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Administering the Implicit Association Test in an Ecological Momentary Assessment study

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Summary

The Implicit Association Test (IAT) is a widely used task for assessing automatic associations in memory. The feasibility of administering the IAT in an ecological momentary assessment (EMA) setting was examined in 15 smokers and 15 nonsmokers who carried a hand-held computer for one week as they went about their daily lives. They completed IAT assessments on the computer at random times 4 times a day, and when they felt suddenly anxious. Overall, participants completed 80.4% of random assessments ($M = 23.4$ assessments). Nonsmokers initially exhibited a more negative IAT effect than smokers. Over repeated testing, however, the IAT effect of nonsmokers (but not smokers) became less negative, and the between-group difference disappeared. The data show that it is feasible to administer the IAT in an EMA setting, and that the IAT effect can change with extensive testing.

The Implicit Association Test (IAT) is a widely used task for investigating automatic associations in memory (Greenwald, Nosek, & Banaji, 2003). The IAT consists of two tasks. On Task 1, participants are required to respond rapidly with a specific key press to items representing two concepts (e.g., smoking + positive) and with a different key press to items from two other concepts (e.g., not smoking + negative). In Task 2, the assignment of one concept is switched, such that, for example, not smoking + positive share a response, and smoking + negative share the other response. The key idea is that it is easier to perform the key presses when the two concepts are strongly associated in memory than when the two concepts are unrelated (de Houwer, 2002). The critical outcome measure (the IAT effect) is the difference in response times on Task 1 vs Task 2.

The IAT effect is an index of the relative strength of automatic associations (de Houwer, 2002). In the example above, it indicates whether associations are stronger between smoking and positive, and not smoking and negative, than between not smoking and positive, and smoking and negative. In studies in which positive and negative are used as two concepts (as above), the IAT effect is assumed to capture an implicit attitude. An implicit attitude has been characterized as the automatic association people have between an object and evaluation (good or bad) (Rudman, 2004). Numerous studies have used the IAT to

investigate associative memory in individuals with psychopathology (e.g., Teachman & Woody, 2003), including addictions (e.g., Wiers, von Woerden, Smulders, & de Jong, 2002). Although the psychological processes that underlie the IAT effect are not completely understood (e.g., de Houwer, Teige-Mocigemba, Spruyt, & Moors, 2009), there is good evidence for the predictive validity of the IAT effect across a number of domains (Greenwald, Poehlman, Uhlmann, & Banaji, 2009).

In most studies the IAT has been administered in a laboratory setting. Here, we examined the feasibility of administering the IAT in an ecological momentary assessment (EMA) setting. EMA is an emerging methodology in clinical and psychological research (Stone, Shiffman, Atienza, & Nebeling, 2007). In EMA, participants complete assessments in their natural environment. Assessments may be done at random times ("random assessments") or when participants experience heightened emotions (e.g., feeling particularly stressed). The emergence of hand-held computers has facilitated the collection of EMA data (Stone, et al., 2007). Most importantly, reaction time tasks can be administered on a hand-held computer in a manner similar to one in which they are administered on desktop or laptop computers (e.g., Shiffman, Patten, Gwaltney, Paty, Gnys, Kassel, et al., 2006; Waters & Li, 2008).

The rationale for administering the IAT in an EMA setting is as follows. First, the IAT effect can be monitored more intensively over time than would generally be possible in a laboratory setting. Administering the IAT in an EMA setting may allow one to detect within-day or across-day changes in the IAT effect. Within-day or across-day changes in the IAT effect may precede a lapse (or other addiction outcomes). Detection of such changes in the IAT effect (or other implicit cognitions) might potentially be useful for preventing relapse. Many studies in social cognition research have reported that the IAT effect can be influenced by contextual manipulations and affective variables (e.g., Rudman, 2004; Wiers, de Jong, Havermans, & Jelicic, 2004). More specifically, the smoking IAT effect can also be influenced by contextual factors or by the degree of smoking deprivation/recent smoking at the time of test (e.g., Sherman, Rose, & Koch, 2003; Waters, Carter, Robinson, Wetter, Lam, & Cinciripini, 2007). Because context and state vary across assessments, the IAT effect might similarly be expected to vary within or across days. Second, in an EMA setting the IAT effect can be assessed in a naturalistic real-world context. This assessment may capture individuals' "true" implicit attitudes as they go about their lives better than a laboratory assessment. Thus, information on the IAT effect assessed in the participants' natural environment may compliment data from laboratory settings. In a search of the literature, no previous study was identified in which the IAT was administered in an EMA setting.

