2. Chornock WM, Stitzer ML, Gross J, Leischow S: Experimental-model of smoking reexposure - Effects on relapse *Psychopharmacology.* 1992, *108:*495-500.

3. Shadel WG, Martino SC, Setodji C, et al.: Lapse-induced surges in craving influence relapse in adult smokers: An experimental investigation. *Health Psychology.* 2011, *30:*588-596.

4. Shiffman S: Responses to smoking cues are relevant to smoking and relapse. *Addiction.* 2009, *104:*1617-1618.

5. Ferguson SG, Shiffman S: The relevance and treatment of cue-induced cravings in tobacco dependence. *Journal of Substance Abuse Treatment.* 2009, *36:*235-243.

6. O'Connell KA, Schwartz JE, Shiffman S: Do resisted temptations during smoking cessation deplete or augment self-control resources? *Psychology of Addictive Behaviors.* 2008, *22:*486-495.

7. West R: The Multiple facets of cigarette addiction and what they mean for encouraging and helping smokers to stop. *Journal of Chronic Obstructive Pulmonary Disease.* 2009, *6:*277-283.

8. Baumeister RF, Bratslavsky E, Muraven M, Tice DM: Ego depletion: Is the active self a limited resource? *Journal of Personality and Social Psychology.* 1998, *74:*1252-1265.

9. Muraven M, Tice DM, Baumeister RF: Self-control as a limited resource: Regulatory depletion patterns. *Journal of Personality and Social Psychology.* 1998, *74:*774-789.

10. Hagger MS, Wood C, Stiff C, Chatzisarantis NLD: Ego depletion and the strength model of self-control: A meta-analysis. *Psychological Bulletin.* 2010, *136:*495-525.

11. Muraven M, Shmueli D: The self-control costs of fighting the temptation to drink. *Psychology of Addictive Behaviors.* 2006, *20:*154-160.

12. Shmueli D, Prochaska JJ: Resisting tempting foods and smoking behavior: Implications from a self-control theory perspective. *Health Psychology.* 2009, *28:*300-306.

13. Heckman BW, Ditre JW, Brandon TH: The restorative effects of smoking upon self-control resources: A negative reinforcement pathway. *Journal of Abnormal Psychology.* 2012, *121:*244-249.

14. Muraven M, Baumeister RF: Self-regulation and depletion of limited resources: Does self-control resemble a muscle? *Psychological Bulletin.* 2000, *126:*247-259.

15. Nordgren LF, Chou EY: The push and pull of temptation: The bidirectional influence of temptation on self-control. *Psychological Science.* 2011.

16. Webb TL, Sniehotta FF, Michie S: Using theories of behaviour change to inform interventions for addictive behaviours. *Addiction.* 2010, *105:*1879-1892.

17. Baxter BW, Hinson RE: Is smoking automatic? Demands of smoking behavior on attentional resources. *Journal of Abnormal Psychology.* 2001, *110:*59-66.

18. Cox LS, Tiffany ST, Christen AG: Evaluation of the brief questionnaire of smoking urges (QSU-brief) in laboratory and clinical settings. *Nicotine & Tobacco Research.* 2001, *3:*7-16.

19. Morgan MJ, Davies GM, Willner P: The Questionnaire of Smoking Urges is sensitive to abstinence and exposure to smoking-related cues. *Behavioural Pharmacology.* 1999, *10:*619-626.

20. LaRowe SD, Saladin ME, Carpenter MJ, Upadhyaya HP: Reactivity to nicotine cues over repeated cue reactivity sessions. *Addictive Behaviors.* 2007, *32:*2888-2899.

21. Kawakami N, Takatsuka N, Inaba S, Shimizu H: Development of a screening questionnaire for tobacco/nicotine dependence according to ICD-10, DSM-III-r, and DSM-IV. *Addictive Behaviors.* 1999, *24:*155-166.

22. Gilbert DG, Rabinovitch NE: *International Smoking Image Series with neutral counterparts* (1.2 Ed.). Carbondale, IL: Southern Illinois University at Carbondale, 1998.

23. Attwood AS, O'Sullivan H, Leonards U, Mackintosh B, Munafo MR: Attentional bias training and cue reactivity in cigarette smokers. *Addiction.* 2008, *103:*1875-1882.

24. Waters AJ, Shiffman S, Sayette MA, et al.: Cue-provoked craving and nicotine replacement therapy in smoking cessation. *Journal of Consulting and Clinical Psychology.* 2004, *72:*1136-1143.

25. Sayette MA, Hufford MR: Effects of cue exposure and deprivation on cognitive resources in smokers. *Journal of Abnormal Psychology.* 1994, *103:*812-818.

26. Mayer JD, Gaschke YN: The experience and meta-experience of mood. *Journal of Personality and Social Psychology.* 1988, *55:*102-111.

27. Baumeister RF, Vohs KD, Tice DM: The strength model of self-control. *Current Directions in Psychological Science.* 2007, *16:*351-355.

28. Hagger MS, Wood C, Stiff C, Chatzisarantis NLD: The strength model of self-regulation failure and health-related behavior. *Health Psychology Review.* 2009, *3:*208-238.

29. Soar K, Dawkins L, Begum H, Parrott AC: The effects of cigarette smoking and abstinence on auditory verbal learning. *Human Psychopharmacology-Clinical and Experimental.* 2008, *23:*621-627.

30. Hughes JR, Keenan RM, Yellin A: Effect of tobacco withdrawal on sustained attention. *Addictive Behaviors.* 1989, *14:*577-580.

31. Muraven M, Baumeister RF, Tice DM: Longitudinal improvement of self-regulation through practice: Building self-control strength through repeated exercise. *Journal of Social Psychology.* 1999, *139:*446-457.

32. Hagger MS, Chatzisarantis NLD: The sweet taste of success: The presence of glucose in the oral cavity moderates the depletion of self-control resources. *Personality and Social Psychology Bulletin.* 2013, *39:*27-41.

33. Knauper B, Pillay R, Lacaille J, McCollam A, Kelso E: Replacing craving imagery with alternative pleasant imagery reduces craving intensity. *Appetite.* 2011, *57:*173-178.

34. Hagger MS, Lonsdale A, Koka A, et al.: An intervention to reduce alcohol consumption in undergraduate students using implementation intentions and mental simulations: A cross-national study. *International Journal of Behavioral Medicine.* 2012, *19:*82-96.

35. Erblich J, Bovbjerg DH: In vivo versus imaginal smoking cue exposures: Is seeing believing? *Experimental and Clinical Psychopharmacology.* 2004, *12:*208-215.

Figure 1. Mean score on dependent self-control task (Study 1, primary y-axis: baseline-adjusted time spent on handgrip task; Study 2, primary y-axis: baseline-adjusted time spent on handgrip task, secondary y-axis: response latencies for Stroop color-naming task) as a function of cue set. Smoking cue = condition in which participants received the smoking-related cue set; Neutral cue = condition in which participants received the neutral cue set.