Here, the smoking IAT was administered in an EMA setting in smokers and nonsmokers. The rationale for this choice was twofold. First, numerous studies have demonstrated the utility of the EMA approach in smoking research (e.g., Shiffman & Waters, 2004). Second, many laboratory studies have examined the IAT effect in smokers vs nonsmokers. These studies have often (but not always, e.g., Swanson, Rudman, & Greenwald, exps. 1 and 2) demonstrated between-group (smoker vs nonsmoker) differences in the IAT effect. For example, Swanson, et al. (2001, exp. 3) investigated the IAT effect for smoking vs not smoking pictures and positive vs negative words. The smokers exhibited a negative IAT effect (preference for not smoking), but nonsmokers exhibited an even more negative IAT

effect. The effect size for the between-group difference in the IAT effect was moderate to large ($d = .70$). Three other studies have also reported that nonsmokers exhibited a significantly more negative IAT effect than smokers (Sherman, et al., 2003; Huijding, de Jong, Wiers, & Verkoijen, 2005, exp. 1; de Houwer, Custers, & de Clercq, 2006, exp. 1). Between-group (smoker vs nonsmoker) differences have also been documented on two variant formats of the IAT - the single-target IAT (Huijding & de Jong, 2006), and the Go/No-go association test (Bassett & Dabbs, 2005).

Numerous studies have examined the effects of parametric variables on the IAT effect (e.g., Greenwald, et al., 2003). For an EMA setting, one variable of particular relevance is the effect of repeated testing (experience) on the IAT effect. As noted by Greenwald, et al. (2003), it would be desirable if there were no association between prior experience with the IAT and the magnitude of the IAT effect. The presence of an association between prior experience and the IAT effect would complicate interpretation of pre-post changes in the IAT effect (e.g., in clinical studies). It would also complicate the comparison of data from practiced vs naïve participants. In fact, Greenwald, et al.'s (2003) data revealed that practiced (completed at least one IAT) participants generally produced an IAT effect smaller in magnitude (closer to zero) than naïve (never completed an IAT) participants. However, the effect of more extensive testing on the IAT effect is not known. An EMA setting would allow examination of the effects of extensive testing on the IAT effect.

Thus, here, the feasibility of administering the IAT in an EMA study was examined. The effect of extensive testing on the IAT effect in smokers and nonsmokers was also examined.

Method

Participants

Participants were 15 smokers ($M = 33.3$ yr., $SD = 12.9$, 46.7% women) and 15 nonsmokers ($M = 34.6$ yr., $SD = 13.5$, 80.0% women) recruited from the Houston area. To be eligible, smokers had to report that they smoked 10+ cigarettes per day for the past two years, and nonsmokers had to report that they had smoked fewer than 100 cigarettes in their lifetime. Participants were excluded if they reported that English was not their first language. The study was approved by the Institutional Review Board of the University of Texas M. D. Anderson Cancer Center.

Procedure

The experimental procedures were based on those described by Waters and Li (2008), except that the participants completed the IAT (rather than the Stroop) at each assessment. Participants attended two laboratory sessions. At session 1, breath carbon monoxide (CO) levels were taken to validate smoking status (SRNT, 2002). Participants signed the informed consent form, and completed an IAT assessment on a hand-held computer which they then carried around for one week. They were beeped at random times four times per day (random assessments) between their wake-up time and their scheduled bed time on each day. (Random assessments were not presented during night time). Participants were also instructed to press an "anxiety assessment" button on the hand-held computer whenever they

felt suddenly anxious. Anxiety assessments were included to increase the range of anxiety scores. At each assessment (random or anxiety) participants first responded to items assessing subjective, pharmacological, and contextual variables, and subsequently completed an IAT (detailed below). At session 1, participants were told that they would receive \$10 for each day that they contributed data to the study and that they also would receive \$2 for each completed random assessment. At session 2, the participant returned the hand-held computer, completed up to two questionnaires, and received compensation.

Laboratory Measures

Nonsmokers with CO levels > 6 ppm were excluded. The mean CO of smokers was 18.9 ppm ($SD = 6.1$) and the mean of nonsmokers was 1.1 ppm ($SD = 1.3$). At session 2, participants completed the 20-item trait version of the State Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) ($M = 16.4$, $SD = 12.2$, Range = 2 to 42). Smokers also completed the Fagerstrom Test for Nicotine Dependence (Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991) ($M = 4.1$, $SD = 1.4$, Range = 2 to 6).

EMA Measures

Participants responded to a number of subjective, contextual, and pharmacological measures (detailed by Waters & Li, 2008; not reported here).

IAT

The hand-held computer version of the IAT has four blocks: (1) First block of Task 1 (e.g., smoking + good/not smoking + bad) (20 trials); (2) Second block of Task 1 (40 trials); (3) First block of Task 2 (e.g., not smoking + good/smoking + bad) (40 trials); (4) Second block of Task 2 (40 trials). At each assessment, participants were randomly assigned to one of four IATs: (a) smoking + good first, good on left; (b) smoking + good first, bad on left; (c) smoking + bad first, good on left; (d) smoking + bad first, bad on left. There were no practice blocks because practice blocks were not considered necessary for the EMA application.

Stimulus materials—Ten smoking pictures and 10 neutral pictures were used. For the hand-held computer version of the IAT, single object pictures (e.g., cigarette, umbrella) were used. The picture dimensions were 4.34 cm x 3.25 cm. Words captured the good concept (e.g., Beautiful, Nice, Pleasant, Calm, Relaxing, Soothing, Restful, Smooth, Positive, Friendly, Satisfying, Peaceful) and the bad concept (e.g., Nasty, Unpleasant, Ugly, Negative, Depressing, Annoying, Antisocial, Distressing, Harsh, Irritating).

Procedure—On each trial, a stimulus (word, picture) was presented in the center of the computer screen. On the top of the screen were labels (on each side of the screen) to remind participants of the categories assigned to each key for the current task. Participants responded to the categorization task by pressing either a left or a right button on the hand-held computer (Fig 1). They were instructed to respond as quickly and as accurately as possible. No specific instruction was given as to which fingers should be used; at the laboratory session the participants generally made the button-press responses using their thumbs (Fig 1). The program randomly selected items under the constraint that the sequence

of trials alternated between the presentation of a smoking/not smoking picture and the presentation of a good/bad word. If the participant responded correctly, the program proceeded to the next trial after an inter-trial interval of 150 ms. If the participant made an error, a red “X” appeared below the stimulus and remained there until the participant responded correctly.

Scoring—The scoring algorithm recommended by Greenwald and colleagues was used to derive the IAT effect (Greenwald, et al., 2003, Table 4). Thus, data from all four blocks were used to compute the IAT effect. All response times > 10,000 msec were eliminated (0.12% of reaction times (RTs) in current study). The algorithm eliminates assessments on which a participant had response times of less than 300 msec on more than 10% of the trials (1.7% of completed assessments in current study). The computed IAT effect, *D*, is similar to an effect-size measure (Greenwald, et al. 2003). The internal (split-half) reliability of the IAT effect (*D*) is good in a laboratory setting (Waters, et al., 2007). In the current study, the internal reliability - estimated by computing the IAT effects derived from blocks 1 + 3 and blocks 2 + 4, correlating these measures, and applying the Spearman-Brown formula to derive the split-half reliability coefficient (Waters, et al., 2007) - was .73 in the laboratory (first) assessment, and .70 in the EMA assessments.

All analyses used the *D* score—The untransformed IAT effect (in msec) is also reported to assist in interpretation. The mean error rate on the IAT was 7.9% (*SD* = 7.0) (smokers) and 8.9% (*SD* = 10.6) (nonsmokers).

Hand-held Computer Hardware and Software

EMA procedures were as described in Waters and Li (2008). Stated briefly, the study was implemented on a HP iPAQ Pocket PC running the Microsoft Windows Pocket PC operating system. Application programming was done in C#.NET. Participants could prevent the hand-held computer from presenting random assessments for up to 2 hours (“suspend” function). Participants could also delay random assessments by 5 minutes (up to three times per random assessment) by pressing a “delay” button on the hand-held computer during the auditory alert. The delay function is important on those occasions when the participant could complete the assessment after a few minutes, but not immediately (e.g., if they were driving). If the participant failed to respond to a random assessment (or failed to delay the random assessment), the auditory alert (beeping) timed out and the participant was coded as non-compliant on that random assessment.

Data Reduction and Analysis

Generalized Estimating Equations (GEE; Zeger, Liang, & Albert, 1988) were used for the primary analyses (see Shiffman & Waters, 2004; Waters & Li, 2008, for similar approaches). GEE analyses take into account the dependence between observations due to clustering of the data by participants. The analyses also allow for different numbers of observations across participants. To select an appropriate working correlation structure for the GEE analyses, we first ran linear mixed model analyses under two commonly used correlation structures and compared the resulting Akaike/Schwartz information criteria (AIC/BIC) (smaller is better). The linear mixed model analysis using a compound symmetry correlation structure yielded

an AIC/BIC of 784.0 and 786.8, respectively. The model using a first-order autoregressive correlation structure yielded an AIC/BIC of 900.0 and 902.8, respectively. Based on the reported AIC/BIC, compound symmetry was a more appropriate working correlation structure for the GEE analyses.

Empirically-based robust estimates of standard errors and z scores were used. The estimated intraclass correlation coefficient (ICC) using a GEE model was .40. The IAT effect (D) appeared normally distributed and was treated as such when used as the dependent variable in the GEE analyses. Assessment number was entered as a continuous variable (range 1 to 38; data from the laboratory (first) assessment was included in analysis). Status (smoker vs nonsmoker) was entered as a class variable. Assessment type (anxiety vs random) was not associated with the IAT effect, so it was not included as a variable in the primary analysis. The interaction term between Status and Assessment Number was first tested. We then used an independent groups t-test to examine between-status differences in the IAT effect at the laboratory assessment (assessment number = 1). To simplify between-status comparisons in the EMA data, separate GEE analyses were conducted over the following groups of three assessments: 2 to 4, 5 to 7, 8 to 10, 11 to 13, 14 to 16, 17 to 19, 20 to 22. Three was the whole number closest in magnitude to the mean number of assessments completed over a whole day (3.3). A between-status comparison was also conducted on data pooled from assessment 23 and subsequent assessments.

Results

On the average, participants completed 19.2 random assessments ($SD = 4.9$) (80.4% of presented random assessments) and 3.2 anxiety assessments ($SD = 4.6$). The study yielded a total of 702 assessments with IAT scores (30 laboratory, 576 random, 96 anxiety). The mean completion time for the IAT was 3.01 min ($SD = 1.19$). The mean duration for each assessment was 4.56 min ($SD = 1.76$). Participants completed random assessments at the first opportunity (no delay) on 88.0% of occasions. On the average, smokers completed 22.7 IATs (range 11 to 38), and nonsmokers completed 24.1 IATs (range 16 to 28). Number of completed assessments was not associated with smoking status or mean IAT scores ($ps > .3$).

IAT effect by Status and Assessment Number

The effect of Status (smokers vs nonsmokers) and Assessment Number (1 – 38) on the IAT effect was examined (Fig 2). As suggested by the figure, the Status by Assessment Number interaction was significant (Parameter Estimate (PE) = 0.21, Standard Error (SE) = 0.005, $p < .001$). The effect of Assessment Number was significant for nonsmokers ($PE = 0.018$, $SE = 0.003$, $p < .001$) but not for smokers ($PE = -0.0027$, $SE = 0.003$, $p > .4$). Post-hoc analyses indicated that there was no evidence for a non-linear (quadratic, cubic, or quartic) effect of Assessment Number for either the smokers or nonsmokers (all $ps > .2$).

At the laboratory assessment (first assessment), smokers exhibited a more positive (less negative) IAT effect ($M = -65.1$ msec, $SD = 487$; $M = -0.09$, $SD = 0.60$ (D score)) than the nonsmokers ($M = -531.6$ msec, $SD = 606$; $M = -0.68$, $SD = 0.58$ (D score)) ($t = -2.75$, $df = 28$, $p < .05$). The IAT effect for the nonsmokers was significantly different from zero ($t =$

−4.51, $df = 14$, $p < .001$). The IAT effect for the smokers was not significantly different from zero ($t = -0.56$, $df = 14$, $p > .5$).

In the EMA data, the effect of Status was significant or fell just short of significance for analyses restricted to Assessments 2 to 4 ($PE = -0.32$, $SE = 0.14$, $p < .05$), Assessments 5 to 7 ($PE = -0.29$, $SE = 0.14$, $p < .05$), Assessments 8 to 10 ($PE = -0.22$, $SE = 0.12$, $p = .07$), and Assessments 11 to 13 ($PE = -0.33$, $SE = 0.14$, $p < .05$). In contrast there were no between-status differences in the IAT effect for Assessments 14 to 16 ($p > .3$), Assessments 17 to 19 ($p > .8$), Assessments 20 to 22 ($p > .8$), and Assessments 23+ ($p > .3$). The IAT effect of nonsmokers was significantly different from zero for analyses restricted to Assessments 2 to 4 ($p < .001$), Assessments 5 to 7 ($p < .001$), Assessments 8 to 10 ($p < .001$), Assessments 11 to 13 ($p < .001$), Assessments 14 to 16 ($p < .05$), Assessments 17 to 19, ($p < .01$), and Assessments 20 to 22 ($p < .05$), but not Assessments 23+ ($p > .5$). The IAT effect for smokers was not significantly different from zero ($p > .2$).

Discussion

The study shows the feasibility of administering the IAT in an EMA setting. Participants responded to 80.4% of random assessments. Thus, adequate compliance can be achieved when the IAT is administered. IAT assessments were completed in an average of 3.01 minutes, meaning that the hand-held computer version of the IAT was not excessively burdensome. The estimated internal split-half reliability of the IAT assessed during EMA was also adequate.

There was a robust between-group difference in the IAT effect at an initial laboratory assessment. The IAT effect of nonsmokers was negative, whereas the IAT effect of smokers was less negative. These data replicate the findings of previous laboratory studies (e.g., Swanson, et al., 2001; Sherman, et al., 2003). The present data extend previous findings in two ways. First, they show that between-group differences in the IAT effect persist for at least 13 assessments, when conducted in an EMA setting (Fig 2). Second, the IAT effect of nonsmokers became less negative (more positive) over time, whereas that for smokers did not change. After extensive testing, the between-group difference in the IAT effect was no longer present (Fig 2).

The study did not reveal why the IAT effect changed over time for the nonsmokers. This change over time does not likely represent statistical regression to the mean, because there is no reason to suppose that nonsmokers initially exhibited more (extreme) negative IAT effects due to chance alone. It has been argued that the IAT effect can be influenced by strategic processes (e.g., Roethmund & Wentura, 2004). Speculatively, after extensive testing participants may adopt strategies which facilitate performance on the incompatible (difficult) condition (smoking + good) more than performance in the compatible (easy) condition. Alternatively, the smoking pictures may elicit different affective responses over repeated presentations, such that they eventually do not elicit automatic negative responses in nonsmokers. Future research can ascertain whether changes in automatic or strategic processes underlie the observed effects of repeated assessments.

The effect of repeated assessments was not observed in the smokers. They initially exhibited a small negative IAT effect which was not significantly different from zero. As noted earlier, experience with the IAT generally reduces the magnitude of the IAT effect (the IAT effect moves closer to zero). The effect of repeated assessments would presumably be less likely to be observed in groups who exhibited an IAT effect of modest magnitude on the first assessment (because there is less room to change toward zero). Further analysis of the observed testing effects will be facilitated by the development of a comprehensive process model of the cognitive mechanisms underlying the IAT effect (Nosek, et al., 2007).

The study had limitations. We do not know if the results would generalize to different assessment contexts. For example, it is not known whether extensive testing would exert the same effect if the lags between IAT assessments were of briefer or longer duration than the lags in an EMA study. In the current study, the same IAT format was presented at every assessment. The effect of extensive testing using different IAT formats remains unknown. Moreover, in the current study, the same stimuli (pictures, words) were presented at every smoking IAT assessment. It is not known whether the effects of extensive testing would be mitigated by the use of different materials at each assessment. To minimize the duration of each IAT assessment and therefore the assessment burden, the practice blocks that are typically used in laboratory IAT applications were not included. We cannot exclude the possibility that this alteration impacts on the IAT effect. Finally, explicit (self-reported) attitudes to smoking and not smoking were not assessed. Thus, it is not known whether the pattern of data is specific to an implicit measure (IAT effect).

These limitations notwithstanding, the study also had significant strengths. The data provide evidence that (1) the IAT can be administered on a hand-held computer in an EMA setting; (2) the magnitude of the IAT effect can be significantly changed in a particular population after extensive testing; and (3) a between-group difference in the IAT effect can be significantly moderated by repeated testing. As noted earlier, although the effect of practice on the IAT effect has been previously noted (e.g., Greenwald, et al., 2003; Huijding & de Jong, 2007), the present study is the first to show the effect of extensive testing on the IAT effect. In addition, although previous research has documented associations between an IAT effect assessed in the laboratory and spontaneous affect assessed using EMA (Conner & Barrett, 2005), to the best current knowledge the present study is the first to demonstrate the feasibility of administering the IAT at random assessments in an EMA setting. Given that the IAT is such a widely used measure of automatic cognition, this methodology holds promise for the investigation of cognitive processes in real world settings.

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References

- Bassett JF, Dabbs JM. A portable version of the go/no-go association task (GNAT). *Behavior Research Methods, Instruments, & Computers*. 2005; 37:506–512.
- Conner T, Barrett LF. Implicit self-attitudes predict spontaneous affect in daily life. *Emotion*. 2005; 5:476–488. [PubMed: 16366751]

- de Houwer J. The implicit association test as a tool for studying dysfunctional associations in psychopathology. *Behavior Therapy and Experimental Psychiatry*. 2002; 53:115–133.
- de Houwer J, Custers R, de Clercq A. Do smokers have a negative implicit attitude toward smoking? *Cognition and Emotion*. 2006; 20:1274–1284.
- De Houwer J, Teige-Mocigemba S, Spruyt A, Moors A. Implicit measures: a normative analysis and review. *Psychological Bulletin*. 2009; 135:347–368. [PubMed: 19379018]
- Greenwald AG, Nosek BA, Banaji MR. Understanding and using the Implicit Association Test: I. An improved scoring algorithm. *Journal of Personality and Social Psychology*. 2003; 85:197–216. [PubMed: 12916565]
- Greenwald AG, Poehlman TA, Uhlmann E, Banaji MR. Understanding and using the Implicit Association Test: III. Meta-analysis of predictive validity. *Journal of Personality and Social Psychology*. 2009 in press.
- Heatherton TF, Kozlowski LT, Frecker RC, Fagerstrom KO. The Fagerstrom Test for nicotine dependence: A revision of the Fagerstrom Tolerance Questionnaire. *British Journal of Addiction*. 1991; 86:1119–1127. [PubMed: 1932883]
- Huijding J, de Jong PJ, Wiers RW, Verkooijen K. Implicit and explicit attitudes toward smoking in a smoking and nonsmoking context. *Addictive Behaviors*. 2005; 30:949–961. [PubMed: 15893091]
- Huijding J, de Jong PJ. Automatic associations with the sensory aspects of smoking: positive in habitual smokers but negative in nonsmokers. *Addictive Behaviors*. 2006; 31:182–186. [PubMed: 15919160]
- Huijding J, de Jong PJ. Beyond fear and disgust: The role of (automatic) contamination-related associations in spider phobia. *Journal of Behavior Therapy and Experimental Psychiatry*. 2007; 38:200–211. [PubMed: 17125734]
- Nosek, B., Greenwald, AG., Banaji. The Implicit Association Test at age 7: a methodological and conceptual review. In: Bargh, JA., editor. *Automatic processes in social thinking and behavior*. New York: Psychology Press; 2007. p. 265–292.
- Rothermund K, Wentura D. Underlying processes in the Implicit Association Test: dissociating salience from associations. *Journal of Experimental Psychology: General*. 2004; 133:139–165. [PubMed: 15149248]
- Rudman LA. Sources of implicit attitudes. *Current Directions in Psychological Science*. 2004; 13:79–82.
- Sherman SJ, Rose JS, Koch K. Implicit and explicit attitudes toward cigarette smoking: the effects of context and motivation. *Journal of Social and Clinical Psychology*. 2003; 22:13–39.
- Shiffman S, Waters AJ. Negative affect and smoking lapses: a prospective analysis. *Journal of Consulting and Clinical Psychology*. 2004; 7:192–201.
- Shiffman S, Patten C, Gwaltney CJ, Paty JA, Gnys M, Kassel J, Hickcox M, Waters AJ, Balabanis MH. Natural history of nicotine withdrawal. *Addiction*. 2006; 101:1822–1832. [PubMed: 17156182]
- Spielberger, CD., Gorsuch, RL., Lushene, R., Vagg, PR., Jacobs, GA. *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press; 1983.
- SRNT Subcommittee on Biochemical Verification. Biochemical verification of tobacco use and cessation. *Nicotine and Tobacco Research*. 2002; 4:149–159. [PubMed: 12028847]
- Stone, AA., Shiffman, S., Atienza, A., Nebeling, L. *The science of real time data capture*. Oxford: UK: Oxford University Press; 2007.
- Swanson JE, Rudman LA, Greenwald AG. Using the Implicit Association Test to investigate attitude-behaviour consistency for stigmatized behaviour. *Cognition and Emotion*. 2001; 15:207–230.
- Teachman BA, Woody SR. Automatic processing in spider phobia: implicit fear associations over the course of treatment. *Journal of Abnormal Psychology*. 2003; 112:100–109. [PubMed: 12653418]
- Waters AJ, Carter BL, Robinson JD, Wetter DW, Lam CY, Cinciripini PM. Implicit attitudes to smoking are associated with craving and dependence. *Drug and Alcohol Dependence*. 2007; 91:178–186. [PubMed: 17658701]
- Waters AJ, Li Y. Evaluating the utility of administering a reaction time task on a handheld computer in an ecological momentary assessment study. *Psychopharmacology*. 2008; 197:25–35. [PubMed: 18064440]

- Wiers RW, van Woerden N, Smulders FTY, de Jong PJ. Implicit and explicit alcohol-related cognitions in heavy and light drinkers. *Journal of Abnormal Psychology*. 2002; 111:648–658. [PubMed: 12428778]
- Wiers RW, de Jong PJ, Havermans R, Jelicic M. How to change implicit drug use-related cognitions in prevention: a transdisciplinary integration of findings from experimental psychopathology, social cognition, memory and experimental learning psychology. *Substance Use & Misuse*. 2004; 39:1625–1684. [PubMed: 15587947]
- Zeger SL, Liang KY, Albert PS. Models for longitudinal data: a generalized estimating equation approach. *Biometrics*. 1988; 44:1049–1060. [PubMed: 3233245]

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Fig. 1. Hand-held computer version of the IAT showing an example of a smoking picture for which the correct response is a left button press.

Fig. 2.

Mean IAT effect (D score) and standard error by assessment number for smokers (filled circles) and nonsmokers (open circles) (ns = 15). [Note: 23' = data from Assessment number 23 and subsequent Assessments were pooled in one bin.]